HILLSIDE FOUNDATIONS

PART TWO: FOR A SAFE AND SUCCESSFUL JOB, STABILIZE THE SLOPE, CHOOSE THE RIGHT PIER-DRILLING EQUIPMENT, AND PROVIDE GOOD DRAINAGE

This is the second half of a two-part story on hillside foundations. Part One, covering plans, specifications, and soils reports, ran last month.

Hillside foundation construction requires more than a knowledge of concrete construction. As a foundation contractor, I regularly take on the responsibilities of excavation and grading, trenching for footings, backfilling, and other earth work (see "A Good Excavator Is Hard to Find," page 28). Some of my most important work comes before and after I form and pour the concrete, including drilling piers, stabilizing the hillside, and providing adequate drainage.

Hillside Stability

One of the biggest problems with steep-site construction is that as you dig into a hillside, you remove material that holds the hill together, creating an unstable and potentially life-threatening situation. Unfortunately, hillside excavation is often left solely under the direction of the contractor, who may be working from plans that omit any mention of the problem. In fact, there have been so many accidents caused by builders ignoring this issue that the City of San Francisco, where I do a lot of work, may soon require shoring plans before issuing a permit.

Stabilizing a hillside requires the active participation of the soils engineer who prepared the soils report; I avoid contractual agreements that do not provide for it. Establish inspection and quality assurance procedures before work begins, especially if you are in an area known to have expansive soils, slope movement, soil creep, creek erosion, landslides, artisan springs, slip planes, or other geotechnical concerns. The engineer should be present in the field while the work is performed, not after the fact, and should provide timely documentation. The owner, who usually hires and pays the engineer separately from the foundation contractor, should also be reasonably accessible in the event of an unanticipated field condition or emergency. Do not allow the owner to skimp on the cost, though it can be very expensive.

There are a variety of procedures you can use to help stabilize a steep hill.

Angle of repose. Excavate the hill back to an angle of repose — the angle at which the slope is stable, usually a 2:1 slope. This is the easiest and least expensive way to stabilize a hillside, but it's usually not practical on a single family lot because there simply isn't enough room.

Vertical cut. Sometimes an unshored vertical cut excavated 5 feet to 8 feet behind the work area will sustain itself long enough for you to complete the work (see Figure 1, next page). Be sure to reduce the danger of collapse by removing mounded dirt and rubble that can add a surcharge to the area above the cut.

I-beam shoring. You can install steel I-beam shoring behind the area to be excavated (see Figure 2, next page). The shoring should be engineered and can be expensive, but the procedure is safe and eliminates worry about how delays, change orders, or bad weather will affect the hillside. This type of shoring commonly uses pressure-treated timber lagging. Some designs use reinforced concrete in the steel I-beam soldier piles. More sophisticated hillside shoring schemes use a system of

BY GREG CASORSO

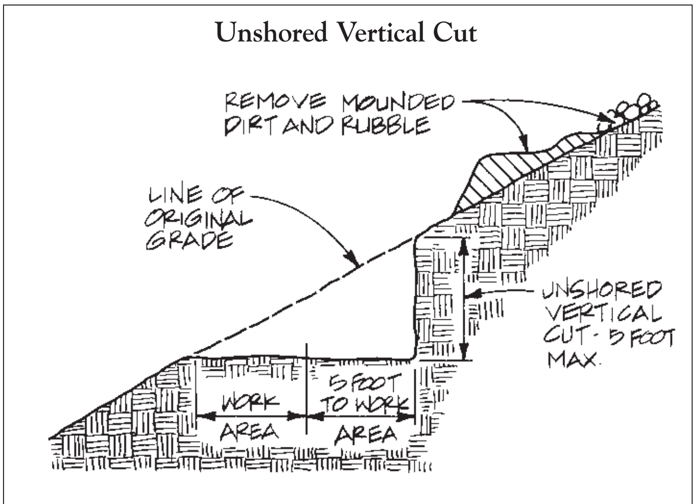

Figure 1. *OSHA regulations in many areas restrict the height of an unshored vertical cut in a hillside to a maximum of 5 feet. Your work area should be at least as far away from the cut as the cut is high. Reduce the pressure above an unshored vertical cut by removing mounded dirt and rubble.*

Figure 2. *This I-beam shoring design uses pressure-treated timbers between soldier piles anchored in concrete. Some require steel tie-backs that work like toggle bolts screwed into the hillside to hold the wall in place.*

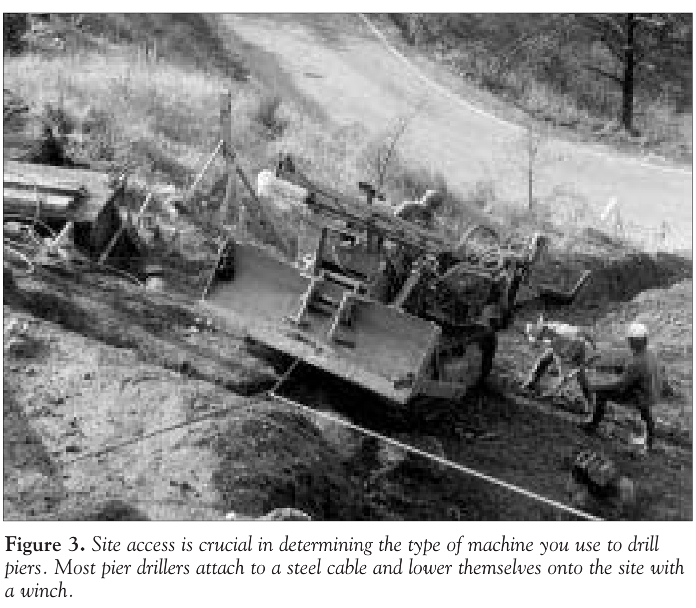

Figure 3. *Site access is crucial in determining the type of machine you use to drill piers. Most pier drillers attach to a steel cable and lower themselves onto the site with a winch.*

steel tie-backs extending horizontally into the hillside to help support the shoring.

Pressure grouting. In porous soils, which are very much at risk of collapse, you can drill a pattern of small diameter holes in the hillside and inject them with concrete. This kind of "pressure grouting" is expensive and is best left to an experienced specialty subcontractor.

Drilling and Pouring Piers

The first step in drilling piers is selecting equipment appropriate to the job. Pier drilling equipment varies in size, from rubber-tire machines as big as concrete trucks to small track machines the size of a jeep. A large drill rig is faster because the whole weight of the machine can be forced down onto the drill. Large drillers can also maneuver well, but they require good access to the site. If the site is strewn with rubble or you have to drill between two existing structures, a portable drill machine is the best choice. The deisel-powered compressor can be set up on the street, and the hydraulic drilling lines stretched to the rig. These small specialized drill rigs are very handy in tight spots. But they are much slower than larger rigs and have to be moved by hand.

Most drill rigs are attached to a steel cable and lowered onto the site with a winch (see Figure 3). They stay attached the whole time they're on the site, so it's important to know ahead of time what kind of drill rig you will be using so you can adequately prepare the site. I usually interview several drillers who have been referred to me by other builders. Most drilling companies will want to do the job with the equipment they have, so it's important to talk with several drillers to get a variety of opinions about which equipment will work best.

Layout. Once you know what kind of driller you'll be using and you've graded the site for access, clearly mark the center of each pier. I use 12-inch lengths of rebar or long barn spikes because they can be buried and then dug up again. I spray-paint them orange to make them more visible. Offset all of the batter boards you use for layout so you can reset the layout after the piers are drilled. Make sure the batter boards are high enough off the ground to make it easy to work around the mounds of dirt created by the drilling.

Drilling. If there's no hard rock on site, a good-size drill rig can drill an 18-inch-diameter pier hole 22 feet deep in about 40 minutes, including repositioning time. As it drills, it brings up dirt from the hole, which can bury adjacent pier markers and fall back into holes that have already been drilled. Loose dirt spread around the site also becomes mud when it rains, making the site more difficult to work in. For these reasons, have plenty of laborers on site to shovel dirt away from the pier hole as it is being drilled. This is the most dangerous part of drilling work, so this crew should be very well supervised. After a hole is drilled, I cover it completely with a half-sheet of plywood to keep dirt from falling in (see Figure 4). Often, this sheet is completely covered by dirt from the next hole, but it can easily be uncovered by hand. Make sure you have a supply of plywood on site before you start drilling so it's available as you need it.

Rebar cages. Because access on a hillside is limited, prepare all of the rebar cages ahead of time and stockpile them in several locations that will be easy to reach when you need them (see Figure 5). A drill rig can sometimes be used to lift the rebar cages into place, but this work is usually done by hand after the drill rig has left the site. This is because once the cage is in the hole, it sticks out the top, making it impossible to keep dirt from drilling operations from falling in.

Most cages require 3 inches of clearance to the sidewall of the pier hole. We use "dobie blocks" — 3-inch concrete cubes with embedded tie-wire — for spacers. Tie a set of three blocks to the bottom of the cage, the middle, and near the top. This will keep the concrete from shoving the cage to one side of the hole.

Pouring concrete. The best way to get concrete into a pier hole is to use a pump truck with a boom. It keeps the hose off the ground and makes it easier to move from pier to pier. The wire cage takes up most of the space in the pier hole, leaving only the sides or the empty center of the cage itself to pour concrete. You should move the hose around the cage so the concrete falls evenly into the hole. If you have to "tremie" the concrete (use the concrete to displace water in the hole), it will take a lot longer and cost more because you have to thread the hose all the way to the bottom of the hole. Stop the concrete at the top of the hole, leaving 2 or 3 feet of the cage sticking out. This part will be formed and poured with the grade beams.

Inspections. There are usually four inspections in a pier drilling operation. The first is by the soils engineer, who confirms the depth of the holes, evaluates the quality of the material coming out, and gives advice on how to deal with collapsing holes, water, and hard rock. The soils engineer spends a lot of time on site: In five days of drilling, he might spend six hours the first day, and two hours each day after that, unless special problems require more time.

The structural engineer inspects the rebar, once before the cages are lowered into the holes and once after they're in place to check on sidewall spacing. Although the soils engineer and structural engineer should both sign the job card, they don't need to be on site together unless you encounter special problems.

The city building inspector must come to the site to check the job card to see that the soils engineer and structural engineer have signed off. He will also sign the card.

The fourth inspection is optional, but is being required more frequently. This is a "special inspection" from an engineering testing firm, who checks the slump of the concrete and monitors placement techniques. This inspector is almost always required for tremie operations. He will also take test cylinders from the site to test the strength of the concrete mix.

With all of these inspections and a variety of equipment on site, coordinating the sequence of events is very important. On an upslope lot, for example, you may have to drill the uppermost piers for the house first, before you excavate for the garage. Then the driller has to return, possibly with a different machine, to drill for the garage. For this reason, it usually takes about a month to complete pier drilling operations: two weeks to grade the site and lay out the piers, and two weeks to drill the holes and pour the concrete. On a house of average size with no special soil conditions and easy access, the cost is about $50,000. But a more complex foundation on a difficult site can cost $100,000 to $200,000.

Drainage

Drainage is an especially important feature of steep hillside foundations. Poor drainage increases the chance of landslides, foundation settlement and uplift, tilting of retaining walls, and settling and failure of structural support posts. Lack of good drainage can also cause flooding of living areas, corrosion of underground ductwork, and cracking and movement in patios, driveways, and walkways. In fact, any distress in the foundation is carried up through the house, where it can cause binding of doors or windows, cracking of drywall and exterior siding, out-of-level floors, constant dampness and mildew, and a host of other unpleasant consequences.

Poor drainage is very expensive to correct after a structure is built, and it can quickly lead to expensive litigation. The irony of drainage work in residential construction is that, with proper planning and a little education, it is straightforward and inexpensive to construct beforehand.

Retaining wall drainage. The most crucial place requiring good drainage is behind a retaining wall (see Figure 6). I consider any wall over 3 feet high that retains earth to be a retaining wall. Retaining walls are usually made of concrete or concrete block, and are a unique feature of hillside construction. In 12 years of building hillside foundations, I have never built a retaining wall that didn't have drainage behind the wall specified by the soils engineer, structural engineer, or architect. Whenever possible, I prefer to take responsibility for building the wall and installing the drainage; it's the best way I know to ensure that the work is done properly.

Many sites in the San Francisco area have expansive soil that swells when saturated with water and contracts when it dries out. This can cause serious damage to structural and finish materials on level lots, and when expansive soil swells up against a retaining wall on a hillside, the forces exerted against the wall are Herculean. An 8-foot-high retaining wall, for example, in expansive soil with poor drainage, can deflect 2 to 3 inches, putting a strain on the entire structure. Simply put, good drainage reduces these potentially destructive forces by taking water out of the soil.

Drain rock. Good drainage behind retaining walls requires backfilling with drain rock. Drain rock material varies greatly, from certain types of free-draining sand to crushed rock 3 inches in diameter. I prefer to use clean, well-graded rock 3/4 inch to 1 1/2 inches in diameter, but it is good policy to discuss the exact choice with the soils engineer. At least half the cost of rock is the trucking expense, so use rock from the closest source.

Crushed rock works well on hillsides because it doesn't roll downhill as easily as round rock, but round rock, or "river run," is easier to shovel by hand. Crushed rock has coarse, angular edges, and without filter fabric, it tends to "silt up," or bond together, especially if it supports a lot of vehicular traffic. A rock called Class II Permeable — a blending of fine sands and larger river run — is a California Department of Transportation specification sometimes used in residential construction. The idea behind this blending is that the fine sands act as a filter to prevent muddy silt intrusion.

Laying drain rock. Blueprints usually show nice, straight, plumb excavation outlines against which the drain rock is placed with laser precision. What happens in practice, however, is that you overexcavate behind the wall down to the bottom of the footing or the top of the piers, creating a large space between the wall and the earth embankment. I almost always fill this entire cavity with drain rock. For one thing, the limited access and heavy loading equipment make it impractical to alternately place rock and dirt precisely as you work your way from the bottom to the top of the wall. And there is rarely enough space on site to stockpile both dirt and rock, and still leave room for the loading equipment, the dump trucks delivering the rock, and whatever else is being done on site. Because of the confined space, I usually have to place the rock immediately as it is being delivered. And I always overestimate the amount of rock I'll need, because everything comes to a standstill if you run out early. If you are using heavy equipment to place the drain rock, be sure not to overload the wall by working too close.

There are drainage products on the

Figure 4. *Use half sheets of plywood to protect pier holes from contamination by loose dirt and to prevent workers from falling in. Pour concrete to grade in the pier holes; the exposed rebar connections will be poured later as part of the grade beams and retaining walls.*

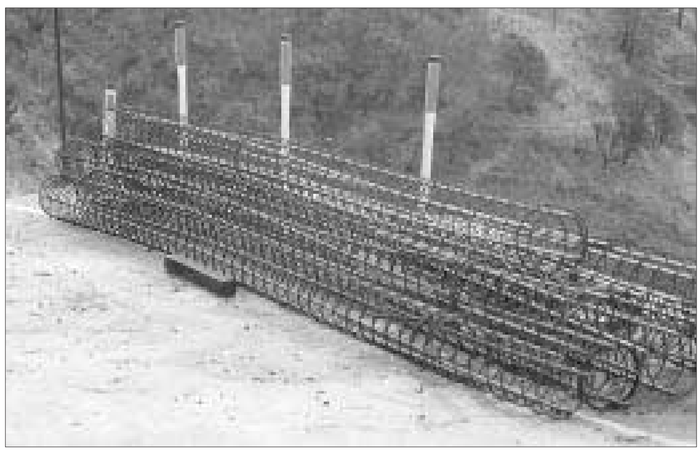

Figure 5. *If parts of the site will be inaccessible after pier drilling and wall forming are done, stockpile material, such as stone and rebar cages, beforehand.*

Retaining Wall Drainage

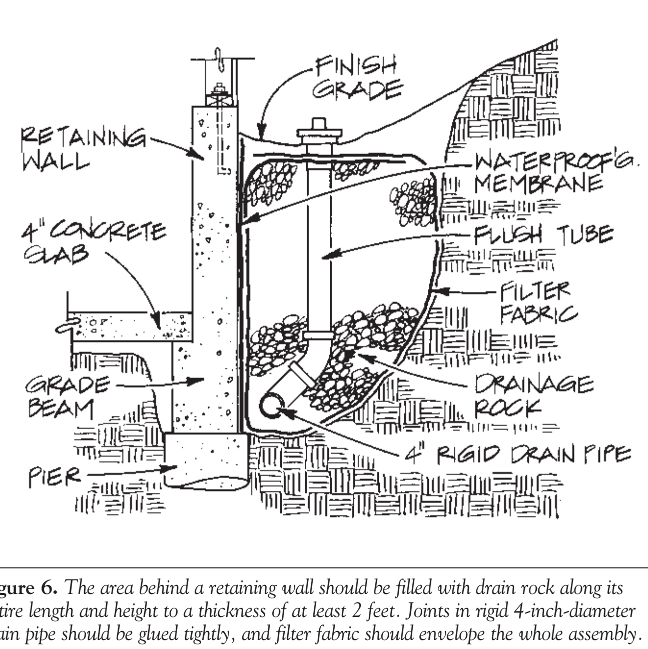

Figure 6. *The area behind a retaining wall should be filled with drain rock along its entire length and height to a thickness of at least 2 feet. Joints in rigid 4-inch-diameter drain pipe should be glued tightly, and filter fabric should envelope the whole assembly.*

A Good Excavator Is Hard to Find

Few general contractors know, or care to know, much about grading. It's noisy and expensive, it dominates the entire site, and the equipment operators can be a pretty tough lot. Most builders just want to get it over with as quickly as possible so they can start the interesting work.

However, I prefer to be responsible for all site preparation. I am usually asked to approve the grading anyway because it has to conform to the foundation. Unless I take on the site work myself, my inspection occurs after the earth work is done and the equipment is gone.

The best reason to take on the sitework is that you can plan, initiate, and control the flow of work. For example, if the foundation includes an upslope retaining wall, you need to stockpile drain rock and rebar ahead of time because your equipment may not have access to the area above and behind the wall after the wall is built.

Equipment

Sitework requires a variety of equipment, but it's most economical to use one type of machine to perform more than one task. For example, trenching equipment can be used to trench for footings, remove dirt dug up from pier drilling, trench for utilities, and excavate for drainage discharge. There are also jackhammer attachments that are useful for demolition.

The most versatile equipment, however, is a track-mounted front-end loader. With the right accessory attachments, it can grade, load dump trucks, place drain rock, spread fill, help with the initial compaction, move bulk material around, place heavy timbers, and demolish existing structures.

Choosing a Sub

I subcontract most of my earthwork to people with whom I have worked in the past and with whom I expect to work in the future. They are experienced, established owner-operators — people who own and operate a particular piece of equipment, and who bill me by the hour. I don't like to rent from an equipment yard because I have to find an operator. And I'm not comfortable using a large grading contractor who furnishes operated equipment because an unknown or inexperienced operator can be very dangerous on a cramped hillside lot.

Good equipment operators are rare and are usually busy, so it pays to develop a relationship with them. I prefer quiet, careful, experienced operators who are willing to make helpful suggestions. Bad equipment operators, on the other hand, usually talk to excess, brag about their abilities, have short tempers, are inflexible, and create problems. And if they don't cause someone else's injury, they often injure themselves. Before you hire anyone, watch operators on other jobs and ask around among other contractors. With experience you can tell very quickly if an operator is competent. In time, you may even learn to operate some rental equipment yourself, leaving the more sophisticated procedures to an experienced professional. I stress the word "experienced" with operators because this is the key factor distinguishing successful hillside excavation from flat terrain grading. No matter what, it is dangerous, difficult, expensive work requiring your full attention.

— G.C.

market that claim to act as both drainage and waterproofing, allowing you to backfill with only dirt, but for retaining walls, I remain a believer in full aggregate backfill. I feel very strongly that, to reduce the powerful forces of expansive soils and take away as much water as possible, there must be a cushion of aggregate between the water-saturated soil embankment and the retaining wall. In nonexpansive soil, it may be possible to backfill without drain rock, but I would first carefully check this with the project engineer.

Filter fabric. Regardless of which type of drain rock you use, make sure to completely envelope the drain rock with a geotextile drainage filter fabric. Drain rock saturated with mud ceases to function. The fabric filters the water and keeps out fine silt particles that over time would plug the voids between drain rocks.

It's also good to use drainage fabric under gravel roads and paths. This keeps the gravel from sinking into the ground, and is especially useful when building during a rainy season.

Drain pipe. The final component of the drainage system is the drain pipe. For most residential applications, I use 4-inch-diameter SDR-35 drain pipe (6-inch-diameter pipe is available but the fittings can be expensive). I always use rigid pipe because I've had trouble with corrugated flexible pipe: The connections come apart easily, the pipe cannot easily be laid in a straight line, and it tends to undulate up and down. Flexible pipe also crushes more easily than rigid pipe.

SDR-35 drain pipe is similar to PVC and ABS sewer pipe. The smooth inside walls carry water away easily and won't snag a sewer snake. I prefer to use pipe with built-in rubber gaskets at the joints because they're both strong and flexible. This is important on a hillside. If a joint pulls apart underground, the concentrated stream of water in the pipe flows into the hillside, and can potentially create a mud flow or landslide.

Rigid drain pipe has a series of perforations, which should always be laid face down so they are positioned at 4 o'clock and 8 o'clock. If the perforations face up, then water must rise up almost the entire diameter of the pipe before it can get inside and be carried away. With the perforations face down, the pipe takes on water sooner and carries it away more quickly.

You should lay drain pipe at an elevation that is lower than the interior space you want to protect from water. Place drain rock evenly along the entire length of drain pipe until the pipe is completely buried and cannot move.

It takes some effort to find rigid drain pipe. It isn't usually available at the local lumber yard or hardware store. Plumbing supply houses are a better source. In San Francisco there are suppliers that specialize in drainage pipe and accessories.

Discharge. Convey all drainwater to a safe, legal discharge point. In San Francisco, drainwater can discharge into the sewer pipe, but this may not be allowed in your area. Depending on circumstances, you may be able to safely discharge into a creek, a storm drain, or the street curb in front of the house, but you should check with the local building department. Do not discharge your water onto your neighbor's property.

If you can't use gravity — a so-called "passive system" — to discharge the drainage, then use a sump pump that's large enough to do the job. Route the drainage water to a sump basin, where it can be pumped to an appropriate discharge point.

Route all gutter downspouts into a separate, nonperforated drain pipe, never into the perforated pipe of the soil drainage system, where leaves and other small particles from the roof can clog the pipe. You can combine the two types of drain water, but only below the house, and only in a discharge pipe whose sole purpose is to convey water to the discharge point.

All drainage trenches should slope either to a pump or to a discharge point. Keep the trenches straight and the slope even. Water should not pool in a trench, it should flow. ■

Greg Casorso is the owner of Casorso Construction in Lafayette, Calif., specializing in foundation construction and repair, and installation of drainage systems.