Energy-Efficient
Resource-Efficient

Frost-Protected Shallow Foundations

NAHB
National Association of Home Builders

Home Builders Care · Across the Country

Energy-Efficient
Resource-Efficient

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About Frost-Protected Shallow Foundations

Builders and remodelers across the northern United States are learning the advantages of frost-protected shallow foundations (FPSFs) and the use of the technology is spreading. Approved for slab-on-grade construction for heated buildings in the CABO/ICC *One and Two Family Dwelling Code*, 1995 and 1998 editions, the technology is also gaining acceptance for remodeling additions, apartments, and light commercial construction. An estimated 3,000 such foundations have now been built in the United States, with builders reporting a 40-percent savings in foundation costs.

Condominiums in Frisco, Colorado by McCrerey & Roberts Construction - Condos are on FPSFs, while the unheated garages are on conventional deep foundations extending to the frost line.

Well over a million FPSFs have been built over the past 45 years in Scandinavia. They have been standard practice there for nearly 30 years for homes, townhouses, apartments, stores, malls, schools and low-rise office buildings.

They have been standard practice for NAHB member Bill Eich from Spirit Lake, Iowa, for more than a decade. Since 1984, he has built more than 200 new homes or remodeling projects using this technique in Spirit Lake's 8,000 heating degree day climate, without a single failure or foundation-related callback. Bill says, "We save approximately $10 to $15 per lineal foot over conventional deep foundations. This means a $1,500 to $4,000 savings on most of our homes or remodeling projects.

"The current mindset of consumers and builders is that if the footings are four feet deep it only costs a little more to go eight feet deep and put in a full basement, which is true. But with a FPSF, the footings only have to be 16 inches deep. With FPSFs as an option, the full basement is an expensive premium: $10,000 to $15,000 more than the same house built on a slab with an FPSF."

Affordable Housing

In 1995, Casson Building Corporation built 113 low-income duplex and quadplex units for the Denver Housing Authority. Estimated savings from FPSFs was $399,707. FPSFs significantly reduced ownership and energy costs.

Dan McCrerey of McCrerey and Roberts Construction, Frisco, CO, has built 84 low-income condos in 42 duplexes using FPSFs in the past 5 years, all at an elevation of 9,000 feet. "On 14 of the buildings," says McCrerey, "we were awarded a design build contract over nine other companies. It is my belief that the cost savings of the foundation system contributed to our success." He plans to build 48 more units in 2000.

Cox Development, Norfolk, Nebraska, uses plywood forms for monolithic slabs. Plastic ties are preinstalled to fasten insulation to the slab, and steel rebar, to strengthen the slab edge. House on the left is built on a shallow FPSF, except that the foundation of the unheated garage on the right extends to the frost line.

Building Green

Frost-protected shallow foundations are included as an energy-efficient and resource-efficient technology in the Green Builder Program of Colorado (www.builtgreen.org/checklist.htm, Materials: Foundations).

Single-Family Homes

Cox Development Corp. has built 51 homes on FPSFs in Norfolk, Woodland Park, and Dakota City, Nebraska, including ranch houses and split entry raised ranches with the lower level entirely above grade. "All 51 homes are attached to garages with deep foundations," says Wayne Cox, "and we have never had a failure."

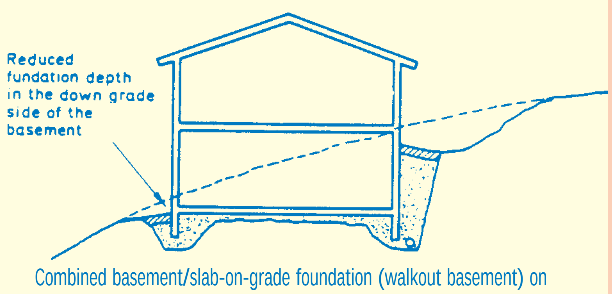
"For homes with full depth basements," says Sid Cox, "we use FPSFs with great success on the rear walkout. Competitive prices from FPSFs help keep homes affordable and enable more people to buy homes."

Judy Niemeyer, President of Tierra Concrete Homes in Pueblo, has built 15 homes with frost-protected shallow foundations in Colorado in five different counties ranging in heating degree days from 5000 to 8200 and frost levels from 27 to 36 inches. Judy made presentations on FPSFs to officials in each county to explain the system. "The FPSFs perform well," Judy says. "Under its Exemplary Building Program, the National Renewable Energy Laboratory (DOE) monitored one of the houses and found that the temperature under the footings on the cold north side never went below 50°F."

In Missoula, Montana, builder Steve Loken has built three homes on FPSFs. Steve reports that "the climates have ranged between 8,000 and 8,500 heating degree days and the design frost lines up to five feet. The technology allows less soil to be disturbed on site, saves energy and reduces construction costs. Since it eliminates outside stairs, it is an excellent component of universal design, for elderly with walkers, people in wheelchairs, young mothers with strollers, kids on tricycles, and people pulling suitcases."

In Duluth, Minnesota, a climate with 10,000 heating degree days and frost lines up to 72 inches deep, builder Randy Larson of Meteek Shop & Construction has built several homes on FPSFs. One of the homes is 9,000 square feet in size. "I used the shallow foundation technique for unheated buildings on this project. This allowed me to eliminate any heating costs or cover the foundation through the winter of 1993. Instead of putting insulation blankets or straw on top of the slab, we put insulation board under the slab. During

Split-foyer home built in 1996 by Bill Eich, Spirit Lake, Iowa. Right side is a full basement (a conventional deep foundation) while the left side garage and walk-out basement are on frost-protected shallow foundations.



Combined basement/slab-on-grade foundation (walkout basement) on sloping terrain marries deep and shallow foundations in one structure. Drawing is from Design Details by the Norwegian Building Research Institute. This FPSF design is widely used in Norway's hilly terrain.

HUD/PATH demonstration house under construction by K. Hovnanian Homes in New Jersey.

Drug store on FPSF, built by Citation Homes, Inc., Spirit Lake, Iowa.

frame-in, the air temperature reached -40°F for extended periods of time and the structure sustained no frost heave whatsoever."

Dryden, New York, builder Bruno Schickel of Schickel Construction has built 15 homes on FPSFs. The Dryden climate has 7,000 heating degree days with a design frost line depth of 48 inches. "In building these homes, we followed the NAHB guidelines. As you may know, New York has its own building code, which simply requires foundations to be protected from frost. We found that the building inspectors had no problems with our designs and accepted them without hesitation."

Homes for Elderly & Physically Disabled

Gerald Eid is a long-time NAHB member from Fargo, North Dakota, who has chaired numerous NAHB committees at the national level. His company, Eid-Co Buildings, Inc., is the largest homebuilder in North Dakota and has been building homes for over 45 years. "We build homes for the elderly and physically disabled using this construction technique," says Eid. "Slab-on-grade construction is ideal for this market because it eliminates steps, inside and out, and long ramps to the entrance. FPSFs also reduce the cost of the home by several thousand dollars." Eid built one of the five NAHB Research Center FPSF demonstration homes funded by HUD in 1992 to prove that the technology works. For more information, see the HUD web site, www.huduser.org/publications/destech/frostprt.html.

Advanced Technology Demonstration

NAHB's Research Center is working with K. Hovnanian Homes to demonstrate the FPSF technology and other advanced technologies for housing. The work, sponsored by the U.S. Department of Housing and Urban Development under the White House PATH initiative, is aimed at evaluating and advancing technologies that improve durability, energy efficiency, and affordability. The FPSF method is a rare technology that addresses all of these criteria.

Apartment Construction

Now that the Fair Housing Act requires apartment buildings to have wheelchair accessible ground floors, slab-on-grade construction is becoming more common for apartments, and FPSFs are a perfect fit. In Albion, Iowa, near Des Moines, builder Jacob Kvinlaug designed and built a one-story 8-plex elderly apartment complex in 1996, and a three two-story 8-plex in Marshalltown, Iowa, in 1997. Mr. Kvinlaug states, "There has been no evidence of frost action whatsoever on any of these buildings." He is planning to start 64 more units on FPSFs in the near future.

Remodeling Additions

In Spokane, Washington, remodeler Bob Wright has used FPSFs for 12 additions in the Spokane, Pullman and Othello, Washington, area, and nearby Idaho. "These climates have up to 7,000 heating degree days and design frost lines up to 36 inches deep," says Bob. He likes FPSFs

Housing for the elderly and disabled. Eid-Co Buildings, Inc. Fargo, ND. Living space is on shallow monolithic slabs, while garages are on permanent wood foundations. One extends to the frost line while other garages have FPSFs designed for unheated buildings.

Eight-plex apartments on FPSFs by Jacob Kvinlaug in Marshalltown, Iowa.

Left, concrete/EPS slab-edge insulated forms and sub-slab insulation on FPSF for an elementary school in Stockholm, Sweden. In Norway, Sweden and Finland, 2-inch thick sub-slab insulation, either EPS or XPS, is widely used under concrete slabs to keep the concrete warm for thermal comfort. BPA Construction.

Left, shopping mall in Trondheim, Norway. Steel columns and non-load-bearing walls on FPSFs. A.S. Anlegg Construction.

In Scandinavia, reinforced FPSF slabs have been used on other commercial buildings to span weak soil between deep piles.

especially because they disturb much less soil, shrubs and trees on the site. "We could dig these footings by hand if we had to."

Low-Rise Commercial

The national building codes have not yet approved FPSFs for commercial construction and apartments. Special approval must be sought locally based on residential code approvals. Yet, low-rise commercial construction is certain to be a major application for FPSFs in the future because of the widespread use of slab-on-grade foundations in low-rise commercial. In Scandinavia, FPSFs are used on virtually all low-rise commercial construction.

In the U.S., Tony Weber of Citation Homes, Inc., a custom designer and fabricator of building components for residential and light commercial construction in Spirit Lake, Iowa, has built many homes on FPSFs over the past decade and says they are ideal for high water table areas. In 1996-97 Citation also built a 10,000 sq. ft. drug store in Windom, Minnesota using FPSF techniques.

In Burlington, Vermont, Jim Ewing, past president of the HBA of the State of Vermont, built a 200-foot-by-50-foot strip mall in 1993–the first shopping mall in the U.S. constructed on an FPSF. He also has built a 140-foot-by-70-foot multiple use building with offices and shops with overhead doors. Jim says, "My experience with shallow foundations started many years ago when I attended a seminar at the NAHB International Builders' Show (www.BuildersShow.com) on shallow foundations. After giving it a great deal of thought I decided to try to construct one. I have completed two now. There has been no problem with either one of these foundations. Thanks to NAHB for another idea to make construction a little easier and more affordable."

NAHB's Research Center pioneered U.S. research and development of FPSFs. The U.S. Department of Housing and Urban Development funded five FPSF demonstration homes. NAHB Research Center publishes the primary reference on FPSFs, *Design Guide for Frost-Protected Shallow Foundations*, 2nd Edition, available by calling (800) 638-8556. NAHB Construction, Codes and Standards Department led the way for code approval for FPSFs in the CABO Code in 1994 (800-368-5242, ext. 444).

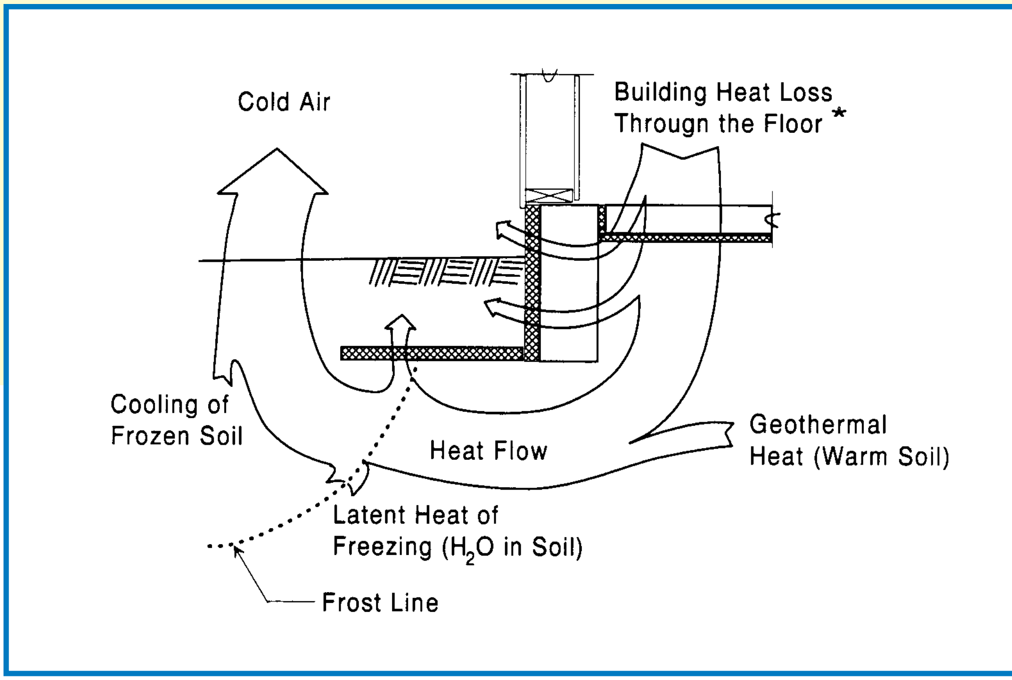
Frost-Protected Shallow Foundations

What are they?

The Frost-Protected Shallow Foundation (FPSF) technique is an internationally recognized alternative method of protecting slab-on-grade foundations of heated buildings against frost heave. The foundations can be monolithic slabs with thickened edges or floating slabs with grade beams made of concrete, concrete block, or treated wood.

First U.S. shopping mall on a FPSF (above), built in 1993 by James Ewing, Burlington, Vermont, who also built the commercial building at right in 1995.

House FPSF by Bill Eich, Spirit Lake, Iowa.



How do they work?

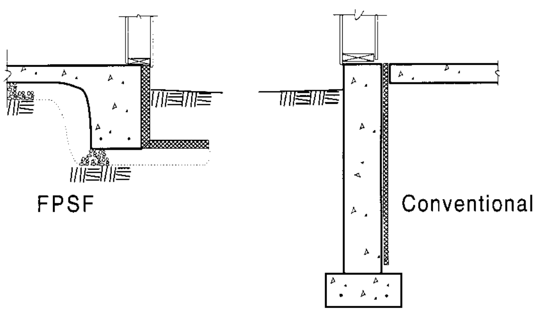
FPSFs use rigid polystyrene slab-edge insulation to reduce slab-edge heat loss and hold heat from the house in the ground under the footings. This keeps the ground temperature under the footings above freezing.

In colder climates, horizontal ground insulation is also placed around the foundation, and extra insulation is placed at the corners of the foundation where heat loss is higher than along the walls.

The insulation raises the frost line around the foundation. It prevents frost heave anywhere in the U.S.–even where footings are placed only 12 inches below grade, plus four inches of non-frost-susceptible gravel.

What are the benefits FPSFs?

FPSFs increase home energy efficiency because the slab edge is insulated. They provide frost protection equal to or better than that provided by deep foundations because FPSFs are based on stringent ground conditions using the coldest winter temperatures likely to occur in each area of the country in 100 years. In addition, raising the frost line reduces construction costs by decreasing excavation depths and disturbs less soil on the site.



Where are they approved?

FPSFs are approved in the 1995 *CABO One and Two Family Dwelling Code*, the 1998 *International One and Two Family Dwelling Code*, and statewide in New Jersey, Montana, West Virginia, Wisconsin and other states that have adopted these codes.

How many have been built?

More than one million FPSFs have been built over the past 45 years in Norway, Sweden and Finland, where they have been approved by code since the 1970s. In Scandinavia, the method is standard practice for low-rise construction, including homes, townhouses, shopping malls, stores, office buildings and schools. In the lower U.S., an estimated 3,000 FPSFs had been built by 2000, including single family houses, townhouses, housing for the elderly and disabled, additions, apartments, stores, and other commercial buildings.

Additional FPSFs have been built in Alaska and Canada. The U.S. Army has built several FPSFs, including an addition to a conventional deep foundation for an airport control tower in Galena, Alaska, near the Arctic Circle, where the frost depth is 13 feet and winter temperatures reach -60° F for weeks at a time. No frost heave or differential settlement has been observed. For more information see www.geofoam.org/pdfs/CRREL9707.pdf.

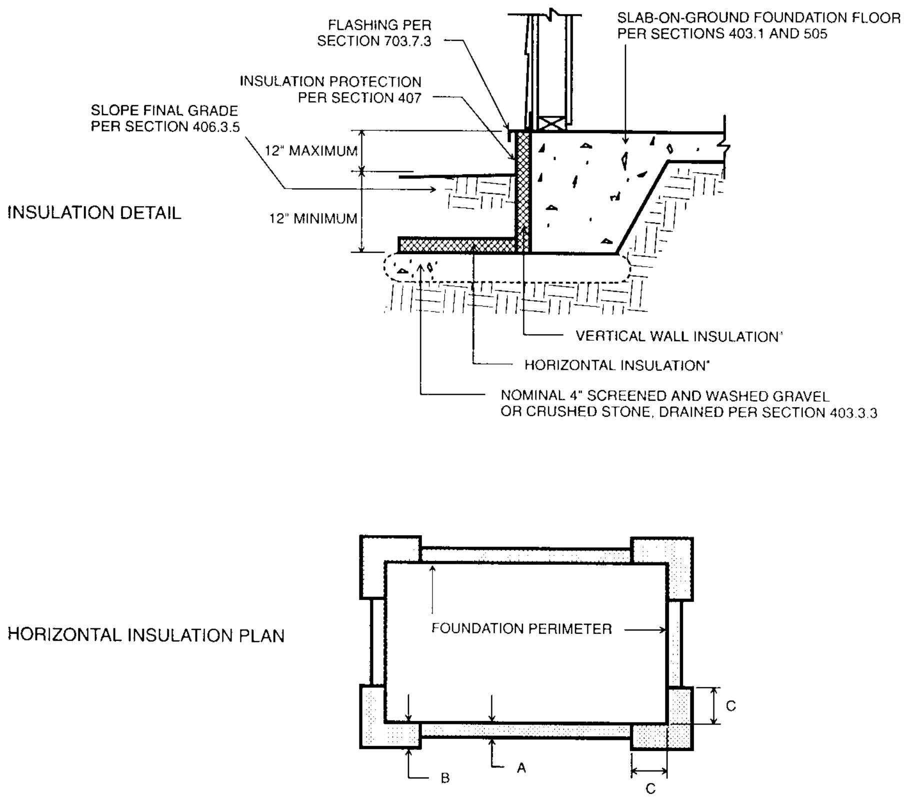


Fig. 403.3 (1)

How are insulation dimensions determined in FPSFs?

1) Find your location and air-freezing index (FDDs) on the air-freezing index map (page 8).
2) Find your air-freezing index in the left hand column in Table No. R-403.3 (page 8). Move to the right to find the required effective (below-grade) R-values for vertical and horizontal insulation along the walls and at the corners.
3) Divide the required effective R-values by the factors in footnote 3 for the particular type of insulation you are using (Type II expanded polystyrene (2.4 R per inch), Type IV extruded polystyrene (4.5 R per inch), or Type IX EPS expanded polystyrene (3.2 R per inch). The answer is the required insulation thickness.
4) In the right three columns of Table R-403.3, find the required width of horizontal insulation along the wall (A), and the width (B) and length (C+B) of corner insulation, if required. See insulation plan in Figure 403.3 (1).

Other Code Requirements

- The monthly mean temperature in the building has to be maintained at a minimum of 64° F. The design specified here is for heated buildings only. Garages or porches must either be heated or the foundations extended to the frost line.
- *No portion of the slab-on-ground foundation using the frost-protected footings can be located underneath unheated spaces such as porches, utility rooms, garages and carports.
- Insulation has to meet ASTM C 578.
- Foam plastic insulation cannot be used in areas of very heavy termite infestation probability (southeastern U.S.). Elsewhere, follow local code requirements using soil treatment, physical barriers and pressure-treated wood.
- *Any horizontal insulation placed less than 12 inches below the ground surface and any portion that extends outward more than 24 inches from the foundation edge must be protected against damage by use of a concrete slab or asphalt paving on the ground surface directly above the insulation or by cementitious board, plywood rated for below-ground use, or other approved materials placed below ground, above the insulation.
- *Ground around the house must be sloped to drain, according to code, and in other than Group I soils, gravel or crushed stone beneath horizontal below-ground insulation must drain to daylight or into an approved sewer system.
- Check your energy code. The more stringent of frost and energy requirements applies.

** 1998 International One and Two Family Dwelling Code*

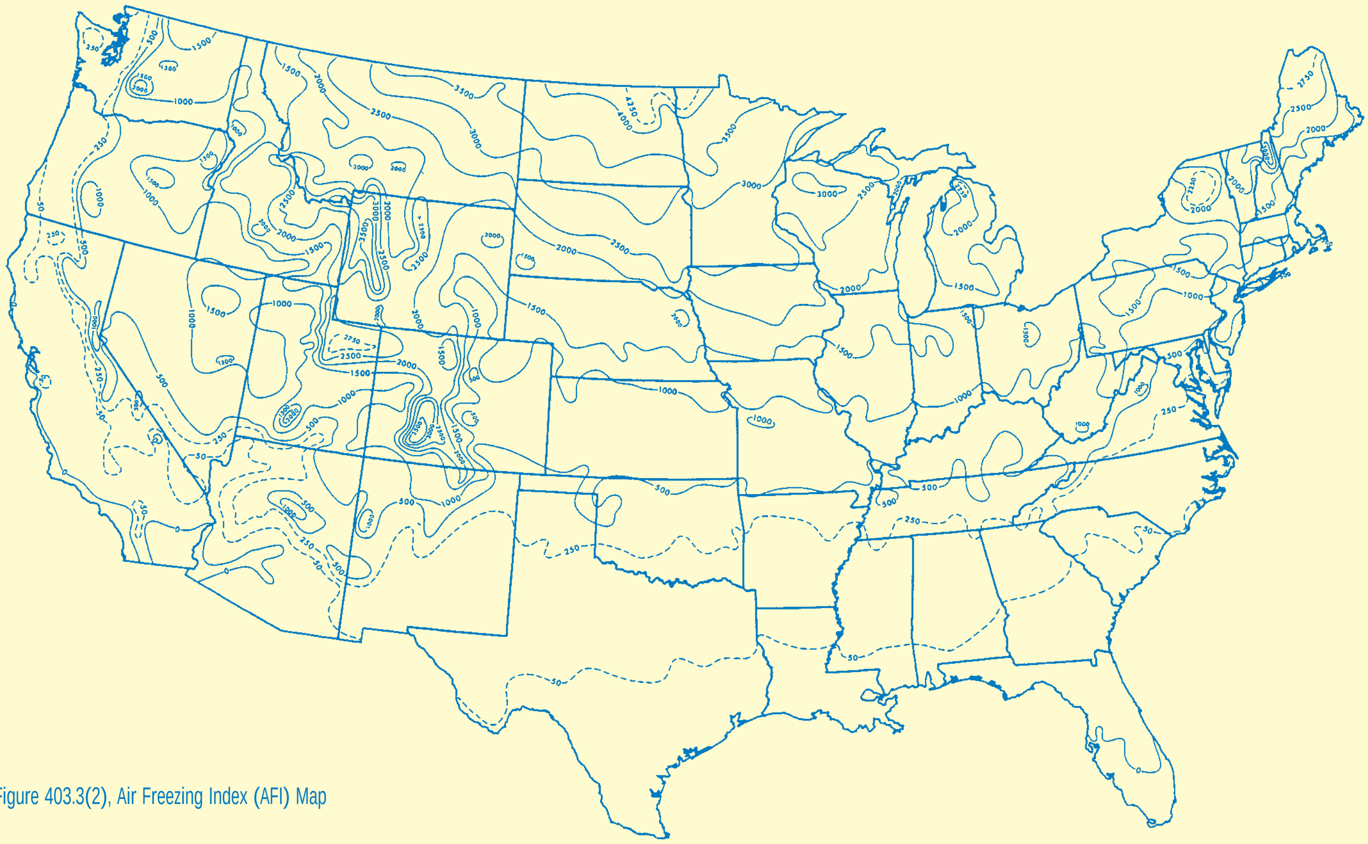


Figure 403.3(2), Air Freezing Index (AFI) Map

AFIs

Do not confuse Heating Degree Days (HDD) with Air Freezing Index (AFI). AFI is a much lower number and is a measure of frost heave potential on your site. AFIs for specific U.S. weather stations may be obtained from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA), 151 Patton Ave., Asheville, NC 28801-5001 or by e-mail at orders@ncdc.noaa.gov. Request TD9712D for digital data or request a hard copy printout for one or more stations or states.

TABLE 403.3
MINIMUM INSULATION REQUIREMENTS FOR FROST-PROTECTED FOOTINGS IN HEATED BUILDINGS[a]

AIR FREEZING INDEX (°F.-days)[b]	VERTICAL INSULATION *R*-VALUE[c,d]	HORIZONTAL INSULATION *R*-VALUE[c,e]		HORIZONTAL INSULATION DIMENSIONS PER FIGURE 403.3(1) (inches)		
		Along walls	At corners	A	B	C
1,500 or less	4.5	NR	NR	NR	NR	NR
2,000	5.6	NR	NR	NR	NR	NR
2,500	6.7	1.7	4.9	12	24	40
3,000	7.8	6.5	8.6	12	24	40
3,500	9.0	8.0	11.2	24	30	60
4,000	10.1	10.5	13.1	24	36	60

NR = Insulation not required.

For SI: 1 inch = 25.4 mm, °C. = [(°F.)-32]/1.8.

[a] Insulation requirements are for protection against frost damage in heated buildings. Where required to meet energy conservation standards, greater values shall be used. Interpolation between values is permissible.

[b] See Figure 403.3(2) for Air Freezing Index values.

[c] Insulation materials shall provide the stated minimum *R*-values under long-term exposure to moist, below-ground conditions in freezing climates. The following *R*-values shall be used to determine insulation thicknesses required for this application: Type II expanded polystyrene—2.4*R* per inch; Type IV extruded polystyrene—4.5*R* per inch; Type VI extruded polystyrene—4.5*R* per inch; Type IX expanded polystyrene—3.2*R* per inch; Type X extruded polystyrene—4.5*R* per inch.

[d] Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

[e] Horizontal insulation shall be extruded polystyrene insulation.

Structural Systems

FPSFs are constructed using various structural systems. These include grade beams made of wood, concrete and concrete block, all with floating (unattached) slabs-on-grade, as well as monolithic (thickened edge) slab-on-grade. Stay-in-place foam forms can be used. In Scandinavia, stay-in-place forms made of EPS covered with 1/2-inch-thick high strength concrete are widely used. Frost-protected designs for unvented crawl spaces can be found in the NAHB Research Center Design Guide.

All FPSFs must be built on soil with sufficient bearing capacity. If you don't know whether you have sufficient bearing capacity, consult a soils specialist and/or structural or geotechnical engineer. Also, consult an engineer for specific slab structural designs.

Construction

The job should start with removing the topsoil and grading a level area for the house down to undisturbed soil. Perimeter trenches are then dug for the grade beams or thickened edge, and utilities installed to the interior of the foundation (see photo). Washed gravel or screened and

Left: Airport terminal addition at Angelholm, Sweden, using EPS-concrete stay-in-place forms (Skanska Construction)

Right: Townhouse excavations showing gravel in trenches and utility preinstallation, prior to forming of grade beams, Oslo, Norway (Moelven Construction)

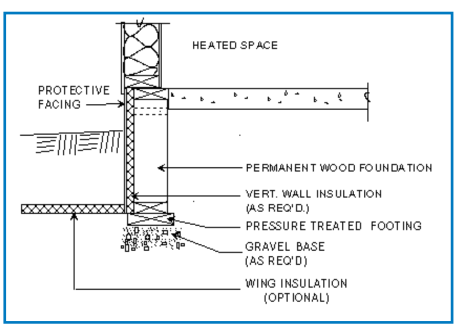
washed crushed rock (3/4"-1"), at least 4 inches thick, is placed into the trenches, graded, and tamped (if greater than 6 inches thick).

Grade Beam. Inner and outer forms are installed on the gravel. Rebar, 1/2 inch or more in diameter, often two at the top and two at the bottom, are installed between the forms to reinforce the beam. After the concrete is placed and hardens, forms are stripped, the interior area is graded, gravel is placed and graded under the slab area, sub-slab insulation is placed (for comfort, maximum R-10), 6 mil polyethylene sheeting is placed and the slab is poured.

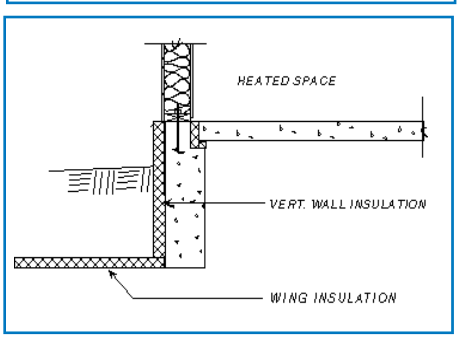
Monolithic Slab. The sub-slab gravel is placed, graded and tamped at the same time as gravel in the perimeter trench. The single outer slab form is installed and reinforcement rods installed–often two at the bottom, two at the top, and vertical rebar bent over to extend into the slab. Sub-slab insulation and polyethylene are then placed, and the entire slab, including the thickened edge is poured at once.

A variation of this method, which saves concrete, is to build forms like grade beams, but hold the inner form 4" lower, backfill against it and pour the slab, leaving the inner form in place under the slab.

Wood Grade Beam on Gravel Footing (follow requirements in the code)



Concrete Grade Beam (with soil of sufficient bearing capacity, spread footing is not needed)

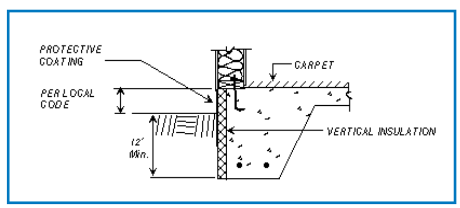


Use the Right Insulation

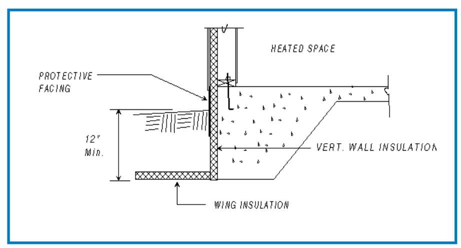
For FPSFs to work, you have to use the right type of insulation. It must be extruded polystyrene (XPS) or expanded polystyrene (EPS). Vertical insulation can be either XPS or EPS. Horizontal insulation required for frost protection has to be XPS. The XPS or EPS must meet ASTM Standard C578. You also must be sure that the type of XPS or EPS that you use is the same type that you used in your thickness calculations in step 2).

Protecting Insulation

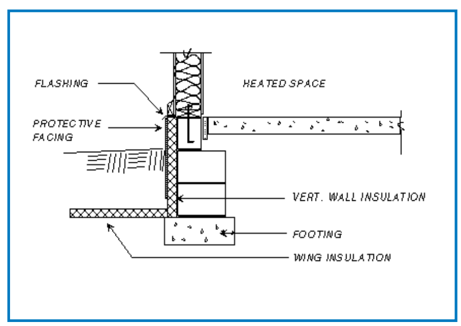
After the slab is poured and forms are stripped, attach the vertical insulation to the slab edge or grade beam, install a drainage pipe from the perimeter gravel to grade, and then install the horizontal insulation around the perimeter if required in your climate (AFI ≥ 2500). Any portion of the horizontal insulation extending more than 24 inches from the slab must be protected with pavement, cementitious board, foundation grade treated plywood, etc. Widths greater than 24 inches are required where the AFI is 3,500 or higher.



Monolithic Slab in a Mild Climate



Monolithic Slab with Horizontal Wing Insulation for Colder Climates



CMU on Concrete Footing

Protective Finishes for Insulation

- Treated plywood, foundation grade, painted above grade
- 2- or 3-coat stucco over mechanically attached wire mesh
- Elastomeric stucco with or without fiberglass reinforcement
- Brush-on elastomeric coatings
- Fiberglass-reinforced panels
- Vinyl siding or panels
- Non-corrosive metal coil stock
- Cementitious sheets (cement board)
- Non-reinforced stucco
- Factory-installed unreinforced stucco finishes

Minor discontinuities in wing insulation will not significantly affect the performance of FPSF designs, but should be minimized.

Above grade vertical insulation and the portion extending to six inches below grade must also be protected from ultra-violet radiation, physical damage and other sources of deterioration. Finishes with low damage resistance should be installed in areas protected from severe physical abuse (e.g., lawn mowers), such as behind shrubbery or flower beds.

The most common Norwegian FPSF design eliminates the need for insulation protection by placing insulation on the interior of the grade beam and under it. For more information, contact NAHB, 800-368-5242, ext. 444.

Termite Protection

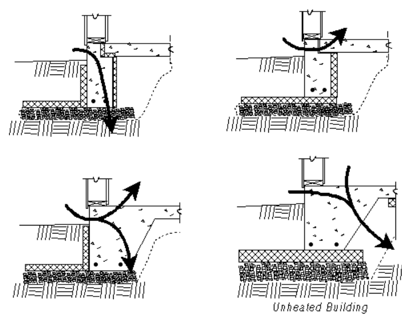
Comply with locally-approved methods when building wood frame buildings in geographical areas subject to termite infestation. For federally-assisted housing, consult your local HUD Field Office. Approved methods include chemical soil treatment and physical barriers such as termite shields.

When required, physical barriers (e.g., aluminum flashing) should be placed between the foundation and the above-grade structure and extend the full thickness of the foundation, so that any termite shelter tubes built around the barrier can be visually inspected.

Structures that are constructed entirely of preservative treated wood, naturally termite-resistant wood, steel, concrete, or other materials not susceptible to termite damage, are usually considered protected against termites. In some highly susceptible termite regions, local codes prohibit use of foundation insulation.

Heated vs. Unheated Spaces

Use the designs in this brochure for heated buildings only! Never use these designs for unheated spaces under screen porches, breezeways and garages. Extend foundations for these portions of the house to the design frost line required in your area. Or, build them according to designs for unheated buildings in the NAHB Research Center Design Guide. The unheated building designs have not yet been approved by code in the U.S., but are widely used in the Nordic countries. Some builders have found that it is less expensive to install deep foundations for these portions of the house than to use the FPSF designs for unheated buildings.



Cold Bridges

Be careful not to build any "cold bridges" that conduct heat from under the footings to the cold air above grade. Cold bridges may cause the foundation to fail. If vertical insulation is used on a slab-on-grade house with brick veneer, it must be continuous on top of the brick ledge and up the wall behind the brick. If insulation is used on the outside of a basement wall below grade on the walk-out side, it must continue up the outside of the basement wall to the top, unless the insulation is within the wall (as in a wood wall). Any discontinuities in insulation will allow heat from the house to "short circuit" to the cold air above ground instead of going into the ground under the footers where it keeps the ground from freezing.

Frost and Frost Heave

With the coming of freezing weather, frost moves into the ground from the top of the ground. Snow, fallen leaves and turf insulate the top of the ground and slow the movement of the frost into the ground.

As the ground freezes, surface water and water from the water table that moves upward to the frost line (frost front) through capillary action, freezes at the line in the soil where the temperature is below freezing. The water gradually builds ice lenses that push the ground upward

Left, home built by Bill Eich in 1990 in Spirit Lake, Iowa. Garage on the left, built on a FPSF, is attached to a walkout basement with a FPSF at grade (three foundation depths). Siding is straight. No differential movement has occurred.

Left, homes on walkout basements built in 1989 by Bill Eich on Spirit Lake, Iowa.

(at a right angle to the frost line). The frost line turns upward as it nears the foundation of a heated building, and the pressure turns horizontal-outward and against the foundation wall or slab edge.

For frost heave to occur, three conditions must be present. If any one is absent, the ground will not heave. These conditions are:

- sub-freezing temperatures
- moisture
- frost-susceptible soil.

Soil type affects the degree of frost heave. Well-drained sand and gravel (large soil particles) do not heave because they do not support capillary movement of water and because the spaces between the sand and gravel are too large to allow the growth of ice lenses. Clay (very fine soil particles) is not very frost-susceptible because it blocks the movement of water. This property allows use of clay in building earthen dams. Silt is most frost-susceptible because its particles are of moderate size and support both capillary action and frost lens growth.

A small amount of water in soil contributes little to frost heave. A large amount of water in soil holds so much heat that the movement of frost into the ground is slowed. A moderate amount of water in soil contributes most to frost heave. In very cold areas, frost can raise the ground 2 feet.

FPSFs prevent frost heave by keeping the ground under the footings above freezing. A heat bulb builds up underneath heated slab-on-grade buildings that stores heat and supplies it to the perimeter to protect the foundation even if the heat in the building is off for a week or more in winter.

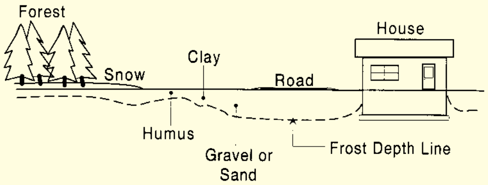
Frost-Line Requirements

Conventional frost-protection provisions require that footings "extend below the frost line" where the temperature stays above freezing "except when erected upon solid rock or otherwise protected from frost." Design frost lines are crude measures, however, usually based on maximum depths of frozen pipes in streets underlain with gravel that conducts heat well and freezes deep. Streets are also cleared of snow and are often away from buildings that supply heat to the ground.

FPSFs Attached to Deep Foundations

Deep foundations can be safely attached to frost-protected foundations, provided both are built on soil with adequate bearing capacity, and frost protection requirements are followed. Differential movement from vertical building loads will not occur where soil is of adequate bearing capacity, even though foundations are at different levels. For example, homes with deep basement foundations are commonly attached to shallower garage slab foundations. Another example is that basements are frequently built on a hillside with one side on a deep foundation and the walk-out portion on a shallower foundation.

Starting foundations below the design frost line and using FPSF techniques are both adequate methods for preventing movement of foundations by frost. For this reason, if a properly designed FPSF is connected to a deep foundation, differential movement from frost will not occur. This is attested to by the large number of homes constructed on FPSFs in the U.S. and Scandinavia that have attached garages built on deep foundations, as well as by walk-out basements that have the at-grade wall built on a FPSF. This walkout basement FPSF design has been the most common FPSF application in Norway for the past 30 years.



Home by Bruno Schickel on FPSF in Dryden, New York.

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For more information on frost-protected shallow foundations, contact Dick Morris at NAHB, 800-368-5242, ext. 444, or e-mail him at dmorris@nahb.com. Call the NAHB Research Center, 800-638-8556, to order the *Design Guide for Frost-Protected Shallow Foundations, 2nd Edition*.

Obtain NAHB Research Center research reports published by the U.S. Department of Housing and Urban Development in 1993 and 1994. Call the Research Center or see the HUD web site, www.huduser.org/publications/destech/frostprt.html.

Obtain U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Monograph 92-1, European Foundations for Seasonally Frozen Ground, which documents the successful use of FPSFs in Scandinavia. Request a copy by e-mail at erhoff@crrel.usace.army.mil.