A Slab-On-Grade Foundation for Cold Climates

Proper drainage (lots of gravel) is the key

by George Nash

The handbooks and structural engineers all say you can't build a slab foundation in frost country and expect it to say put. But about 15 years ago it occurred to me that interstate highways are nothing more than large concrete slabs poured on the ground. They don't have frost walls, yet they don't heave apart. And what about railroad tracks? Why aren't they twisted like spaghetti come spring? Why couldn't the principles of roadbed construction be applied to cold-country slab foundations?

Slab-on-grade foundations are an economical alternative to a full, poured-concrete basement. They require minimal excavation and site disturbance, are quickly laid out, and are easily formed and poured. Also, their suitability as thermal mass in passive-solar and radiant-heating systems is almost unequalled. But slab-on-grade foundations can be extremely vulnerable to frost damage.

Clay soils (like those of northern New England) are typically saturated with ground water. When this trapped water freezes, the soil expands. If this expansion were uniform, it would pose no appreciable threat to a slab-on-grade foundation. The entire slab would rise and fall evenly, like a boat on the tide. But the perimeter of a slab is subjected to more frost action than the interior. Because concrete is not elastic, any significant difference in movement between two areas will cause a crack. Although frost walls (poured-concrete walls exending to a footing below the frost line) prevent cold from penetrating under the slab, they require so much extra excavation, formwork and concrete that they offset the savings of building on a slab in the first place.

Frost heave won't occur, however, if the soil can't hold water. Roads and rails are laid upon a base of porous and well-drained material that allows water to move rapidly through and away from it. There's nothing to freeze. With this in mind, I've developed a slab-on-grade system that doesn't need a frost wall for stability. I've continued to refine the system with each new project, but so far there hasn't been any evidence of cracking or movement in any of the half-dozen foundations I've done. Several engineers, including the father of my latest client, have reviewed the system. And while they were skeptical at first, they agree that it will work provided the drainage is good and no water occurs in the soil above the frost line.

Preparing the site—The budget for Walter Breck's house in Fletcher, Vermont, was tight. The site had wet, heavy clay soil underlaid with rock—it would have been hard to find a worse place for a basement. Because of this, and because Breck wanted radiant heating, a slab-on-grade foundation made sense.

We brought in a bulldozer to scrape away the topsoil. The site sloped toward the southeast corner, so the bulldozer actually dug a shallow pit that varied in depth from grade level to about 2½ ft. deep on the north side. Otherwise, we would have brought in clean gravel fill and built up a level pad, compacting the gravel in layers. On a slightly sloping or level site this is not difficult, but in this case, it was easier to dig to level.

The pit was filled to a depth of at least 6 in. with what we call chestnut stone (coarse, 2-in. stone—the same size used for railroad roadbeds). This size stone rakes and shovels hard. Fortunately, the backhoe was already on site digging utility trenches, and we were able to spare ourselves a lot of bone-numbing handwork. I used a hand-held sight level to check the rough grade. Taking the time to do this saves a lot of shoveling later.

We compacted the stone with a gas-powered mechanical tamper (photo facing page) and set up batter boards for the layout strings. Setting all the strings at the same height makes leveling the formboards a simple matter of measuring down from string to board. Here, a transit level is absolutely necessary, particularly for laying out right angles at corners.

A modified grade beam—A thickened edge is recommended for monolithic (one-piece, sans frost wall) slabs. The extra thickness acts as a footing for the load-bearing exterior walls, and the extra depth prevents the foundation from being undermined and provides a surface to install foundation insulation against. Typically, when a slab is poured on a flat compacted base, the perimeter is trenched 8 in. to 12 in. deep and at least a shovel's breadth wide. The slab form boards are set along the outside of the trench, and the inside edge of the trench is sloped upward to the slab depth. This works fine, so long as there is no under-slab insulation and if the depth of the thickened edge does not exceed the width of a 2x12. Also, to minimize rot, wood framing should begin at least 8 in. above grade. But with a 2x12 form board and a 4 in. slab, the finished thickened edge is barely below grade.

I remember one of my early attempts at a slab-on-grade foundation in which I tried to cut and neatly piece together insulation on a crumbly and irregular gravel backslope. During the pour, some of the foam insulation boards tilted, and the concrete flowed under them. Others simply floated away.

On another project I sought to avoid these problems by forming a slab with a 2-ft. turndown, using 2-ft. by 8-ft. strips of plywood for forms. Although I used lots of stakes and braces, I was amazed to discover how much outward pressure 8 or 9 yards of wet concrete can exert. I didn't lose the wall, but setting the sills to compensate for the free-form curves in the slab edge was rather challenging.

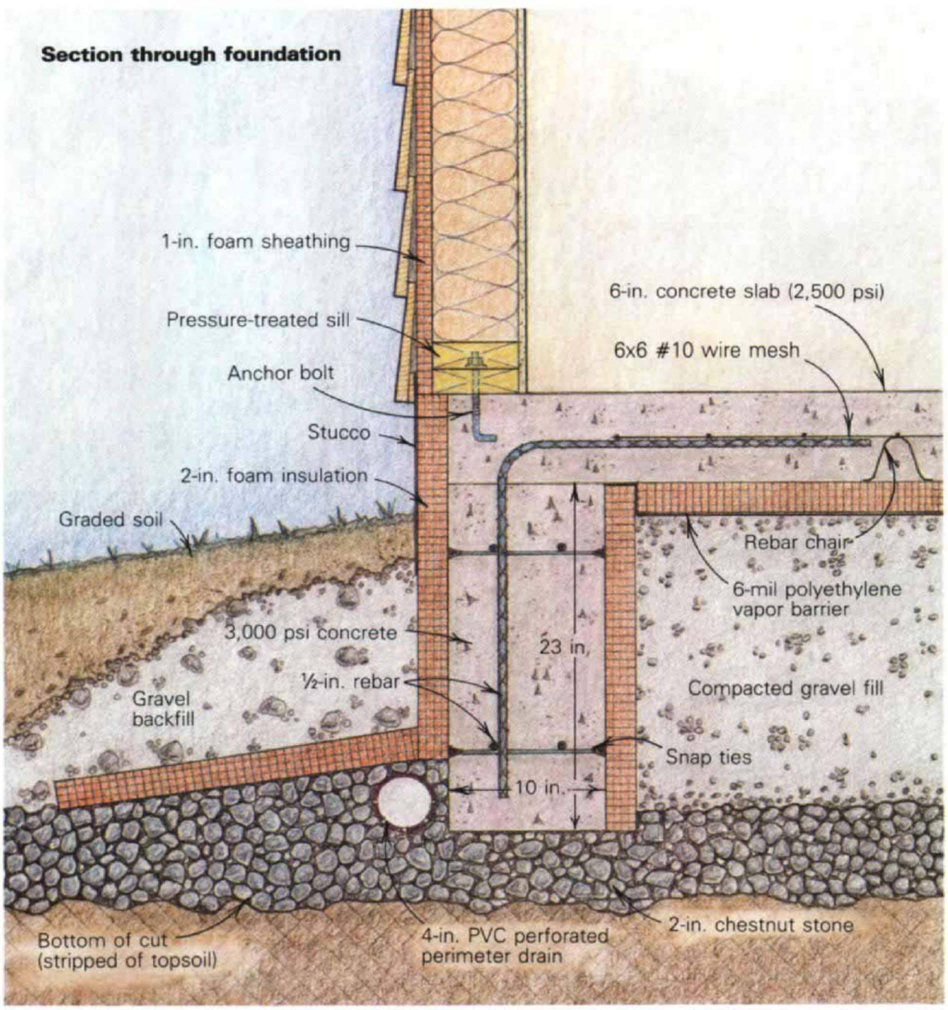
I had read a magazine article about grade beams and it suggested an approach that might resolve the problems of slab edges and insulation. What if, instead of a monolithic pour, I were to form and pour a beefed-up footing and then pour the slab on top of the footing? Reinforcing rods bent at right angles and tied to the wire mesh of the slab would ensure structural connection between the components. Using 2x12s with a 2x4, or even a 2x6, would give a thickened edge of 15 in. or 17 in. and greatly simplify underslab insulation. I tried this for a slab poured over a very gravelly and extremely well-drained site. Gravel was compacted over a base of coarse demolition rubble to ensure drainage. PVC drain tiles were also installed around the perimeter. It worked fine.

Because the base for the Breck foundation was considerably below grade, I decided to double up the 2x12s to form a 23-in. deep beefed-up footing. The formwork was the same as setting footings for an ordinary foundation, except that the beam was only 10 in. wide (drawing below). I set the bottom of the outside form first, leveling it with the batter-board strings. To accommodate snap ties, I had predrilled holes in the planks 4 in. up from the bottom edge on 3-ft. centers. Next I set up the inside form boards, and marked and drilled corresponding holes. We used round ties designed for a 10-in. wall with 2x4 strongbacks.

Once the snap ties were in place, we tied the first layer of rebar to them. An occasional stake at the center of the sections and at the corners secured the forms while the top section of form boards was added. These we drilled for ties 4 in. down from the top edge.

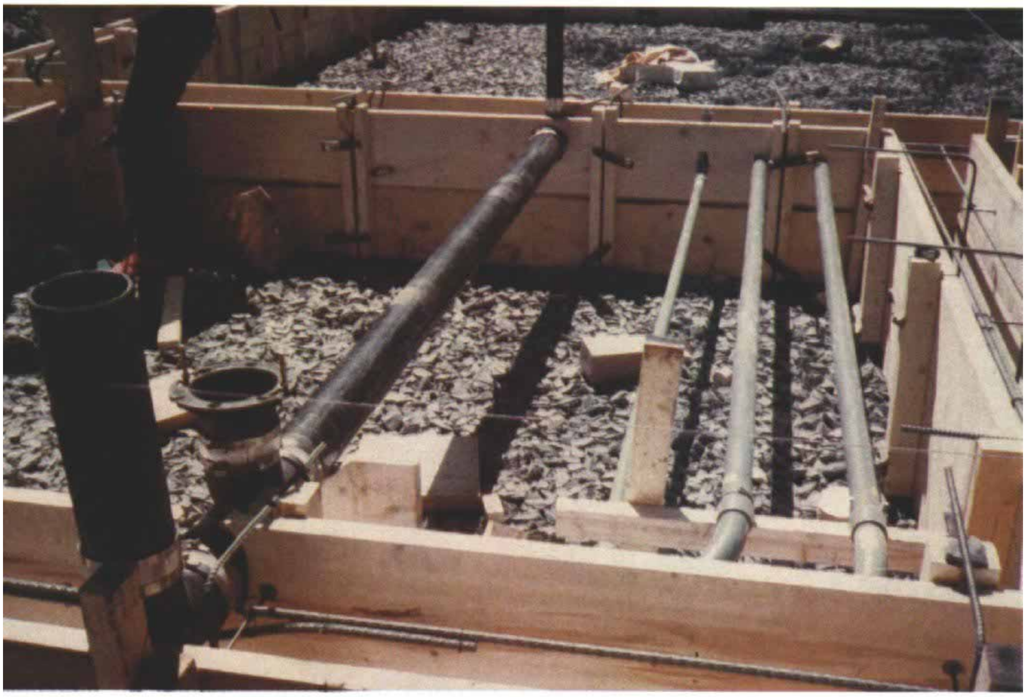
After the ties were installed in the top section of the form, the forms were tied together and stiffened by strongbacks. The entire form could be moved in or out as a unit to line up with the strings, or raised and lowered to level as needed, using pinchbars and a mattock. Pieces of chestnut stones served as shims. The second layer of rebar was wired to the snap ties, and the 2-ft. long right-angle lengths that would secure the slab mesh were also wired to the cross-ties and the rebar. After making final adjustments, we anchored the forms by backfilling them with chestnut stones and boulders.

Routing mechanicals—The mechanical drawings indicated the exact locations and dimensions for the vent stack, toilet drain, and



other waste and supply lines that would penetrate our beefed-up footing, either horizontally or vertically. Because concrete is rather unforgiving of error, I gave particular attention to these areas, especially when setting the height of the toilet flange relative to the future finish slab (top photo below). I installed a piece of 6-in. PVC pipe as a sleeve at the bottom of the beefed-up footing where the sewer line was to exit. With the exception of the LP gas line, all utilities entered below the beefed-up footing and could be installed after the beam was poured, and prior to pouring the slab itself.

I used hubless cast-iron for all underslab drainlines. The neoprene fittings allow some flexibility in alignment and are easy to install. For the electric service, I ran 200-amp cable through 2½-in. PVC conduit. It's easier to slip the conduit over the cable one section at a time than to pull or push the cable through the conduit. The wire is so stiff that 2½-in. conduit barely gives enough leeway. Normally, at least two or three wiring circuits are run under a slab. Using two pieces of 12-3 nonmetallic sheathed cable (often called Romex) in 1½-in. PVC, I can fit four circuits into the space of two. The stouter 12-3 pushes more easily than 12-2 cable. Telephone cables and ½-in. flexible copper LP gas lines fit easily into 1-in. PVC.


The vent stack, toilet drain, and other waste and supply lines that penetrated the modified grade beam had to be carefully positioned before the pour.


The top of the modified grade beam was screeded off with a 2x4 and left rough for better bonding to the slab. The strongbacks extend above the 2x12s in order to serve later as supports for the 2x6 slab form. While the concrete cured, the right-angle rebar, which would tie the slab to the beam, was held at the proper angle by stone shims on top of the 2x4 strongbacks.

I use ¾-in. polybutylene tubing (Qest Systems, Eljer Industries, 901 10th St., P. O. Box 869037, Piano, Tex. 75086) for underslab hot and cold water distribution lines, once again run through 1½- in. PVC. Polybutylene provides security against winter power failures because it can withstand temperatures of -50° F to + 180° F without damage. With the exception of the virtually indestructible cast-iron drain lines, all underslab utilities should be replaceable if necessary. We avoided tees and right-angle elbows in either conduits or utility lines because they make it impossible to fish new wires once the slab is poured. Sweep elbows, on the other hand, have gentle curves that won't obstruct cables or pipes, so that's what we used. Teed connections were limited to use above slab.

All measurements were given a final check, and the forms were once again checked against the layout strings before the concrete pour. We used a 3,000-psi mix, poured a bit wet to make dragging easier. The top of the beam was screeded off with a 2x4 and left rough for better bonding to the slab. After screeding, the angled rebars were supported at proper height by stones placed on top of the strongbacks (bottom left photo).

The edges and corners of "green" concrete are easily damaged if forms are removed too soon, so the foundation was left to set up over the weekend before stripping, and then only the inside forms were stripped. The snap ties, now set in concrete, held the outside strongbacks and form boards snugly in place. The outside forms were later built up to serve as forms for the slab.

We laid 2-ft. by 8-ft. panels of 2-in. extruded polystyrene insulation against the inside face of the beefed-up footing, flush with the top edge. The rest of the cast-iron drains and the PVC conduits were then connected to the stubs protruding from the footings, and the sewer line was sealed to its sleeve with Thorobond Waterplug (Thoro System Products, a division of Imperial Chemical Industries, 7800 Northwest 38th St., Miami, Fla. 33166).

I supported the drain line temporarily with wood blocks at a slope of about a 6-in. drop over 10 ft. so that it would exit at the bottom of the beam, roughly 2 ft. below finished grade. Meanwhile, the backhoe dug trenches for water and power below the frost line. The trenches were carefully finished by hand under the beefed-up footing. Then we ran the water line, submersible-pump cable, service cable, telephone and gas lines through their respective conduits. Doing this before the pour makes it easier to troubleshoot any snags.

Clean gravel was compacted in 4-in. lifts to within 2 in. of the top of the beefed-up footing, except for the areas under a bearing post and under the chimney; those areas were left 4 in. deeper to provide extra support. The 24-ft. wide sheet of 6-mil polyethylene used for the underslab vapor barrier required only one overlapping seam at the woodshed/entry ell.

We insulated the slab by laying sheets of 2-in. rigid foam over the gravel and 4 ft. in from the walls. On the south wall, though, they were laid to 8 ft. The ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) handbook recommends this technique because the bulk of heat loss occurs at the perimeter of a slab. In retrospect, I probably should have insulated the entire slab, because some heat loss to the earth from the radiant-heating tubes would be likely. Next time.

More pipes, concrete and foam—Because of all the radiant-heat tubing, we decided to pour a 5½-in. slab to guarantee the strength of the floor. The outside strongbacks had been deliberately left projecting about 5 in. above the top edge of the beefed-up footings. Forming for the slab was simply a matter of nailing a 2x6 to them. This also provided another opportunity to adjust for any irregularities in the form work.

Six-by-six wire reinforcing mesh was tied to the angled rebars coming out of the beefed-up footings and supported at proper height above the insulation by rebar chairs. These are U-shaped pieces of rebar that we bought from the local building-supply house. The mesh also held the tubing for the radiant heating system in place (top photo right). Breck's system was designed, and its components were furnished by, Bob Starr of Radiantec (P. O. Box 1111 Lyndonville, Vt. 05851). It consisted of continuous loops of cross-linked polyethylene tubing that distributed hot water from a central manifold to each zone. This system, along with the domestic hot water, was supplied by a 100,000 Btu Polaris high-efficiency (94%), high-recovery LP gas water heater (Mor-Flo Industries, Inc., 18450 S. Miles Rd., Cleveland, Ohio 44128) with an integral heat exchanger (for more on radiant-floor heating, see *FHB* #27, pp. 68-71).

The concrete slab was poured, finished and wet-cured for several days—we sprayed it repeatedly with a garden hose (bottom photo right). After the rest of the forms were stripped, we glued sheets of rigid foam insulation to the outside face of the foundation, flush with the top of the slab. The upper foot or so of the insulation was parged using a foundation coating kit (Retro Technologies Inc., 328 Raemisch Rd., Waunakee, Wis. 53597).

We laid a 4-in. PVC perforated drain pipe around the perimeter at the base of the beefed-up footing, with an outlet to grade at the low corner, and covered it with leftover chestnut stone shoveled up against the bottom of the insulation. This drain is a critical component of the cold-climate slab foundation as it must intercept subsurface and ground water before it can work under the beefed-up footing and up into the gravel slab base.

A horizontal layer of rigid foam insulation was placed over the drainage stone, sloping away from the beefed-up footing, to help protect the bottom of the beefed-up footing and the slab against frost penetration. Finally, the foundation was backfilled with gravel to within a few inches of finish grade, covered with the native soil, and sloped away from the house for positive drainage.

I'm sure that this latest version will be subject to further refinements. But the basic soundness of an insulated slab-on-grade foundation system has been borne out by my experience. □

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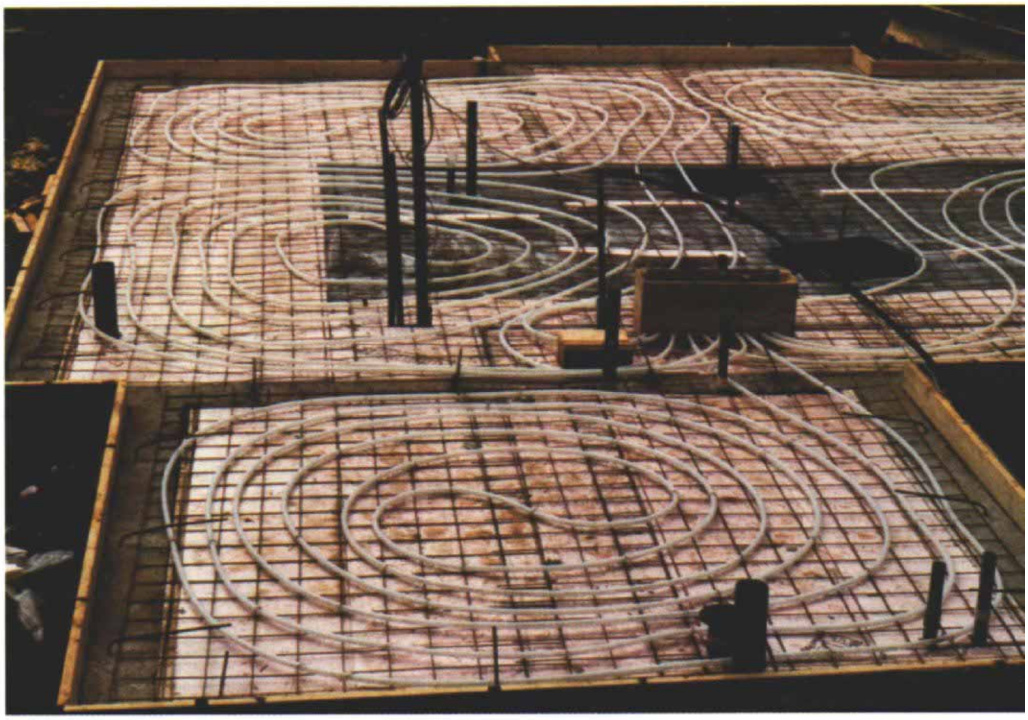

The perimeter of the slab was insulated with 2-in. rigid foam insulation. Six-by-six wire mesh was then laid out and wired to the angled rebar coming out of the beam. Finally, polyethylene tubing for radiant heating was carefully wired in place over the mesh.

In order to keep shrinkage cracking to a minimum, the slab was kept wet for several days after the pour, allowing the concrete to cure evenly.