Rubble-Trench Foundations

A simple, effective foundation system for residential structures

by Elias Velonis

Although it was first used extensively by Frank Lloyd Wright early in the 20th century, the rubble or gravel-trench foundation has largely been ignored by builders since Wright's time—perhaps because it represents a different way of thinking about what it takes to support a house. The conventional poured-concrete or block perimeter wall attempts to solve a building's load-bearing requirements in monolithic fashion by creating a solid, supposedly immovable and leakproof barrier extending from a footing poured below frost line to 8 in. or more above grade. But since freezing water expands 9% by volume with a force of 150 tons per sq. in., monolithic foundations are unlikely to survive in frost country unless they include a footing-level perimeter drain backfilled with washed stone, which carries away water that might collect and freeze under or against the foundation wall.

The two functions of load-bearing and drainage are solved separately with a solid foundation, but the rubble-trench system unites these two functions in a single solution: the house is built on top of a drainage trench of compacted stone that is capped with a poured-concrete grade beam. The grade beam is above the frost line, but the rubble trench extends below it, and the building's weight is carried to the earth by the stones that fill the trench (drawing, facing page, center). The small airspaces around each stone allow groundwater to find its way easily to the perforated drainage pipe at the bottom of the trench. Atop the grade beam, a short stemwall of concrete block, poured concrete or pressure-treated wood is built to support the floor framing. Or you can pour a slab. More about this later.

While this foundation system has been time-tested in many of Wright's houses, acceptance by building officials and the codes they follow is still not assured. In *The Natural House* (Horizon Press, New York, 1954), Wright speaks of what he calls the dry wall footing. "All those footings at Taliesin have been perfectly static. Ever since I discovered the dry wall footing—about 1902—I have been building houses that way.. . . Occasionally there has been trouble getting the system authorized by building commissions."

The disapproval of a building inspector usually arises from a lack of familiarity with the technique, since the Uniform Building Code states clearly that any system is acceptable as long as it can "support safely the loads imposed." When I first approached our local building inspector with plans for a rubble-trench foundation, he studied them quietly for a moment, ahemmed in good New England fashion, and said, "Yep, that looks as if it oughta work." And so it will, except in what Wright calls "treacherous soils," which I would judge to be any soils with a bearing capacity of less than 1 ton per sq. ft.

Determining the bearing capacity of a soil without engineering analysis is a matter of common sense and experience. If the earth in the trench is dry, seems to be well drained, feels solid when you jump on it, and is a mixture of gravel, rock, sand or clayey sands, it will very likely carry all the weight your house can bear on it. If, on the other hand, your heels sink several inches into soft clay, loose sand or fine silt when you jump into the trench, you'd better consult a soils engineer.

Construction—Assuming you've got stable soil, bulldoze the area of the house level, clearing all topsoil away and saving it for finish grading. If you have a sloping site, you will have to cut a level shelf in the hill, graded away from the house on all sides. This will ensure a good path for surface runoff. Lay out your foundation in the conventional manner (see "Site Layout," *FHB* #11), but make sure the batter boards are set up far enough outside the lines of the building that the backhoe will have room to maneuver. Sprinkle a line of lime 4 in; inside the strings that define the building's outer edge. This white line represents the center of the masonry wall that will rise up from the on-grade footing, or grade beam, and it provides the backhoe operator with a centerline to follow with his bucket. Ask the excavator if he has a narrow bucket for the backhoe—16 in. to 20 in. is perfect for most soils. A wider trench gives you more bearing in softer soils, but it also takes more stone to fill it.

> *'All those footings at Taliesin have been perfectly static. Ever since I discovered the dry wall footing—about 1902—I have been building houses that way.' —Frank Lloyd Wright*

Have the backhoe operator cut the trench with straight sides, as deep as the frost line at the high point and sloping down to one or more outlet trenches along the perimeter (drawing, facing page, bottom). These should run away from the building and out to daylight at a slope of at least 1 in. in 8 ft. If you have a level site, I recommend running trench drains to a drywell, if your water table isn't too high. A drywell is a hole filled with a combination of small (1½-in.) stone and coarser rubble. You can base the depth and diameter of your drywell on the drainage qualities of your soil and the surface runoff you expect. Compute this from average-rainfall data and figures from the site's percolation test.

Clean up all your trenches by hand, making sure that their bottoms are flat and that they slope toward the drain line. Disturbed soil at the bottom of the trench may settle unevenly, so tamp the bottom firm with a pneumatic tamper or the heels of many boots.

Next, pour in a few inches of washed stone, and lay 4-in. dia. perforated PVC drainage pipe on top of it in the foundation and outlet trench. Make sure that the pipe follows the slope without dips that could restrict the flow of water. A ½-in. block taped to the end of a 4-ft. level makes the job of sloping the rigid pipe quite a bit easier. When the bubble reads level, you've got a 1-in. in 8-ft. slope.

I place the perforated pipe with its holes down (that is, at 4 o'clock and 8 o'clock), as I would in laying out a leach field, because as the trench fills with water, I think this orientation gets rid of it quicker. On the other hand, a case could be made for putting the holes up. It would take longer for them to silt up, but this shouldn't be a problem in good soils.

Now begin filling the trench with washed stone, taking care not to disturb the pipe as you cover it. I use 1½-in. stone because it's easy to find and easy to shovel, but larger washed stone is okay, too, as is the occasional clean fieldstone. (This is where the technique gets the name rubble trench.) Tamp the stone every vertical foot or so to make sure it is compact. To this end, I have even driven a loaded dump truck along the filled trench to make sure it was well settled, although this seemed to have little effect.

The outlet trench need not be filled with

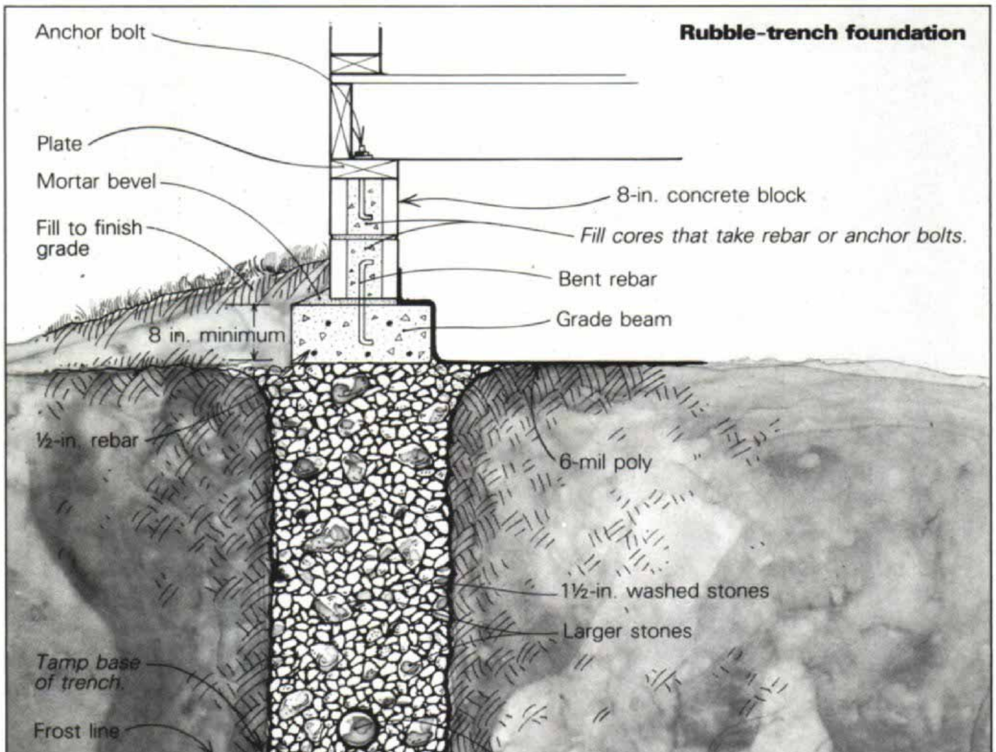
Washed stone is dumped straight from the truck into the foundation and outlet trenches.

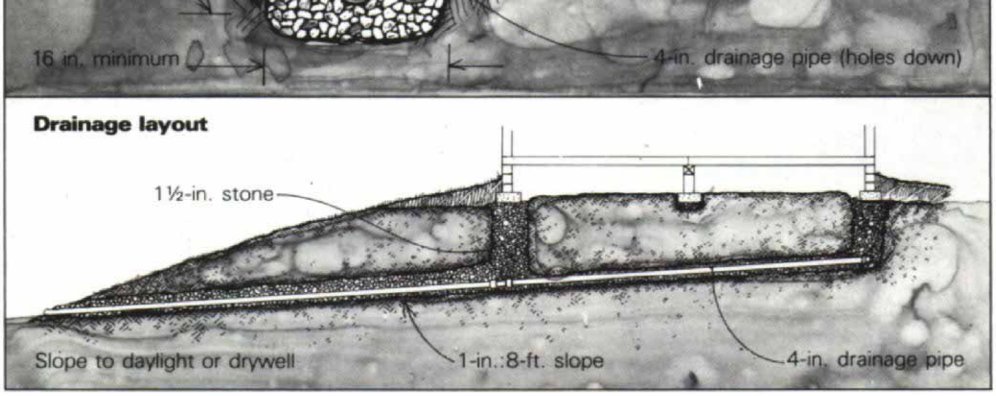
stone except for a foot in all directions around the pipe. Cover this stone with hay, burlap or tar paper as a filter, and backfill it with the original soil. If the pipe is running to daylight, be sure to leave its end exposed on a bed of stone. You want it to drain freely, so don't cover it with soil. Cap the end of the pipe with wire mesh to keep out rodents.

The grade beam–After the drains are installed and the trenches filled with stone, you're ready to build the forms for the grade beam. For one-story wood-frame structures, a 16-in. wide by 8-in. deep grade beam with three runs of ½-in. rebar is more than adequate. For a two-story structure, increase the depth of the beam to 10 in. or 12 in., and add two more lengths of rebar in its upper third.

Restring the lines from the batter boards and place the form boards on edge beneath them. I use 2x8s or 2x10s and brace them with stakes every 3 ft. Level the top edges of the form boards all around, nailing in 1x2 spreaders every 4 ft. to 6 ft. across the top to hold the forms in place. To reinforce the corners, use metal strapping or plumber's tape (perforated steel strapping), nailing it around outside corners. Place three runs of ½-in. rebar spaced evenly along the bottom of the beam, wiring them securely at the joints, and stagger these joints around the perimeter. Wire short pieces of rebar across these runs every 6 ft. Bend the lengths of rebar around all corners rather than splicing them there. Lift the rebar about 2 in. off the bottom of the beam with small stones. For a two-story building, prepare two more perimeter runs of rebar, and put them alongside the forms, ready to be dropped in the top third of the beam during the pour.

As the concrete is poured into the form, vi-



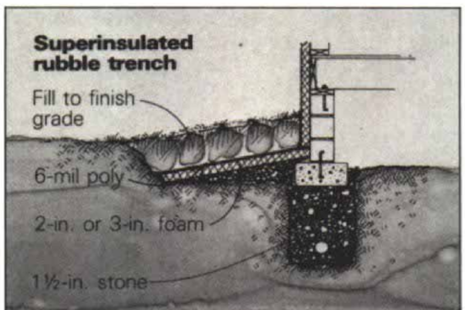


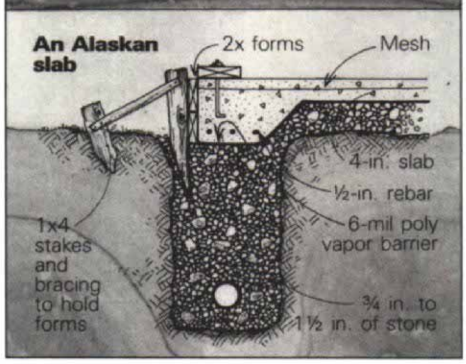
Illustrations: Jackie Rogers

Forming and pouring the grade beam. **At left, forms for the grade beam are being set up on top of the stone-filled trenches. The 2x10 form boards are held together by steel plumber's strapping and by 1x2 wood stretchers nailed across their tops. Below left, rebar has been placed between the forms, and tied off to spreaders. The transit mixer is discharging its load of concrete, which is being spread and leveled by the crew of Heartwood students.**

brate it well with a short piece of 2x4 to get rid of air pockets. Screed along the tops of the forms to get a level surface. If you intend to build a masonry wall, rough up the top of the grade beam with a broom before the concrete cures to ensure a good bond between it and the mortar. In areas where high winds are a problem, set 1-ft. lengths of bent rebar vertically in the top of the grade beam. They will anchor the stemwall. For a pressure-treated stemwall, place anchor bolts for the sill plate every 6 ft., and 1 in. from the end of each plate member.

If your design calls for a slab floor, you can pour the grade beam and slab at the same time, using a turned-down or "Alaskan" slab. For this you need only build outside forms, as shown in the second drawing below. For houses with wooden floors, however, the height of the stemwall will determine the height of the crawl space, which should be at least 26 in. Since this may make the level of the finished floor higher than you want, raise the grade around the perimeter by 1 ft. or so, which will help slope it away from the house for surface runoff. Leave adequate ventilation ports on the stemwall, and when the building is roofed, cover the earth in the crawl space with 6-mil poly. Place anchor bolts for the plate in the usual manner, and parge the outside of the wall that will be above grade for a clean appearance. You might also add a bevel of mortar between the stemwall and the grade beam, to shed any water that might want to find its way between them.



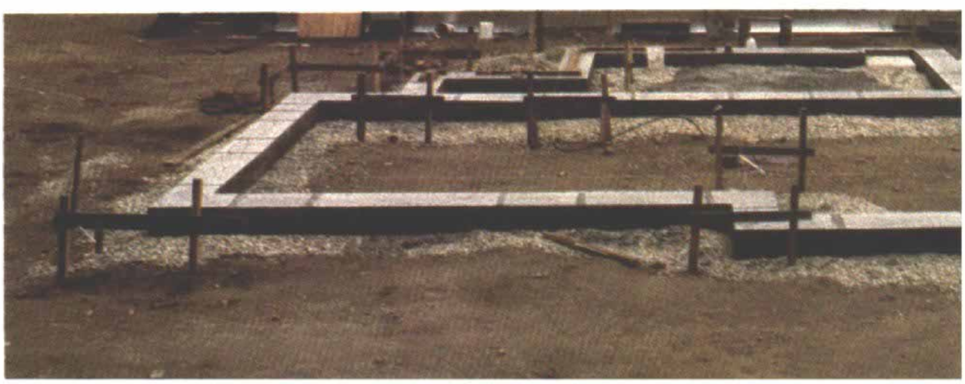


Insulation alternatives—If you've designed an energy-efficient building and want to extend the insulation down below grade on the exterior, modify the foundation as shown in the first drawing at left. In an area where the frost line is 4 ft. deep, dig the trench only 2 ft. to 2½ ft. below initial grade, as you will be raising the finished grade around the building by 1½ ft. to 2 ft. Fill the trench with stone to 8 in. below initial grade, and then pour the grade beam to the surface. Lay up four courses of block (surface-bonded block walls work very well in this application) and build the floor.

When you're ready to insulate the exterior of the building, glue 2-in. or 3-in. thick panels of rigid foam insulation to the exterior of the stemwall down to the grade beam, then lay more foam panels on a sloping bed (at least 3 in. in 1 ft.) of stone, 2 ft. to 4 ft. around the entire perimeter. This insulation apron preserves a large bubble of relatively warm earth beneath the house, tempering the crawl space with its warmth. Cover this apron with 6-mil poly to protect the foam from water, and backfill up to finish grade. The exposed foam above grade and below the siding should be covered with asbestos board or the equivalent, or parged (see pp. 33-35) with a surface-bonding compound troweled on ⅛ in. thick over a wet coat of Styrofoam adhesive. The adhesive helps eliminate expansion cracks in the surface bonding between panels, but if cracks do appear, they can be caulked.

The only reservation I've heard from other builders about the rubble-trench foundation is that it might settle unevenly. In non-uniform soils this might be a problem, although the reinforcing in the grade beam is ample to span a good deal of uneven settling. We've built four rubble-trench foundations over the last five years, and none has shown the slightest sign of settling, cracking or frost damage. The great advantage of the system, of course, besides speed and relatively low cost, is that instead of building a massive wall underground, you just pour stones into a trench and are free to carry on building above ground. □

Elias Velonis is the founder and co-director of Heartwood Owner-Builder School in Washington, Mass. Photos by the Heartwood staff.



The finished grade beam, with its forms stripped.