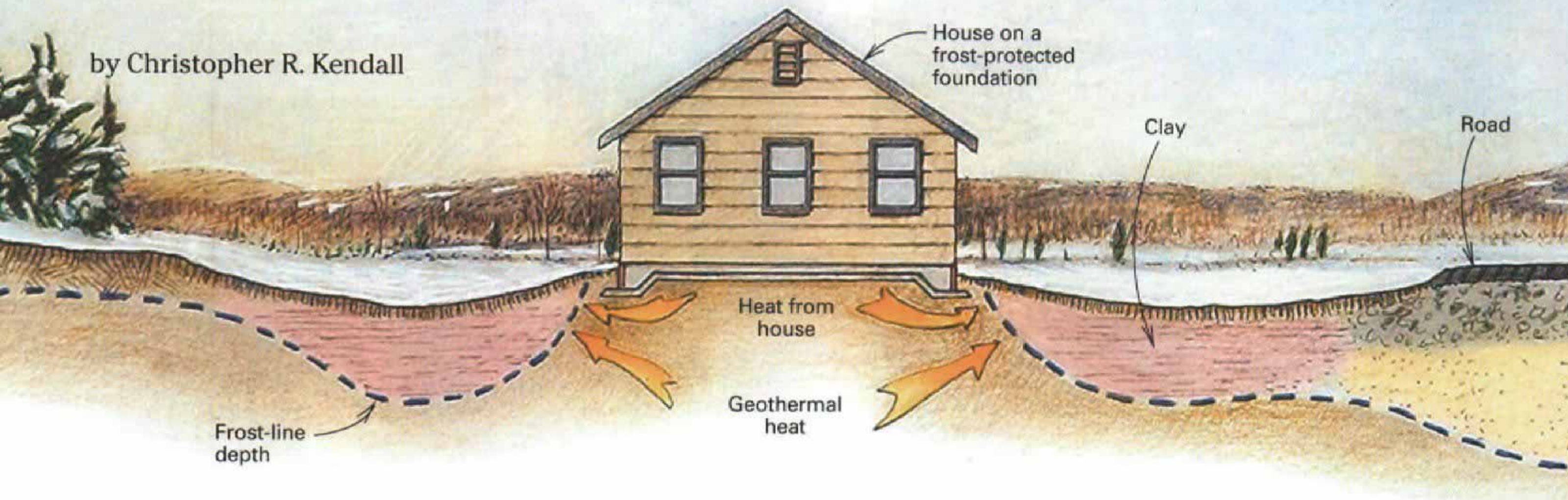
Frost-Protected Shallow Foundations

Used overseas successfully for decades, this innovative foundation system uses carefully placed insulation and a slab with integral footings instead of conventional deep frost walls

by Christopher R. Kendall



I used to work as project manager for a company that builds town houses on top of slab-on-grade foundations. For years we poured our slabs on top of conventional deep foundations built with insulated concrete block. After reading a report from the National Association of Home Builders (NAHB) Research Center (800-638-8556) that is now called *Design Guide for Frost-Protected Shallow Foundations,* I convinced my foreman, Fred Mellott, and the local code-enforcement officer to give this new type of foundation a try. As Fred and I designed the foundations for the 25-unit single-story town-house project on our new site, the NAHB report, which was funded by a federal grant, became our bible.

Admittedly, our first frost-protected shallow foundation did not go as smoothly as we'd hoped. The learning curve was steep, but as often happens, Fred and the crew helped to figure out the best methods for site preparation and form assembly as the first project progressed. By the time the first building was ready for concrete placement, we were up to speed, and watching the crew put in the foundation for the next unit, you'd have thought they had been building shallow foundations for years. We were convinced. We'd never go back to digging deep footings, lugging concrete block and dealing with cranky masons, not to mention backfilling and tamping all that soil.

Thawing out conventional frost wisdom—Frost-protected shallow foundations have been standard building practice in Scandinavian countries since World War II. The idea evolved as a sensible alternative to the usual deep foundation set on a footing for colder regions such as northern Europe, the northern United States and Canada. Frost-protected foundations are less costly in time and materials than deep foundations, and they need less site disturbance.

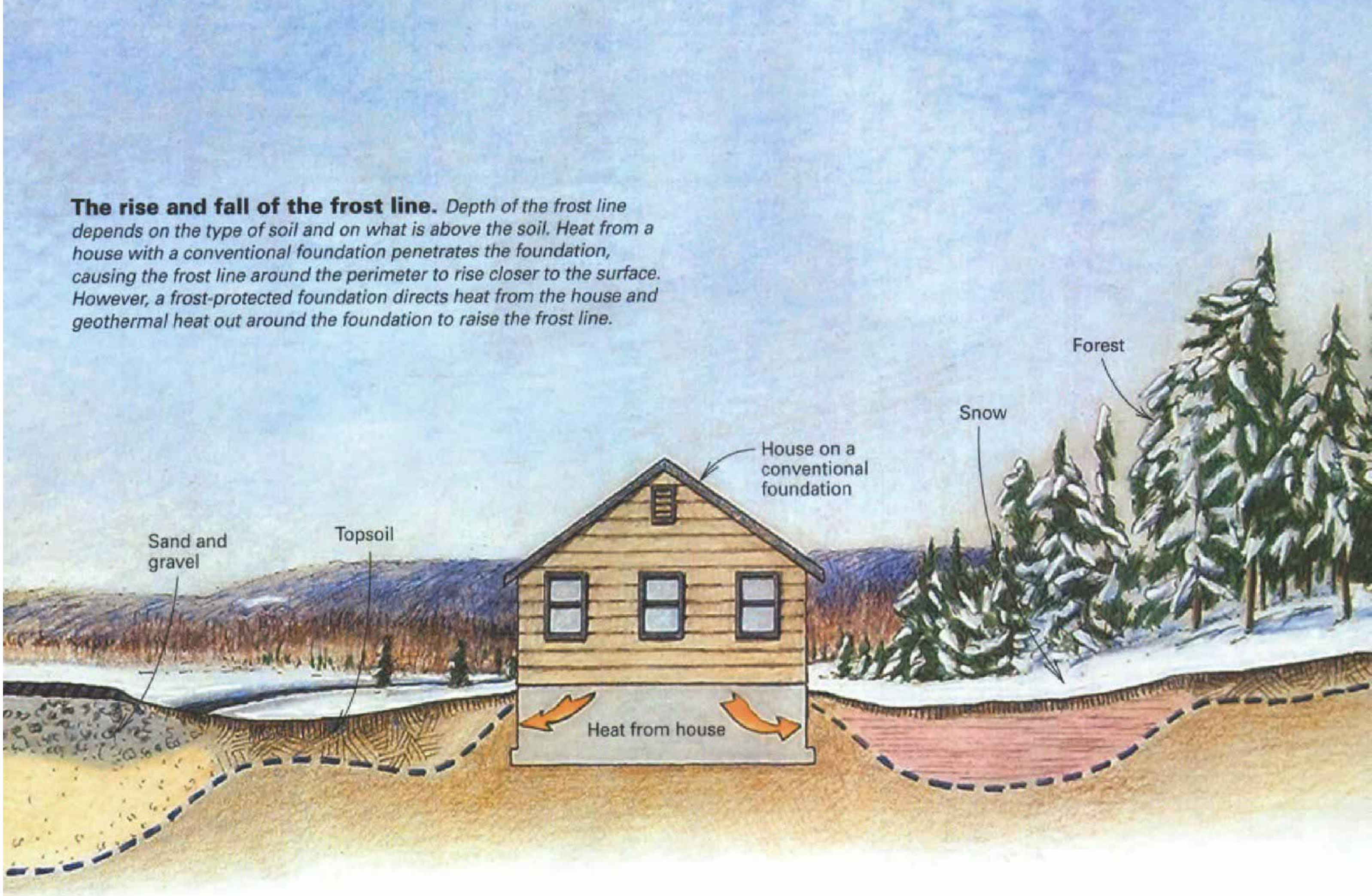
But doesn't a foundation have to be put below the frost line, where it won't be damaged by the freezing and expansion of moisture in the soil, and isn't that line many feet below ground level during the coldest months of the year? To answer these questions, you must first realize that the frost line, or the depth to which frost penetrates the ground, can vary significantly depending on the type of soil and what is on top of that soil (drawing above). For example, the frost line may be relatively shallow in the ground under a wooded area, but a road on a base of sand or gravel allows the frost to penetrate to a much deeper level.

Likewise, the frost line is usually higher around a heated house. Heat escaping from the house into the ground through the slab and foundation plus geothermal heat, or the warmth of the earth trapped beneath the slab, causes the frost line to rise around the perimeter of the foundation. A frost-protected foundation redirects that warmth into the soil by strategically placing insulation on and around the outside of the foundation, thus raising the frost line at the foundation perimeter even more. In fact, with proper insulation most frost-protected shallow foundations need to be only 16 in. deep even in the coldest of climates.

Footings are built into the edges of frost-protected foundations—In addition to the heated living spaces, the town houses we built have attached garages and screened-in porches on slabs (photo facing page). We used frost-protected shallow foundations for each situation, but the exact configuration depended first on whether the space was heated.

If the foundation was going under a heated space, the main area of the slab was excavated down about 8 in. from the projected floor height (top drawing, pp. 78-79). About 2 ft. from the outer edge of the foundation, we sloped the soil

Drawings: Christopher Clapp



The rise and fall of the frost line. *Depth of the frost line depends on the type of soil and on what is above the soil. Heat from a house with a conventional foundation penetrates the foundation, causing the frost line around the perimeter to rise closer to the surface. However, a frost-protected foundation directs heat from the house and geothermal heat out around the foundation to raise the frost line.*

Frost-protected support for any situation. Every section of these town-house units was built on shallow, frost-protected foundations. With properly placed insulation, these foundations can be adapted for heated and unheated spaces as well as for garage stemwalls.

down to a depth of 20 in. at a 45° angle. After the soil was compacted, a 4-in. layer of crushed stone was spread over the entire area, and we were ready for our vapor barrier and forms.

Under an unheated space such as a porch, we took the entire area of the slab down to a depth of 22 in. (bottom drawing). After the soil was compacted, the whole area was covered with a 4-in. layer of crushed stone with 2-in. extruded-polystyrene (EXPS) foam on top of that. The stone and the foam extended beyond the foundation a couple of feet except where the porch abutted the house.

Next, we covered the foam under the main area of the slab with 12 in. of crushed stone. We sloped it down to the level of the foam board around the perimeter to form the same built-up edge that we created under the heated space. If the unheated space was a garage, we formed stemwalls on top of the foam (top photo, p. 81).

We opted for the stemwall rather than a complete slab system for a couple of reasons. First, we are required by law to step the garage floor down 4 in. below the floor of the living space. Putting a monolithic slab at this level would mean not being able to use precut studs, which we were using for the rest of the house. Plus, we liked to pitch the garage floor toward the apron, and pitching the entire foundation structure would make each stud a different length. A stemwall with its top at the same level as the house slab solved both problems.

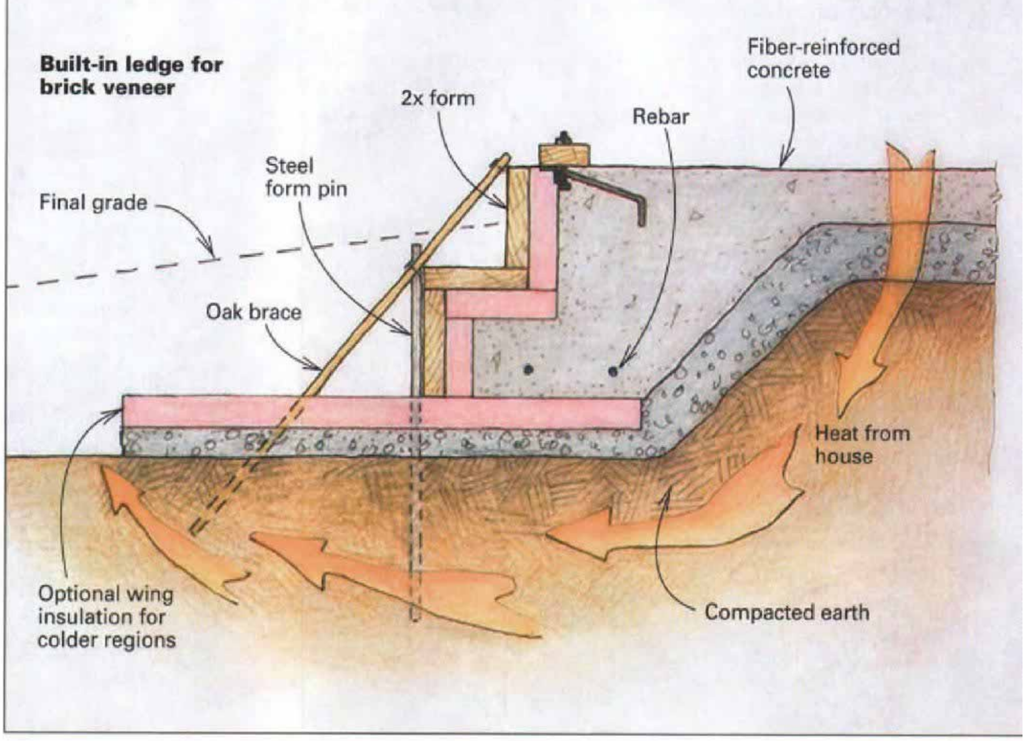
Easy-to-build forms are reusable—Once the ground had been prepared, we were ready to set our forms. Our most basic form consisted of ½-in. oriented strand board (OSB) ripped to 12 in. and rabbeted into a 2x4 top and bottom (bottom photo, facing page). We covered the crushed stone with a 6-mil poly vapor barrier, then set our form panels on edge, keeping them vertical with 30-in. steel form pins (stakes with holes in them for nails) ¾ in. in dia. We added diagonal oak bracing at every pin to keep the forms from blowing out under the weight of the concrete. If we were forming a foundation to go under a heated space, the inside of the form was lined with 2-in. EXPS, which stuck to the concrete (top drawing).

Here in Pennsylvania, placing the insulation inside the forms provided adequate frost protection, according to the HUD report. In areas farther north, additional insulation called wing insulation must be placed around the perimeter of the foundation to keep frost at bay. The width and the thickness of insulation varies with the severity of local climate; the HUD report offers detailed recommendations for specific areas.

All our town houses have brick-veneer front walls that put a fly in the foundation-design ointment. The problem was how to support brick

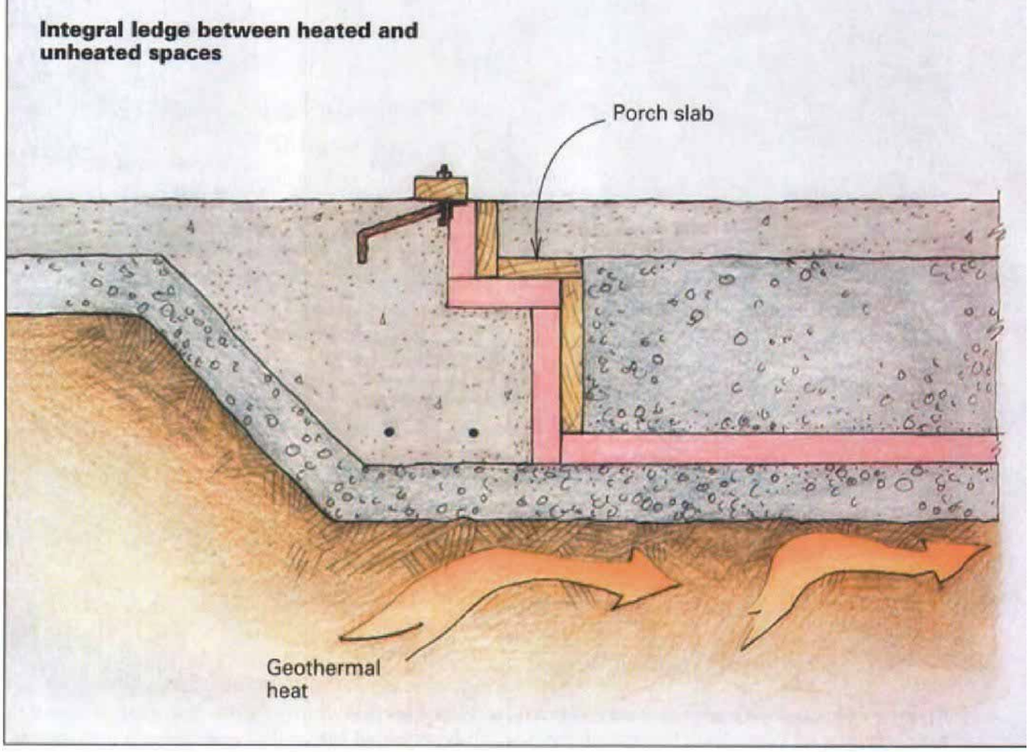
Forming a foundation under a heated space

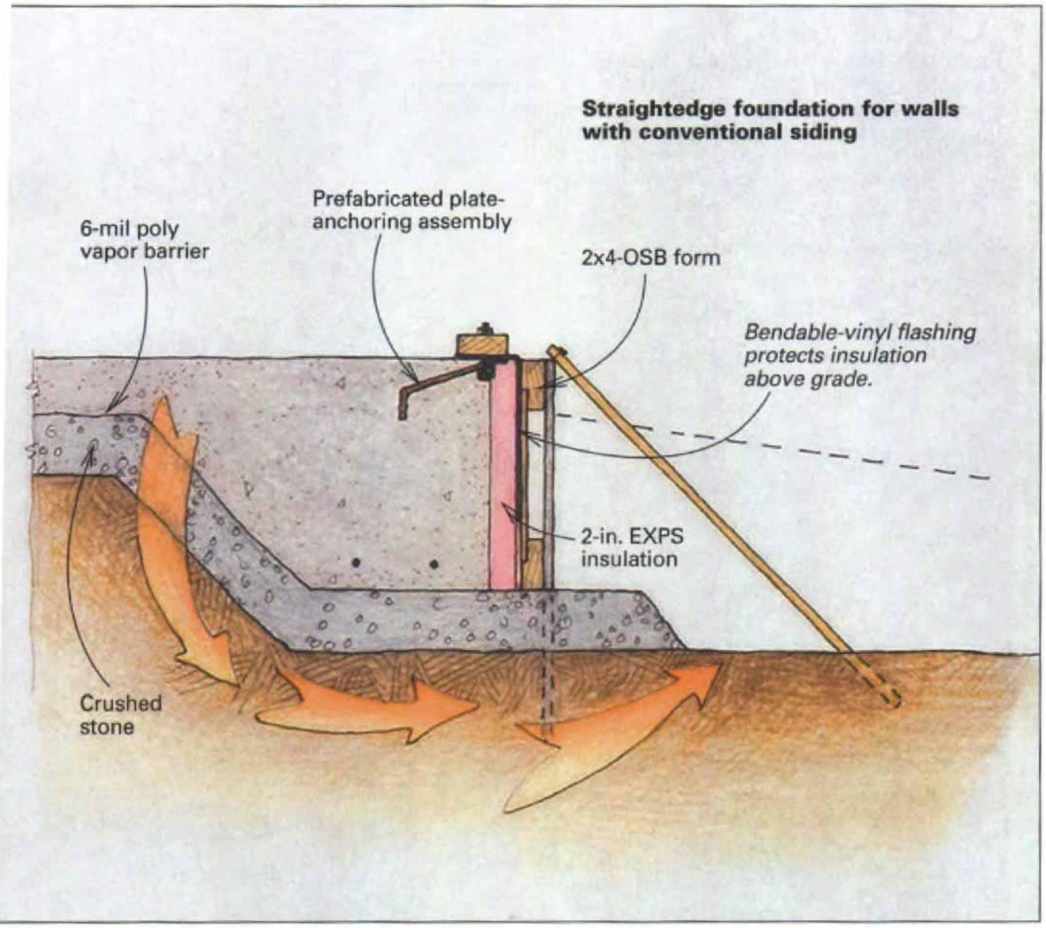
The insulation around the perimeter of a frost-protected foundation under a heated space channels heat from the house into the ground, keeping frost away from the foundation. In colder climates wing insulation, buried in the ground outside the foundation, may be required to trap additional geothermal heat to protect the foundation.

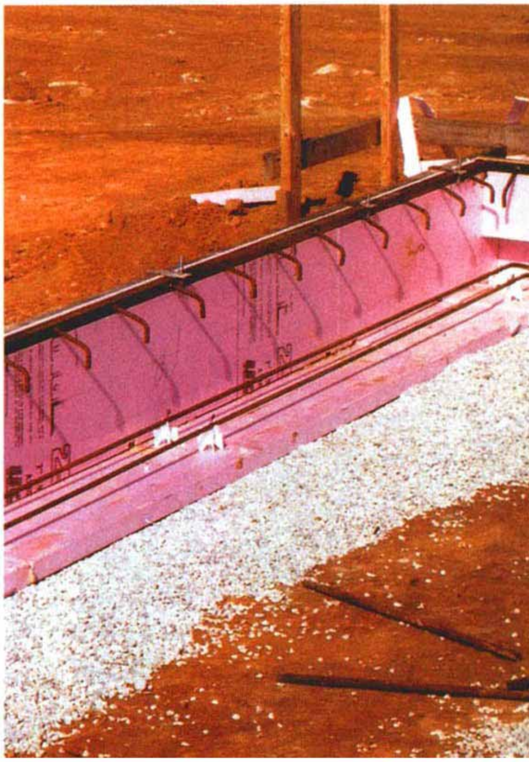


Forming a foundation under an unheated space

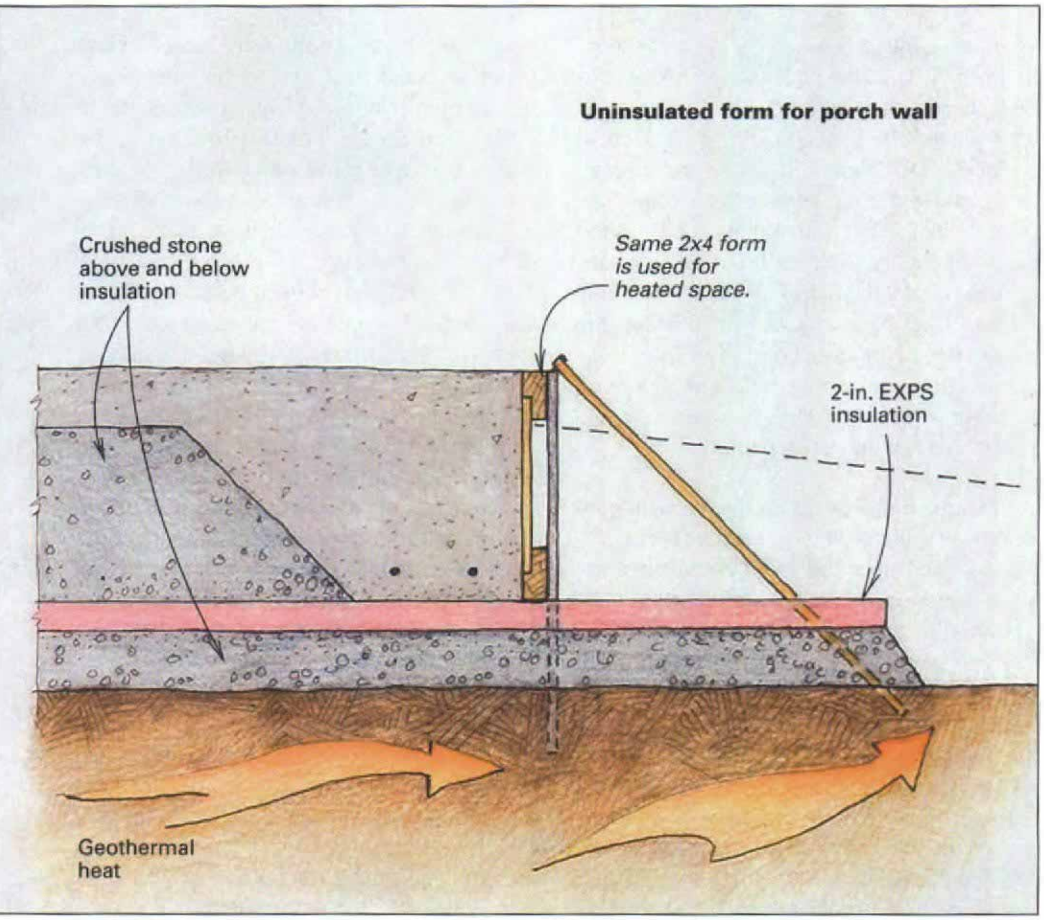
Insulation that runs under an unheated space such as a porch traps geothermal heat to protect the foundation from possible damage from frost. Porch slab fits into an integral ledge formed in the edge of the heated space.

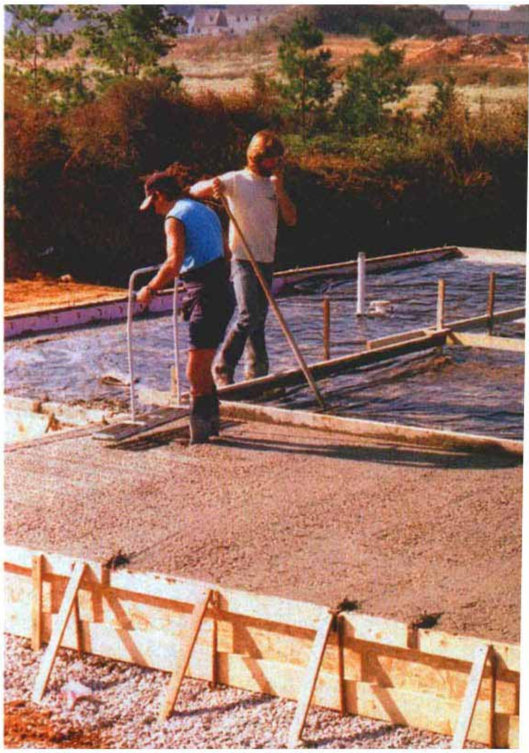






Conventional anchor bolts would have been too near the slab edge. To anchor 2x4 walls, a plate-support system made out of steel angle and rebar is prefabricated and installed along the top edge of the foam board before the concrete is poured.





Site-built forms can be reused. Simple forms that are made from oriented strand board and 2x stock are put together on site and held in place with form pins and wood bracing. The same forms can be used for each phase of the pour.

veneer without compromising the rigid insulation and creating a cold bridge. Our bible, the HUD report, never addressed this detail because none of its test houses had brick. Our idea was to support the brick veneer on a layer of foam insulation that would sit on top of a concrete ledge that would be part of the monolithic slab.

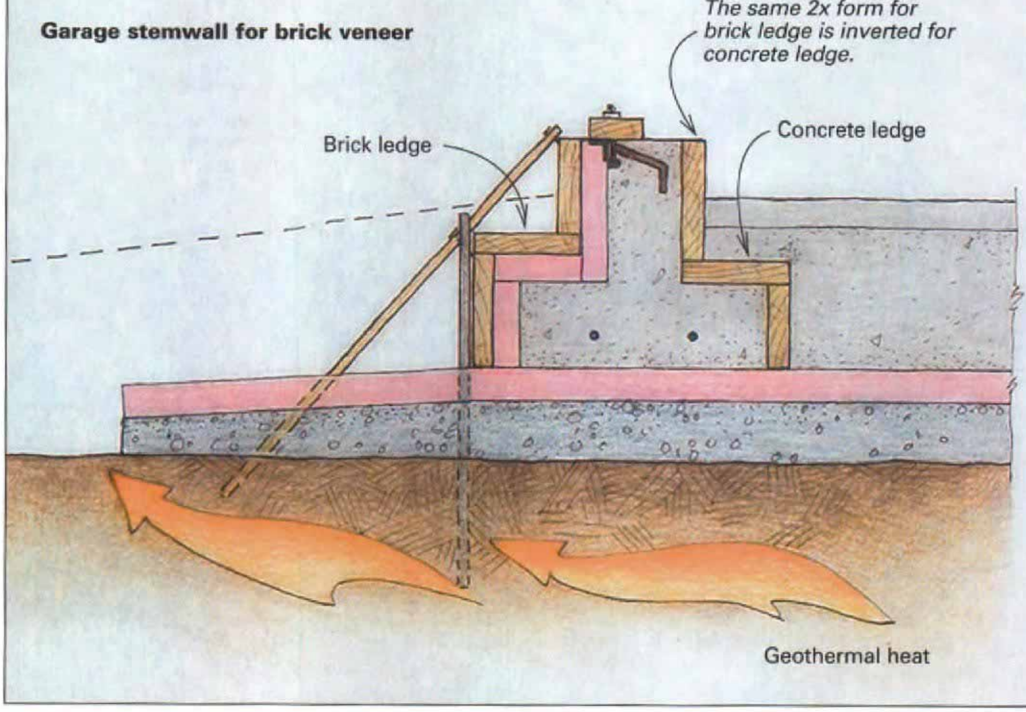
The only drawback to this solution was that the Brick Institute of America had deemed EXPS insulation to be inadequate support for brick. But using their figures, we figured that the load exerted by an 8-ft. column of standard brick was about 8 psi. U. C. Industries rates the compressive strength of its Foamular EXPS insulation at 25 psi, so we risked using this unproved, undocumented detail. In the two years since we built our first brick-veneered wall this way, we have experienced no problems with settlement or mortar-joint failure.

We made the form for this detail from 2x8s ripped to the proper width and screwed together in the shape of a step (top drawing, p. 78). This stepped form is lined with foam board and held in place with form pins and diagonal bracing. A similarly shaped form was used where the unheated space meets a heated space. In this case the stepped forms create an integral concrete ledge to support the slab of the unheated space, rather than the brick veneer (bottom drawing, p. 78). The same 2x4-and-OSB form that we used for the foundation under a heated space is also used on the outside edge of an unheated space, except that the forms are on top of the insulation (bottom drawing, p. 79).

We flipped the form for our brick ledge upside down to use as the inside form for our garage stemwalls (drawing right). The inverted form left us enough vertical space on the stemwall to pitch the 6-in. garage slab toward the door and to have concrete on top of the stemwall base.

Forming frost-protected garage stemwalls

To maintain consistent wall and floor heights, stemwalls are poured to support the garage. A pitched garage slab is then poured between the stemwalls. As with the unheated space, insulation under the slab forces geothermal heat out to warm the soil around the perimeter of the foundation.



Shop-welded steel helps to anchor the walls—Just before the concrete truck arrived, we added two courses of steel-reinforcement rod set on chairs that hold the rebar at 3 in. from the bottom of our built-up edge. We also added a special system for anchoring exterior walls.

For our town houses to qualify for an energy grant from the local power company, we needed to build our units with R-18 sidewalls. The easiest way to achieve this R-factor was by using 2x6 construction. However, because of the extra cost in materials and because of our attempt to maximize available living space, we decided on 2x4 walls with ¾-in. polyisocyanurate sheathing to provide the insulation to qualify for the grant.

Unfortunately, our wall plan created a problem with supporting and anchoring the wall plates. To keep the sheathed walls flush with the outside of the 2-in. EXPS foam on the foundation, the 2x4 bottom plate had to cantilever beyond the edge of the slab 1¼ in., and the remaining 2¼ in. of the plates would not be adequate to carry the wall loads.

We solved the problem with steel. A local welding shop fabricated a reinforced plate-anchoring system out of 1¼-in. by 1¼-in. angle stock 3⁄16 in. thick (top photo, p. 79). The shop welded #4 rebar hooks and ½-in. anchor bolts onto the angle, and the whole system cost only $2 per ft. The angle stock was rabbeted into the inside edge of the foam board, and angle irons slipped over the anchor bolts and extended over the edge of the forms to hold the whole system in place during the pour.

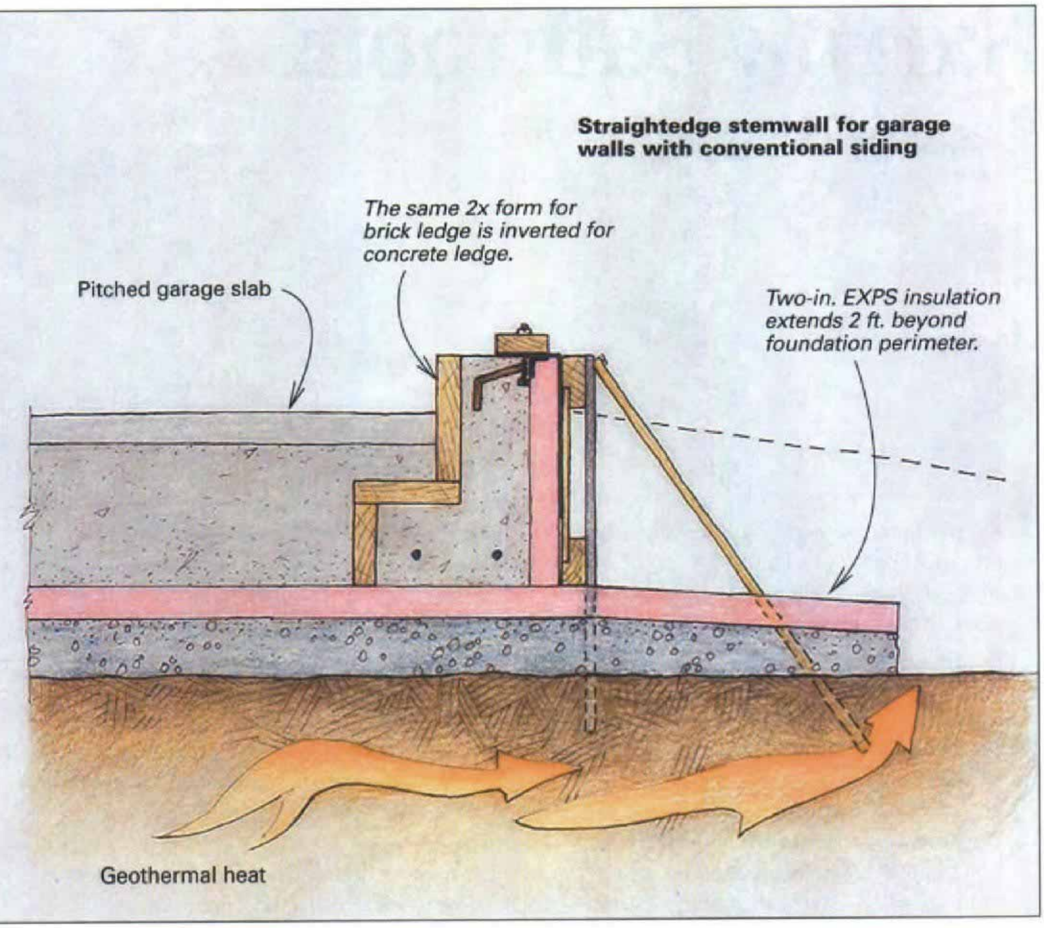
A vibrator helps to fill the forms with concrete—As with any slab, the locations of plumbing stubs and any other under-the-floor systems were double-checked according to the floor plan before we ordered the concrete. When everything was set, we began by pouring all but the top 4 in. in each section (bottom photo, facing page). We specified a 3,500-psi mix with a 4-in. to 5-in. slump, a fairly stiff mix.

Consolidating the concrete beside our straight vertical forms was easy. But the stepped forms that create the ledges for the brick veneer and the integral concrete slab presented a bigger challenge. It was imperative to fill the space beneath the horizontal sections of the form completely with concrete, and a concrete vibrator helped us to ensure complete consolidation in these areas. The head of the vibrator is on the end of a long tube inserted into the wet concrete under the ledge form. As the head vibrates, it forces out trapped air, allowing total consolidation in these areas.

When the edges had been poured and consolidated, we poured the rest of the slab. Wire mesh is ordinarily used to reinforce a slab. However, we found it a headache to get the mesh at the proper height or to pull it through the wet concrete and have it stay while the crew slogged around on top of the mesh. Instead, we used concrete reinforced with polypropylene fibers.

Screeding the concrete was another area where we found shallow foundations superior to block foundations. It's not that easy to get a smooth, even surface on the slab when screeding to the irregularities of the top of a block wall. But screeding to the angle stock of our plate-anchoring system was quick and easy.

While the concrete was still green, we used a diamond-blade saw to cut contraction joints in the slab. Contraction joints minimize the random cracking that occurs naturally as cement cures. With planning, most of these sawcuts can be hidden under interior partitions.



Insulation extends beyond the stemwalls. Garage stemwalls are formed directly on top of the foam-board insulation. The insulation continuing beyond the stemwall perimeter traps heat from the earth to keep frost at bay.

Bendable vinyl keeps out the bugs and the UV-rays—When test houses were built in this country using frost-protected shallow foundations, one problem builders faced was covering the exposed EXPS foam insulation between the grade line and the siding starter course. EXPS degrades when exposed to ultraviolet (UV) radiation and doesn't offer much resistance to impacts from baseballs and string trimmers.

Builders of test houses tried parging, brush-applied coatings and treated plywood. But we came up with a different solution that's simple and easily installed. Bendable-vinyl coil stock manufactured by Pro-Trim (Alum-A-Pole, 1011 Capouse Ave., Scranton, Penn. 18509; 800-421-2586) comes in 24-in. wide by 50-ft. long coils and is perfect for this application.

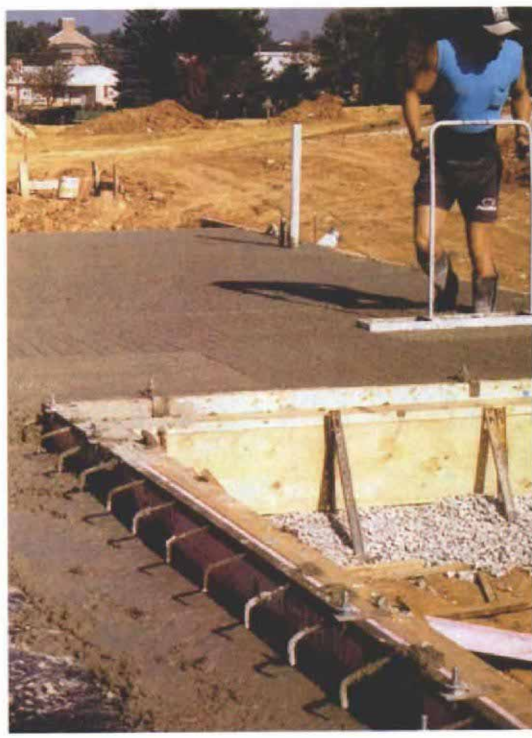
We wrapped the top outer edge of the foundation beginning at the inside edge of the plate. The vinyl bends easily with a standard siding brake to wrap over the foam board and neatly finishes the gap between grade and siding. We glued it to the edge of the slab and to the EXPS with foam-compatible mastic.

Bendable vinyl glued in place also provides an insect barrier. Insect penetration is an area of some concern because certain insects seem to excel at tunneling through foam board. So far, they haven't been able to get by the vinyl and mastic. We filled gaps between the foam board with Great Stuff expanding foam (Insta-Foam Products, 1500 Cedarwood Drive, Joliet, Ill. 60435; 800-800-3626).

Saving money for the contractor and owner—All in all, I figure the cost savings of building frost-protected foundations over conventional methods at just over 3% of the total hard cost per unit. The beauty of frost-protected foundations is that nothing is sacrificed with this method. Although we built in the Northeast, these construction techniques can be applied to areas of high wind-loading or seismic activity.

Another benefit of this type of construction is the ground-coupling effect created by insulating the perimeter of the structure. The large, enclosed thermal mass helps to prevent noticeable temperature swings in living spaces. We installed high-performance air-to-air heat pumps, and with electricity at about 5¢ per kwh, heating during an average season costs less than $300. Likewise, air-conditioning costs average less than $100 for a normal summer. These savings kept the client happy for years to come. □

Christopher R. Kendall is the former project manager for S&A Custom Built Homes Inc. in Chambersburg, Pennsylvania. Photos by the author.



The concrete at the perimeter is poured first. The thicker edges of a frost-protected foundation are poured and consolidated before the top layer is poured for the main slab. When the final layer is poured, the plate-support system acts as a screed guide.