

Design Resources

American Society of Civil Engineers
(www.asce.org)

NAHB Research Center, Inc.
(www.nahbrc.org)

National Association of Home Builders
(www.nahb.com)

U.S. Department of Housing and Urban
Development (www.huduser.org)

codes & standards

Frost-Protected Shallow Foundations

SEI/ASCE 32-01

A Cost-Effective Approach to Foundation Design

Jay H. Crandell, P.E.

With recent adoption of the Frost-Protected Shallow Foundation (FPSF) technology by the 2003 *International Codes* (I-Codes), a revolutionary approach to foundation design is becoming a widely accepted practice for protection of foundations against frost heave in the United States. The approach uses strategic placement and sizing of polystyrene insulation to protect a foundation and underlying soils against freezing temperatures and frost heave. Thus, foundation depths similar to those used in the southern United States are now possible in more northern climates. A typical FPSF slab-on-grade foundation under construction in Fargo, North Dakota is shown in *Figure 1*. A multitude of other applications are possible provided appropriate design principles are followed.

“...a revolutionary approach to foundation design ...”

The primary benefits of this technology over the conventional method of placing footings below a locally prescribed frost depth include:

- Foundation cost savings,
- Increased energy efficiency,
- Efficient use of resources,
- Minimized site disturbance, and
- Simple to design and build.

The concept was first used in the United States by the famous architect, Frank Lloyd Wright, on affordable *Usonian* style homes in the Chicago area during the post-depression era. Later, the Scandinavian countries of Europe adopted and refined the technology shortly after the invention of polystyrene insulation in Europe. Now, more than 1 million commercial and residential buildings have been constructed in Europe using the FPSF technology. The technology has also been used to protect other types of structures such as roads, retaining walls, and underground utilities against freezing temperatures and frost heave.

“The technology has also been used to protect other types of structures ...”

In the past decade, FPSFs have seen steadily increasing use in the United States on an estimated several thousand commercial and residential buildings. With recently expanded building code recognition, this trend is expected to continue. In northern U.S. climates (i.e., where design frost depths exceed about 24 inches), cost savings on a typical small commercial building such as a convenience store or similarly sized house can easily exceed several thousand dollars – more than enough to cover any reasonable foundation design expense. In larger commercial and residential developments, cost savings of several hundreds of thousands of dollars have been documented. With these types of savings and other benefits, this technology is destined to bring success to those who use it appropriately.

How it Works

Frost-heave depends on the presence of three factors: (1) below freezing temperatures, (2) frost-susceptible soil, and (3) adequate supply of moisture in the soil. From a performance-based design perspective, removing any one of these factors will protect a foundation against the devastating effects of frost heave. The FPSF technology uses foundation insulation to effectively raise the frost depth by conserving building and geothermal heat (see Figure 2). In heated (occupied) buildings, heat sources include interior conditioning of the building and geothermal stores, whereas in unheated buildings the only heat source is geothermal. In the latter case, greater amounts of insulation are required and the building foundation is essentially constructed on a foundation pad comprised of a "blanket of insulation" and non-frost susceptible granular fill (see Figure 3).

"...uses foundation insulation to effectively raise the frost depth ..."

Because the technology is meant to conserve heat loss from the building and ground, it is not appropriate for areas subject to permafrost. It is also important to ensure that the proper type and size of insulation is provided and placed (detailed) such that cold-bridges do not occur. A cold-bridge is essentially a thermally conductive pathway around the foundation insulation (see examples in Figure 4). While cold-bridges diminish the effectiveness of the insulation and should be avoided, smaller gaps and seams in the insulation have been shown in field research to have a negligible effect on performance.

"...cold-bridges diminish the effectiveness of the insulation..."

It is also extremely important to be sure that appropriate types of extruded or expanded polystyrene are specified and used, as these products maintain an adjusted or effective thermal resistance value (R-value) in moist, below-ground applications. It is also important to specify an appropriate type of polystyrene when used in load bearing applications supporting distributed footing loads as in Figure 3. Where exposed above-grade, polystyrene must also be protected against damage using a protective facing such as polymer-based or conventional stucco, vinyl, or other materials suitable for exterior use. Other important design considerations, such as bearing value of soil at depth, follow standard design practice or building code requirements.



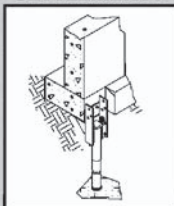
Figure 1. A Typical FPSF application with a slab-on-grade foundation under construction (The local frost depth is 52 inches, but with the FPSF design a footing depth of 16 inches was successfully used).

ATLAS SYSTEMS, INC.™

Developer/Manufacturer of **Rapid Foundation™** Support Products and Equipment

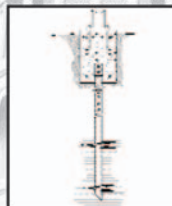
"We Can Change History"™

SETTLEMENT?



Restore with
Atlas Resistance® Piers
Resistance Products

SOIL PROBLEMS?



Support with
ATLAS Helical®
New Construction Products

LATERAL INSTABILITY?



Support with
ATLAS Helical®
Tie-Back Products



MARKETS AVAILABLE:
For your local contractor or dealership inquiries, contact:
Atlas Systems, Inc.™
1026-B South Powell Road
Independence, MO 64056
Fax (816) 796-0919

1-800-325-9375

E-mail: info@atlassys.com

VISIT US AT: www.atlassys.com



How to Design an FPSF

Fortunately, FPSFs are simple to design and a code-compliant standardized design method is available through the American Society of Civil Engineers (ASCE Standard SEI/ASCE 32-01) that addresses monolithic slab construction, various types of footings or grade beams, crawlspace foundations, spread footings, and other applications. The standard includes a step-by-step design procedure and provides all the design data needed for a complete design. A short (2 page) design method is also included for simple slab-on-grade applications with heated (occupied) buildings. In addition, a commentary explains the principles, research, and experience behind the provisions. The standard is modeled after a design guide created for the U.S. Department of Housing and Urban Development, and an International Standards Organization (ISO) standard that reflects knowledge from over 30 years of research and application experience in European countries (primarily Norway, Sweden, and Finland). The design methodology has been proof tested and extensively monitored on building applications in several U.S. states including Vermont, Iowa, North Dakota, Colorado, and Alaska.

“...FPSFs are simple to design ...”

The basic design method in the SEI/ASCE 32-01 standard includes the following typical steps:

1. Determine the building use classification (heated, unheated, or semi-heated).
2. Determine site design climate (from 100-yr Air Freezing Index Map and Mean Annual Temperature Map).
3. Enter insulation tables to determine R-value and dimensions of insulation required based on climate data from Step 2.
4. Select appropriate insulation type (expanded or extruded polystyrene) and effective thermal resistivity from tables that also include information on allowable bearing capacity.
5. Using information from Step 4, determine the required thickness of the insulation.

The standard also includes many typical details and guidelines that are adaptable to a variety of building and foundation configurations. While there is room for creativity in making an FPSF work for a specific building and site, it is important to adhere to the basic principles of FPSF design.■

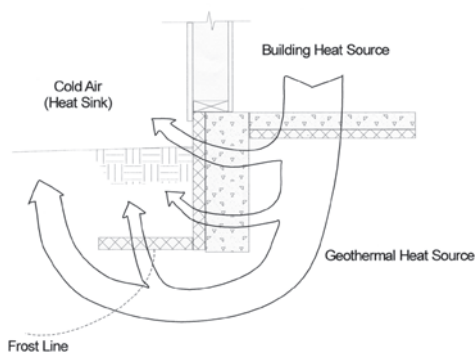


Figure 2. FPSF heat flow for a heated building.

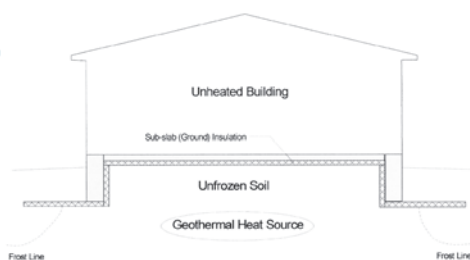


Figure 3. Example of FPSF detail for an unheated building.

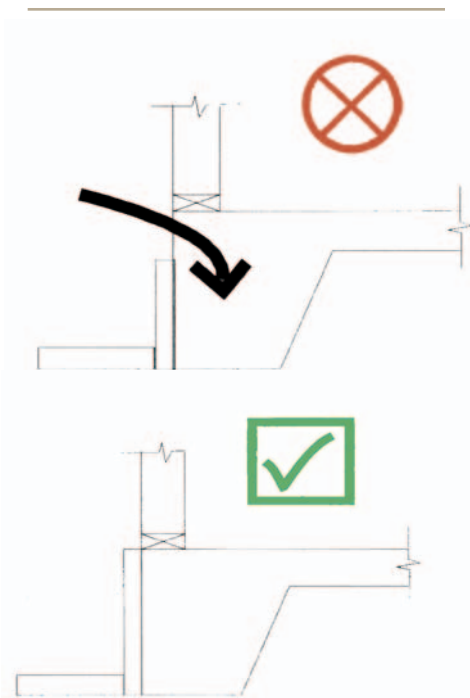


Figure 4. Insulation details to prevent a thermal “short circuit” or “cold-bridge” in an FPSF.

References

Crandell, Jay H. *Design Guide for Frost-Protected Shallow Foundations* (Second Edition) prepared for the U.S. Departments of HUD and DOE by the NAHB Research Center, Inc., Upper Marlboro, MD. June 1996.

Crandell, Jay H. *Frost-Protected Shallow Foundations* (Phase II – Final Report), U.S. Department of Housing and Urban Development, Washington, DC. June 1994.

Design and Construction of Frost-Protected Shallow Foundations (ASCE Standard SEI/ASCE 32-01), American Society of Civil Engineers, Reston, VA. 2001.

Farouki, Omar. *European Foundation Designs for Seasonally Frozen Ground*, U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory. March 1992.

Frost-Protected Shallow Foundations (Informational Brochure), National Association of Home Builders, Washington, DC.

International Building Code, International Code Council, Inc., Falls Church, VA. 2003.

International Residential Code, International Code Council, Inc., Falls Church, VA. 2000 and 2003.

Morris, Richard. “2003 I-Codes Adopt Revolutionary Frost-Protection Technology,” *Building Safety Journal*, Vol. 1, No. 3, International Code Council, Birmingham, AL. May 2003.

Steurer, P. M. and Crandell, J. H. “Comparison of Methods Used to Create Estimate of Air-Freezing Index,” *Journal of Cold Regions Engineering*, Vol. 9, No. 2, American Society of Civil Engineers, Reston, VA. June 1995.

Jay H. Crandell, PE has been involved in research, development, and implementation of several new technologies for building codes and standards in the United States. Frost Protected Shallow Foundations is one of the technologies that Mr. Crandell successfully introduced to U.S. building codes in 1995 under sponsorship of the U.S. Department of Housing and Urban Development and the National Association of Home Builders. Previously the director of the Structures and Materials division at the NAHB Research Center, Inc., Mr. Crandell now operates his own engineering consulting business.