Replacing a Beach-House Foundation

by Jeff Moroso

A modified mat saved this cottage from the sea

Recently, our company was hired to remodel a 1950s beach cottage just south of San Francisco. The job included repairing the house's seriously damaged foundation (see Figure 1, next page).

Our original plan was to shore up the building, replace the support beams, and reuse the existing wood piles. But once we got the house supported by cribbing and temporary steel beams (Figure 2, page 3) and started excavating around the piles, we found that they extended only 4 or 5 feet below grade rather than the 15 to 20 feet we'd been expecting.

Since the existing foundation could not be saved, we had to design, gain approval for, and build a new one from scratch.

And, with the house up on cribbing, we had to hurry. The house mover's liability insurance would not cover us if the shoring remained in place for more than 90 days, a real concern with the winter storm season approaching. If a big wave hit before the foundation was done, the cottage could be destroyed.

Although we had already planned to drill new piers for the decks, these weren't an option for the house unless we moved it out of the way or drilled from below with a handheld rig. But moving the house would be too expensive, and drilling with a handheld rig would be difficult with so little headroom above and so many stone cobbles in the sand and gravel soil below.

Instead, we decided to remove the piles and support the cottage with concrete columns extending up from a modified version of a mat foundation, which was designed for us by Joshua B. Kardon, a structural engineer in Berkeley, Calif. A mat foundation is a thick and heavily reinforced concrete "slab" stiff enough to span weak areas of soil. The mat is usually continuous, but this one would be grid-shaped, because we planned to leave the house where it was and form around the temporary cribbing. We would place the foundation in a monolithic pour, so that the cured grid and columns would act as a unified whole.

Replace the Beams First

The design called for new Port Orford cedar glulam support beams, which we decided to install before forming the mat and columns. That way, there would be fewer things in the way. We could hang the beams from the joists, install the column caps, and then form and pour up to the caps (Figure 3, next page). Since the house was so close to the ocean, we opted to use only stainless steel fasteners and hardware for extra resistance to corrosion.

Forming the Grid And Columns

On the plans, the foundation looked like a perforated mat — a grid of intersecting wide grade beams, four going one way and four others crossing at 90 degrees. Each grade beam measured 4 feet wide and 18 inches thick. Of the 20 columns extending out of the grid, 16

Figure 1. Creosote-treated wood piles supported the cottage 5 feet above the beach, so storm surge could flow under it. The decks were carried by shallow concrete piers (above left). About half of the piles showed signs of rot (left), as did most of the beams that carried the floor system and decks (above).

Figure 2. The crew members did not want to undermine the shoring when they dug down to repair damaged piles, so they excavated the areas where the cribbing would go, then built "forms" around the cribs to protect them from being buried if waves came under the house (below).

would support the cottage and four would support the deck (see "Mat Foundation Details," page 7).

Steel reinforcing. The grid was heavily reinforced, with each grade beam containing 10 #6 bars, five on top and five on the bottom (Figure 4, next page). The crew connected them with #3 ties every 14 inches on-center and spaced them off the ground with small precast blocks called dobies.

The columns projecting up from the footings contained cages of four #7 bars with #3 ties 6 inches on-center. We had the cages tied off site and sent out to be hot-dip galvanized. Before tying the cages into the grid, the crew slipped 16-inch-diameter Sonotubes over them (Figure 5, page 5). Fourteen-inch columns would have been strong enough, but with all that salt water around, we upsized them to get an extra inch of coverage over the steel.

Special concrete for a saltwater environment. Standard concrete is porous and prone to cracking, because as the material hydrates, bleed water forms internally around the aggregate. Once the concrete dries, there are open pores where the water used to be. On larger

Figure 3. It was easier to install the beams before bringing the supports up from below. Here, the beam is hung from the joists before installation of the support columns.

Figure 4. The concrete sub used a skid steer to excavate a flat surface for the grid to sit on (top). Next, his crew formed the perimeter (above), then laid and tied all the steel before forming the inner parts of the grid (right).

pours, the heat of hydration can cause thermal shrinkage cracking all by itself. We were concerned that salt spray — which attacks and corrodes even galvanized steel ferociously — would make its way to the rebar through the cracks and pores that would inevitably exist if we poured the foundation with standard concrete. We wanted the concrete on this job to be impermeable and to contain no cracks at all.

With advice from the manager of our local concrete plant, we came up with a mix containing water, cement, fly ash, $1/2$-inch and 1-inch aggregate, two types of sand, fiber, and three additives. Along with the varied size of the sand, the large and varied size of the aggregate would limit shrinkage — but it also would make the material difficult to pump. Still, because access was poor and we wanted to do a monolithic pour with close to 80 yards of concrete, we needed to pump.

While a concrete pumper's natural response to these circumstances might

Figure 5. Once the steel was tied, crew members finished the formwork by boxing out the grid openings with 2-by lumber, then installed the rebar cages for the columns. They wrapped the Sonotubes with plastic to protect them from exposure to heavy rain.

have been to add more water, we wanted to avoid weakening the concrete, which is why we dealt with the problem by using additives that made the mix easier to pump.

The main additive was the fly ash, a waste product that comes from the dust collectors in coal-burning power plants. A fine powder consisting mostly of glass particles, fly ash can be substituted for some of the cement in a concrete mix. Our local concrete plant has been doing this for years because fly ash is cheaper than cement and has properties that make for a better finished product. As the owner of a "green" building company, I like fly ash because using it reduces the amount of cement I need; cement production is a major source of the carbon dioxide that contributes to global warming. Also, fly ash typically ends up in landfills, so using it for concrete diverts it from the waste stream.

Thus, to minimize shrinkage, we replaced 35 percent of the cement with fly ash. And to reduce cracking, we used Degussa's Polyheed 997, a water-reducing admixture (less water means less cracking), and Pozzolith 300R, a water-

Figure 6. Access was poor, so the crew used a pump to place concrete for the grid (above) and columns (right).

Figure 7. The threaded rod coming down from this column cap (above) is attached to a large nut and washer that will be embedded in the concrete. The Sonotube was lifted to within an inch or two of the beam before the concrete was poured, and the gap was later packed with grout. Because the column received a stuccolike waterproof coating, it's not possible to see the joint between the concrete and the grout (right).

reducing plasticizer (Degussa Admixtures, 800/628-9990, www.degussa.com). With these additives, we could limit the amount of water in the mix yet still have concrete flowable enough to pump and place.

As an extra precaution, we added fiber to reduce cracking still further and used a corrosion-inhibiting admixture — another Degussa product — called Rheocrete CNI.

Pouring the Foundation

Since there wouldn't be room to bring in a drill rig until the pile of excavated soil was used to backfill the grid, we planned to pour the house foundation separately from the deck piers. A couple of days before the pour, the structural engineer and the city inspector inspected the rebar and forms. On the day of the pour, a special inspector from an independent testing company showed up to observe; he verified that we followed proper procedures and saw to it that test cylinders were made from the concrete mix.

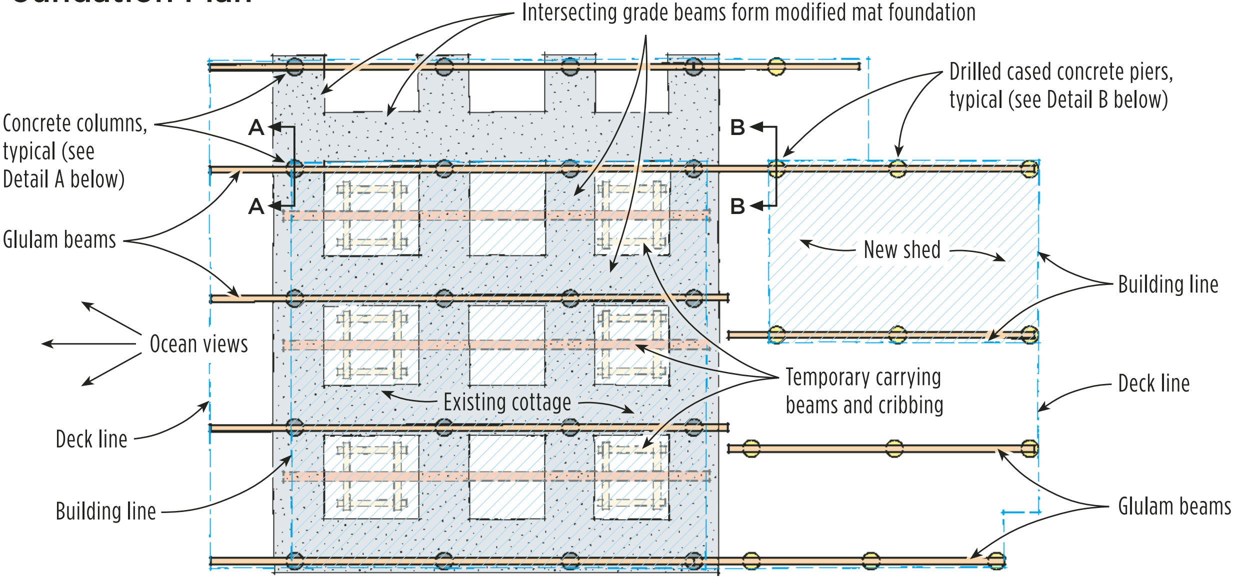
It took eight trucks all morning to deliver the 77 yards of concrete needed to pour the grid and house columns (Figure 6, previous page). The design strength of the mix was 3,000 psi, but when the cylinders were tested at 28 days, we found that the concrete was already at 6,000 psi and would likely continue to gain strength for years.

Pouring the columns tight to the bottom of the column caps wouldn't have

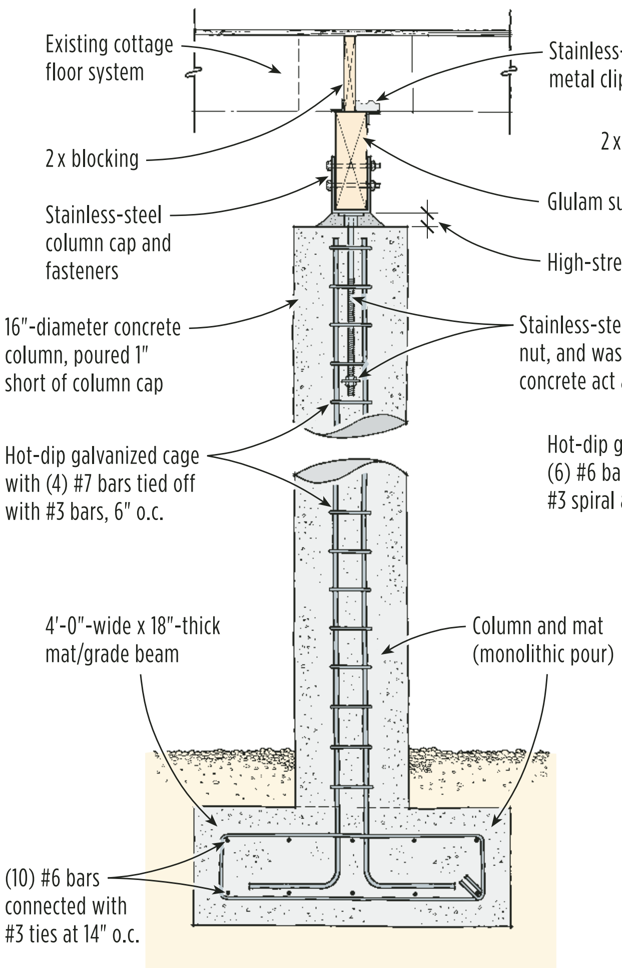
Figure 8. In the photo at left, the grid and columns are both visible. Once the foundation was backfilled, only the columns could be seen (above).

Mat Foundation Details

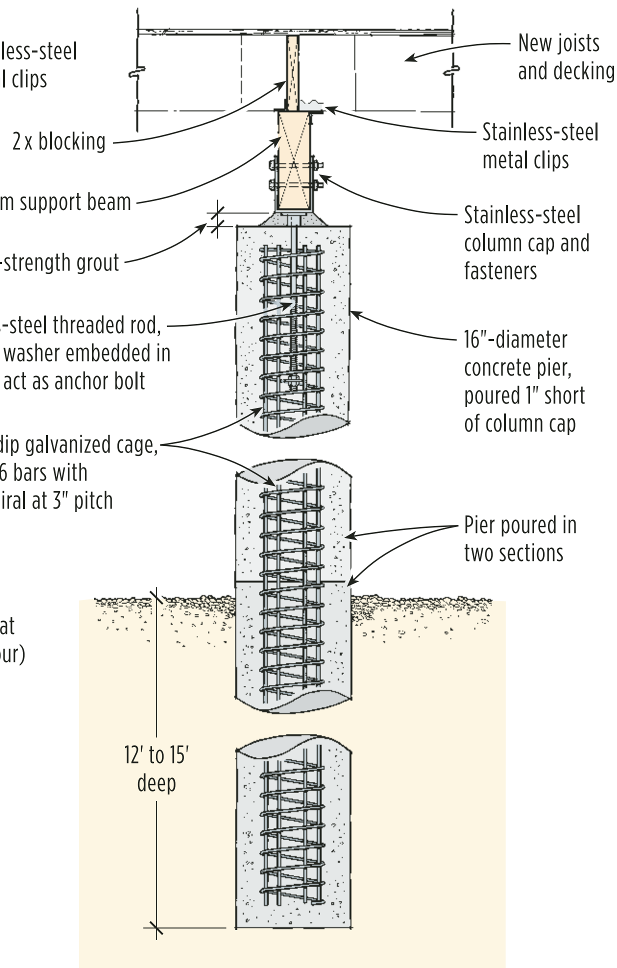
Foundation Plan



Detail A — Column/Mat



Detail B — Pier



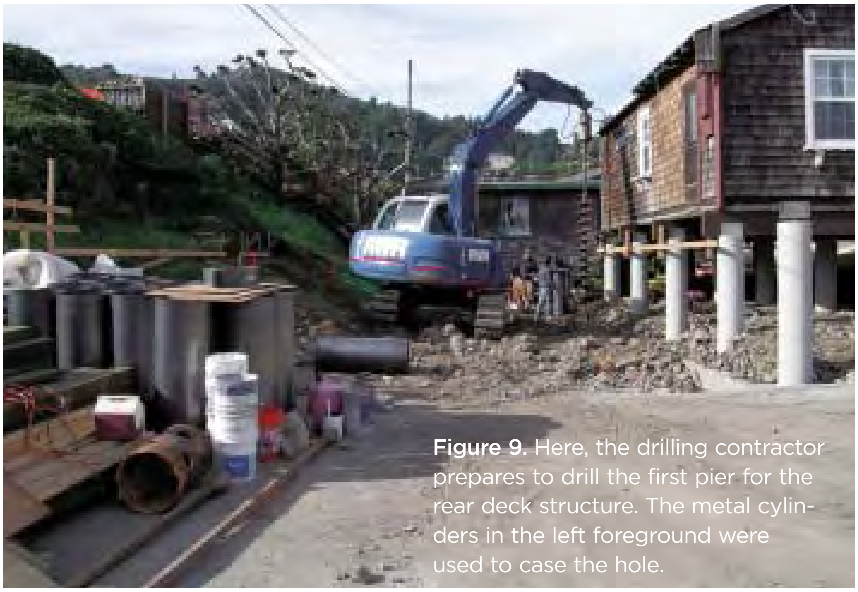


Figure 9. Here, the drilling contractor prepares to drill the first pier for the rear deck structure. The metal cylinders in the left foreground were used to case the hole.

been practical, because when we vibrated them, the concrete would consolidate and separate from the caps. So we poured the columns an inch or so short, then grouted them tight to the bottom of the brackets with high-strength grout once the concrete had set (Figure 7, page 6).

After about a week of cure time, the foundation was strong enough to support the cottage, so the house mover came back and removed the cribbing. We all breathed a sigh of relief once the cottage was firmly bolted to the new foundation. With the cribbing out of the way, we were able to bury the grid with the excavated material and begin working on the individual piers that would support the decks (Figure 8, page 6).

Figure 10. Before pouring a pier, the drilling contractor redrilled the bottom of the hole to make sure it hadn't filled up with silt (above). Like the columns, the piers were heavily reinforced with galvanized rebar cages (right).

Friction Piers for the Deck

It had always been part of the plan to rebuild the rear deck on new concrete piers. The old piers and piles weren't worth saving, and with no obstructions overhead it would be simple to get a drill rig into position.

But end-bearing piers — what you get when you bury a Sonotube and fill it with concrete — weren't practical in this situation. With the high water table, we couldn't pour an end-bearing pier in such iffy soil without first inspecting the bottom of the hole. And even if the hole were dry, it would need to be large enough for someone to climb inside and inspect the bottom. In addition, the low bearing capacity of the soil would require large-diameter end-bearing piers to provide the necessary support.

We decided to use friction piers instead. A friction pier is "gripped" by the surrounding soil, so its bearing capacity depends on how much of it is in the ground — the deeper the pier, the more it will carry. The soils engineer determined that the friction capacity of the soil was 300 psf. Given the local wind

Figure 11. The crew pumped from the bottom up to prevent concrete from mixing with the water in the hole (left). The casing was pulled out as the concrete was poured. Below left, a welder cuts off a section that had just come out of the ground. The silt pouring out of the top indicates that this hole was nearly filled with concrete (below right).

and seismic conditions, and knowing we wanted to use 16-inch piers, the structural engineer designed them to go 12 to 15 feet below grade.

Drilled cased piers. In firmer soil, we could have drilled the holes, dropped in the steel, and gone from there. But with loose soil and a high water table, we had to drill and case the piers. Casing is a steel pipe that prevents a hole from caving in. It's big enough for the drill bit to fit through and is pushed into the ground as the hole is being drilled; it's pulled back out as the concrete is placed. Removing the casing allows the concrete to "key" into the soil, thereby creating the necessary friction. If the casing is not removed, the pier will have less load-bearing capacity.

At each pier location, the drilling contractor drilled several feet down, retracted the bit, and used the rig to push a 4-foot casing most of the way into the hole (Figure 9, previous page). He tack-welded a second section of casing onto the first, reinserted the bit, and drilled deeper before pushing both casings farther into the ground. This continued until the holes were 12 to 15 feet deep and contained multiple sections of casing, with the top one projecting a few inches above grade. While the casing kept the hole from caving in, it didn't prevent ground water from coming halfway up inside.

Pouring the piers. As with the cottage columns, we had rebar cages for the piers fabricated and hot-dip galvanized off site. On the day of the pour, the drilling contractor redrilled the bottom of each hole to clean it out, placed the rebar cage, and began filling the hole with concrete (Figure 10, previous page). Because the holes were half filled with water, he put a tremie pipe on the concrete pump hose, inserted it into the hole, and pumped from the bottom up, making sure to keep the nozzle below

Figure 12. Once the piers were up to grade, members of the crew braced the deck support beams into position and installed the column caps (above). Then they formed up to the beam with Sonotubes and poured the rest of the way (right).

the surface of the liquid concrete.

Since concrete is denser than water, it forced the water and silt up and out of the hole without diluting or mixing with the concrete. As each hole was being filled, the drilling contractor vibrated the concrete and pulled out the casing, one section at a time (Figure 11, previous page). When the process was complete, the rebar cages projected several feet into the air and were encased in concrete up to grade.

Finishing up above grade. It's impractical to pour the above-grade and below-grade portions of a friction pier in a single operation. While the lower end requires no form because it's surrounded by soil, the upper end requires a Sonotube, but there's no way to brace it into position while the drilling crew is working on nearby piers. So we had to pour the piers in two separate operations.

After the lower sections had set, our crew braced the deck beams into position and tacked stainless steel column caps onto them (Figure 12). Then all the drilling contractor had to do was apply a bonding agent, Rezi-Weld 1000 (W.R. Meadows, 800/342-5976, www.wrmeadows.com), to the top of the pier, flex the rebar off to one side, slide a Sonotube over it, and finish the pier by pumping the Sonotube full of concrete. That way, there was no possibility the piers would not line up with the beams or that the mounting brackets would be set at the wrong height.

Once the concrete was set, we stripped the Sonotubes and grouted up to the column caps before bolting them permanently in place. As an added defense against the elements and to give the exposed portions of the foundation a uniform appearance, we coated the columns, piers, and grout with Super Blockade (Merlex Stucco, 714/637-1700, www.merlex.com), a cementitious waterproof coating. After that, finishing the cottage was a regular remodeling job.

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