Hillside Foundations

Part One: Before you start digging, make sure you fully understand the plans, specs, and soils reports

From years of building residential hillside foundations in the San Francisco area, I've learned that poor construction usually isn't caused by a lack of knowledge, but by failing to pay attention to details before construction begins. Hillside foundations typically require extensive grading, lots of retaining walls, and deep piers, not to mention engineered drainage, waterproofing, elevation changes, and difficult driveways. You'll need to juggle all these elements, while making sure, for example, that none of the concrete embedments for plumbing, mechanical, electrical, and framing get overlooked. You can help maintain job quality, your budget, and your sanity by creating a well-thought-out schedule and spending a lot of time studying the plans before the job begins.

Ed. note: This is the first half of a two part story. Part One covers planning for hillside foundations. Part Two, which will appear next month, looks at hillside stability, drainage, and pier drilling.

It's All Uphill From Here

Compared to level ground, hillside foundations are more difficult for many reasons. Most obvious but least appreciated is the way a steep slope affects procedures that contractors take for granted on level ground. To begin with, on level ground you can usually drive right up to your work area. At a hillside site, you may have to park your truck several hundred feet away and carry everything up or down the slope. This is so time consuming that I employ two laborers whose primary job is to move material and equipment into position.

Also, on a steep site your reference points are often either above or below the spot where you are actually working. The natural slope of the hill is often compounded by angled embankments cut in the hill to prevent it from collapsing. It takes a great deal of time to work out and transfer all the reference points (see Figure 1, next page).

Finally, compared to level ground construction, every aspect of residential hillside construction is significantly more dangerous. It's hard to keep your footing, and the slope may give way, taking tools, materials, equipment, and people with it. Consequently, hillside construction takes more time, requires good communication and cooperation, and demands care and attention at every phase of the job.

Before You Start

Most problems originate with the plans. You can tell a lot about an upcoming project from the set of plans you are asked to bid from. For example, if you have to use a scale to find critical dimensions that are missing, you can expect to find that other important parts of the plans — engineering reports, details, specifications — will also be incomplete or in conflict with each other. This lack of design quality on the plans will probably continue throughout the course of construction.

I take an active role in shaping the plans into something I can build from. When I run up against plans that lack critical information, I ask for formal

BY GREG CASORSO

Typical Hillside Structure

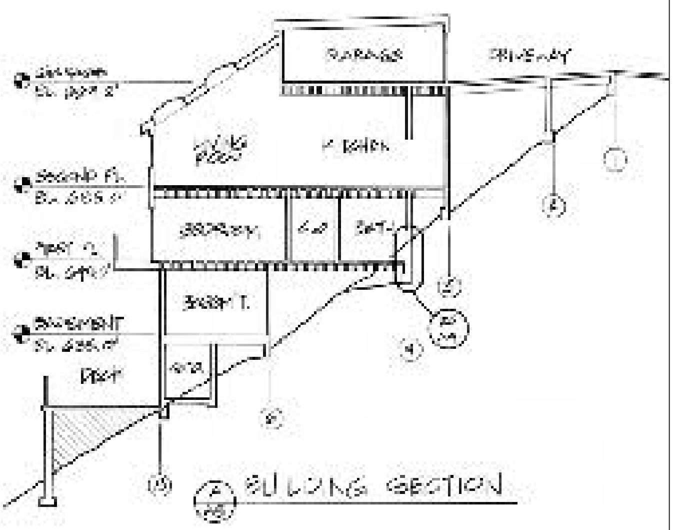

Figure 1. *Steep hillside foundations have many more elevation changes than level ground foundations. Be sure to allow time to transfer elevation references from the plans to the field.*

revisions. If the revisions don't help me get a clear understanding of what my responsibilities will be, then I don't pursue the work. The financial risk and possible damage to my reputation are not worth the effort.

On the other hand, I don't mind spending as much as 60 hours bidding a complex job if the plans are accurate and complete. Taking time to really work through a good set of plans helps me anticipate problems. Good plans include a soils report, a plot plan, structural drawings, and architectural drawings.

Soils Report

The first part of a good set of engineered plans is the soils report. Prepared by a licensed engineer, the soils report documents the geologic history of both the specific site and the general area around it. Even if the soils report is full of technical language, it should at least present the critical issues in a way that makes sense. In the San Francisco area, all property is subject to seismic activity. Hillsides in particular are also subject to landslides, which can be triggered by the construction process. A good soils report should directly address these problems, specifying the construction procedures and techniques required to stabilize the embankment.

Soil borings. I have seen residential hillside sites that required piers 60 feet deep, thousands of feet of hillside drainage, 20-foot-high retaining walls, and hundreds of tons of drain rock. Such extensive site engineering is not possible without a good sample boring analysis (see "Soil Reports: Looking for Water and Rock," below). Sample borings are especially important where piers are involved, because they help determine both the presence of water and the anticipated depth of the piers. Four or five borings are better than one or two, and they are more valuable if they are taken in and around the footprint of the proposed building. Deep borings — 25 feet deep or deeper — are more valuable than shallow borings. A deep boring can better define "bedrock" and help locate subterranean water moving horizontally through the hillside. A deep boring may also identify ancient landslides and waterways, which can affect the stability of the ground above.

The sample boring analysis also determines whether on-site soils will be useful as engineered fill. The analysis should clearly identify expansive soils and provide specifications for building on them. Expansive soil swells when it gets wet and shrinks when it dries, leaving large cracks that channel water down into the hillside. This can cause landslides and foundation settlement. The swelling action of expansive soil can be powerful enough to lift a house, and expansive soil used for perimeter fill can cause windows and doors to stick, and stucco, siding, drywall, and even the foundation to crack. A site with expansive soil may require extensive drainage, deeper piers and footings, and more heavily reinforced concrete slabs. In many cases, the expansive soil must be removed and replaced with nonexpansive fill.

Drainage. The soils report should also address drainage, including a discussion of how to clear the virgin site, especially if erosion and landslides are a concern. (See Part Two of this article next month for more on hillside drainage.)

Plot Plan

A plot plan is a topographical map that locates the new structure on the property (see Figure 2). The most critical information on a topo map are the property lines and elevations, which should be staked in the field by a surveyor. If the plans give you only one benchmark elevation — a sidewalk curb point, for example — then be sure to allow time to set your own reference points closer to the building footprint.

The elevation numbers themselves mean nothing, but pay attention to the difference between the numbers. When you calculate cut and fill quantities, allow extra material to account for small inconsistencies of one or two feet between the topographical elevations on the plans and those in the field. But you should get extra compensation for larger inconsistencies.

A good topo map will also identify all utility easements, previously built structures, rights of way, creeks, and any underground improvements that are a matter of record but may not be visible. The map may also identify which trees to save and which to remove.

Structural Plans

The structural drawings define the foundation in its entirety, and you will refer to them often in the field for actual day-to-day construction. They are prepared by a structural engineer working in conjunction with the architect and the soils engi-

Soils Reports: Looking for Water and Rock

Drilling piers is one of the most expensive parts of hillside foundation work, but the soils report can help you anticipate site conditions. The two most important things I look for in the soils report are the presence of water and hard rock in the sample borings.

Water. If the soils engineer discovers a significant amount of water in a sample boring he will usually note it prominently in his narrative report, but it will also show up on the Exploratory Boring Log.

Water makes pier drilling very difficult because it can fill the hole or cause the sides to collapse. When a hole fills with water but remains sound, you can pump the water out before pouring the concrete. This isn't very expensive, but it can slow you down if you're not expecting it. Another option is to "tremie" the concrete — fill the hole from the bottom up by placing the concrete with a pump hose that runs right to the bottom. As the concrete fills the hole, you keep raising the hose until the concrete has displaced all of the water. It's important to know ahead of time that you need to do this so you can make sure to have a boom pump on site and provide for access.

If there's a lot of water, the pier hole may collapse and you will need to "case" the pier. This involves drilling inside a steel sleeve that supports the wall of the hole. Sections of sleeve are added and driven as you go. It's an expensive process.

Rock. The other thing to look for is the presence of hard rock, which is significantly more expensive to drill through. Pier drillers know they've hit hard rock when their bits take more than 5 minutes to progress 12 inches. Knowing in advance that there's hard rock on the site can make a difference in the type of drilling equipment you bring onto the site, the prep grading required, and so on. If you see an engineer's note on the boring log about "hard rock" or "extremely firm material," it's worth a phone call to the soils engineer to get more information. Sample borings taken near the actual footprint of the proposed house can tell you whether the hard rock you hit is simply a big boulder, or "floater," in the hillside, or a thick layer of solid rock.

Drilling in mud and hard rock can cost four to five times as much as ordinary drilling. Since a pier house can have over 100 piers at an average cost to drill of $150 each (depending on the depth), extra drilling costs can mount up fast. How much extra drilling you have to do is a judgement call made by the soils engineer in the field, so I try to find out as much as I can about his reputation by calling the drillers in the area. I also try to find drillers who have drilled in the neighborhood to see what they encountered in the ground. Usually owners understand that drilling costs are unpredictable and will pay for extra costs, but it's important to document everything and to include language in your contract that stipulates hard rock drilling and casing of piers as work done at additional cost. If the engineer has a reputation for being hard-nosed, and the owners are penny-pinchers, pass up the work.

— G. C.

Steep Site Plot Plan

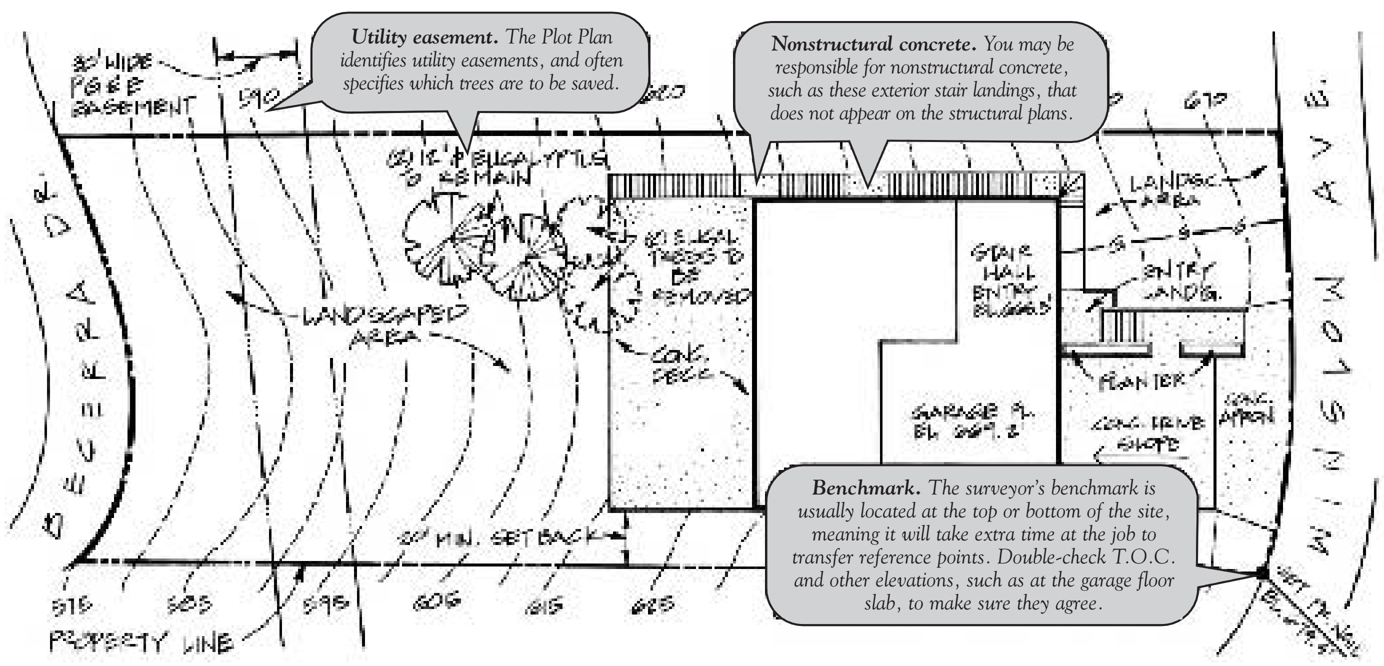

Figure 2. *The most important information on the Plot Plan is property lines and benchmark elevations.*

Steep Site Structural Plan

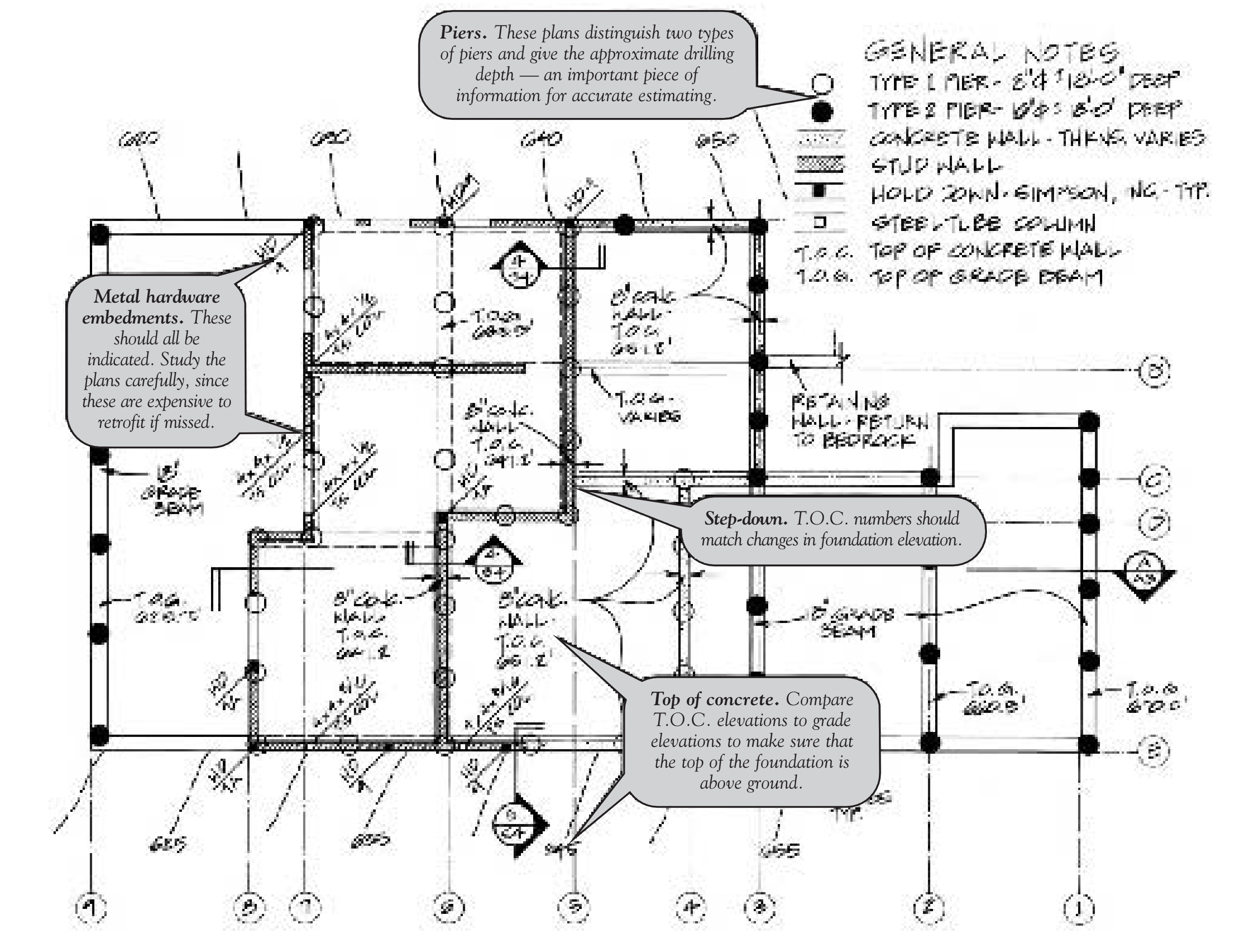

Figure 3. *Building hillside foundations requires accurate and complete structural plans. Check pier locations, hardware embedments, and c hanges in top-of-concrete elevations.*

Comparing Architectural and Structural Details

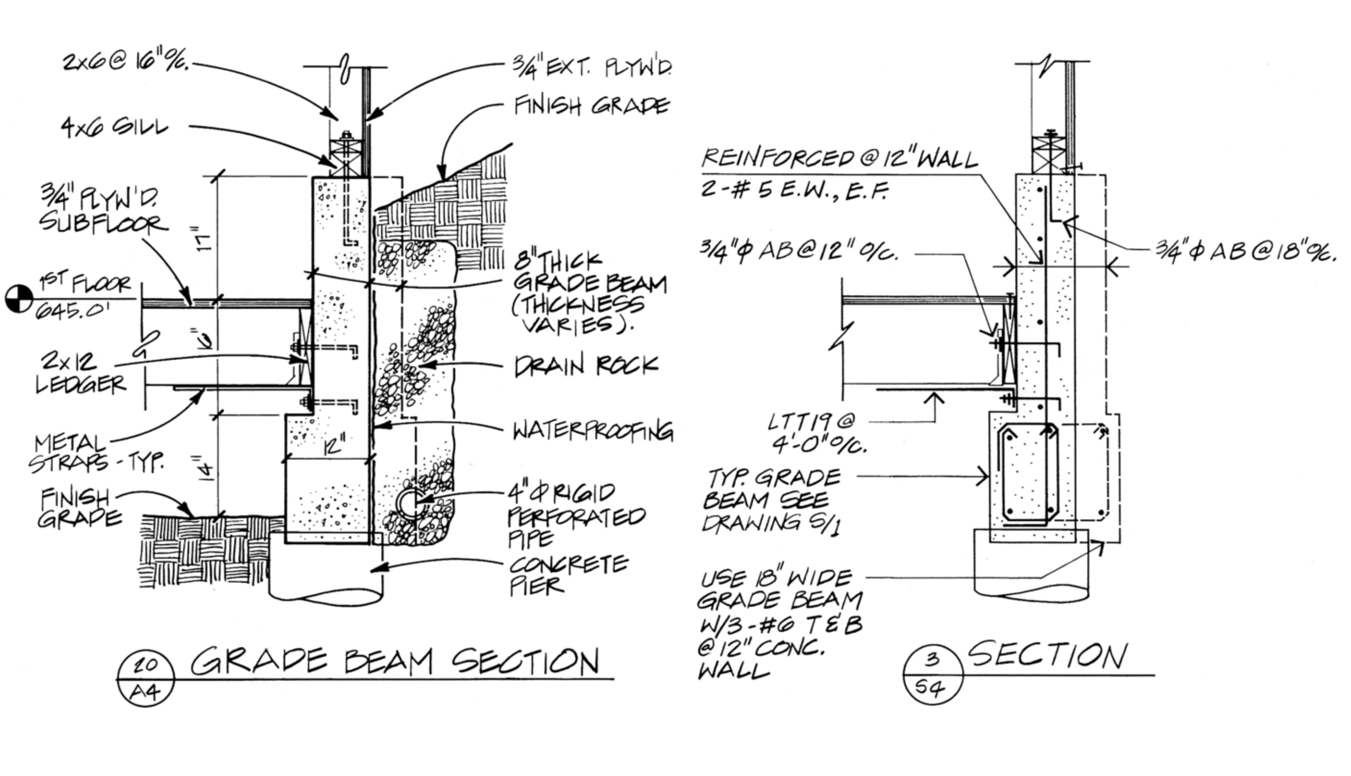

Figure 4. *Architectural and structural plans are often drawn by two different people. Make sure dimensions and notations on architectural details (left) agree with structural details (right), which are more schematic. For example, the structural drawing specifies the diameter and on-center location of anchor bolts for the joist system, but you must read the architectural drawings to determine their elevation. Similarly, the architectural drawing shows "metal straps typical," while the structural drawing specifies the exact piece of hardware to use.*

neer. The information included and omitted from the structural drawings can make or break your job, so it's worthwhile to really study them in depth (see Figure 3, previous page).

Often the structural plans are technically correct, but it's worth the effort to check for specific elements that may be missing or incomplete, or which do not agree with other parts of the plans.

T.O.C. Top of concrete elevations, abbreviated T.O.C., give the finished elevations of the concrete foundation at specific points. These elevations convey a great deal of information, such as grade beams that slope, step, remain level, and are above or below grade. Site grading and preparation can also be inferred from T.O.C. elevations. However, I've found that engineers often supply too few T.O.C. elevations, and that contractors are not careful enough in checking for discrepancies between the elevations that are supplied. There may be only one inch difference, but that difference is important.

Elevation changes. The locations of all foundation elevation changes should be clearly indicated and dimensioned. Check these points to make sure the top of the foundation will still be above grade where it steps down — an obvious detail, but one that's often overlooked.

Garage floor elevation. The structural drawings should also specify the garage floor elevation. I find that often the original site benchmark is nowhere near the building and is either too high or too low to conveniently work from. So I like to use the garage floor elevation as a reference point for all the other T.O.C. elevations, whether upslope or downslope. Keep in mind that the garage floor usually slopes toward the garage door.

Retaining walls. Retaining wall elevations should clearly indicate the height of the wall as well as all embedments, utility raceways, vents, access portals, window openings, and stairs. Details occurring at the top of the wall — such as beam pockets — should be clearly shown. And if the wall is thicker than the wood framing above and the extra thickness is on the outside of the building, the drawings should show a bevel to shed water away from the house. The structural plans should also indicate how far retaining walls extend beyond the house footprint and how they terminate.

Piers. The plans should also locate all piers. I prefer to have all piers numbered because it helps me keep track of them during construction. Instead of saying, "We had a problem with that pier over there," I can say, "We had a problem with pier number eight." I also like the plans to specify the anticipated depth of each pier. This helps my estimating and makes it easy to collect additional money for extra drilling. Statements like, "All piers shall extend into bedrock" are too vague. What is bedrock? Where is bedrock? Who decides and when?

Hardware. The foundation structural drawings should specify and locate all embedded hardware. This includes anchor bolt size and spacing, hold-down anchor bolts, column bases, and embedded beam brackets. Rebar size, type, and spacing should also be called out, along with specifications for rebar splicing and connections.

Architectural Plans

As for the actual foundation, problems occur when the architectural plans and the structural plans do not agree. Technically, it is the responsibility of the architect and engineer to make sure that dimensions and elevations are the same on both sets of plans, that the size and location of beams and columns agree, and that details are complete. But you're the one who will lose money if these problems are not reconciled, so study the plans carefully before you sign the contract. It's too easy for others to say, after work has begun, that you should have caught a particular problem ahead of time, or that a questionable detail is generally accepted practice and that's why they hired a foundation specialist in the first place.

To reconcile architectural plans with structural plans, you need to look for and clarify details implied but not stated, conflicting details, and details that you believe are inaccurate (see Figure 4). First determine whether any nonstructural concrete shown on the architectural plans is a part of your contract. For example, sometimes the architectural plans require that structural slabs have concrete curbs to frame the walls on, or concrete landings for landscaped stairs, as shown in Figure 1. A detail like this may appear in only one place on the plans with the implication that it's typical everywhere else. In fact, this concrete may not be mentioned directly anywhere, even if all other T.O.C. elevations are called out. It can be costly if you fail to catch an omission like this.

Other problem areas include specified dimensions that do not agree, incomplete details, and vague specifications. For example, what exactly is meant by a note on the plans that says "waterproof membrane?" In such a case, get the specifications because, depending on the material the architect has in mind and the installation procedures it requires, a single notation like that can end up being very expensive. ■

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