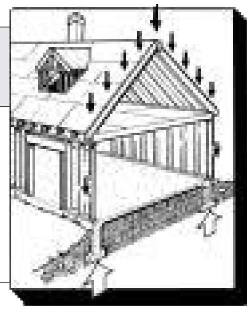

A Foundation for Unstable Soils

by Harris Hyman, P.E.

Nick is a great client — an energetic contractor who always brings fresh ideas to his work. With Nick, there are always new things to try and new ways to do things. His current project is a spec design-build, a group of duplexes in a small infill subdivision in a high-density suburb. Each half-duplex has about 1,800 square feet and costs just above $100 grand. The price includes site development, so cost control is pretty critical — especially on the early units that float the job until the real profit can be made on the final few houses.

Mucking Around

Geotechnically, though, the site is a mess. It appears to be on an ancient bog, where the soft stuff goes very deep into the ground.

On the first duplex, Nick had to remove a portion of the muck and replace it with crushed stone, held in place with a geotextile fabric. This required a trench about 3 feet wide and 4 to 6 feet deep along the entire 190-foot length of the footing. The process was a triple whammy: He had to remove the muck from the footing, buy stone to replace it, then get rid of some 1,000 cubic yards of soil. This he managed to do by spreading it out on the remaining lots. But he knew he couldn't repeat this process too many times, with progressively fewer lots on which to spread the soil.

Nick's next idea was to use concrete grade beams, set on shafts that ran down into a more stable soil. The shafts were to be reinforced concrete placed in paper tubes. Under this reasoning, an auger could be moved into place, the shafts drilled, the tubes inserted and filled, and the grade beams formed on top.

The geotechnical engineer who looked at the soil gave an approximate bearing strength of 2,000 pounds per square foot. A little calculation estimated the weight of the duplex unit at about 170,000 pounds, which required 85 square feet of bearing surface. To get this area, we would need 108 12-inch-diameter shafts, 62 16-inch shafts, or 27 24-inch shafts. The latter looked plausible, so we checked the cost. Each 12-foot-deep shaft would take 2 1/2 yards of excavation, 12 feet of cardboard tube, 80 feet of #6 rebar, and 1 1/2 cubic yards of concrete. The total cost for the 27 shafts came to over $10,000 — clearly not the way to go.

Pin Piles

Then we discovered pin piles. An offshoot of classic piling techniques, these are steel piles, 2 to 4 inches in diameter. They are driven with a hydraulic hammer mounted on a small loader such as a Bobcat (see Figure 1, page 82). The hammer bangs in one 10-foot section at a time, with one length coupled to the next. A number of pins are driven until the "refusal" point is reached, when the Bobcat rig can drive the pin no farther at its set operating pressure.

The hammer mounted on the rig smacks the pin with 300 to 800 foot-pounds of energy, 500 to 800 hits per minute. This controlled and measurable hammering allows the load capacity of the pile to be determined. With the rig we used, for example, we knew a 3-inch pile had a strength of about 28,000 pounds whenever the hammer could drive it less than 1 inch in 20 seconds.

Grade Beams

The concrete grade beams were perched on top of these pin piles. Usually a grade beam is designed to be partially supported by the soil underneath it, but here the soil was too soft. So for this project, we designed the grade beams as true beams, spanning from pin to pin and supported by the piles alone. Nick

Figure 1. *Pin piles are driven by a hydraulic hammer mounted on a small loader or backhoe.*

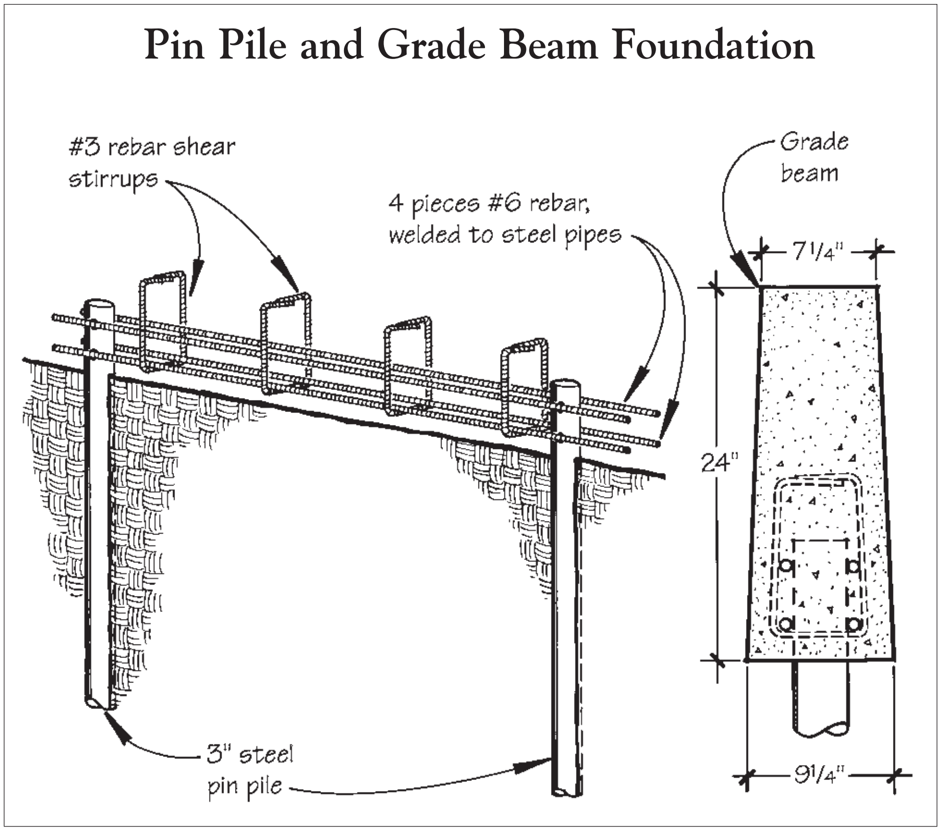

Figure 2. *A pin pile foundation is supported by the resistance of the soil around the steel piles. A reinforced-concrete grade beam poured on top spans from pile to pile. To ensure adequate concrete coverage of the rebar, the grade beam is thicker at the bottom, then steps up to conventional foundation width.*

wanted the grade beams to give the look and feel of a solid foundation, so I specced a beam size of 8x24 inches deep.

The foundation plan had 17 support points, at corners and at the midpoints of the longer beams. This gave an average load on each pin of 10,000 pounds, which yielded a safety factor of 2.8 against the 28,000-pound-per-pin load capacity. The maximum point load in the foundation was 17,500 pounds, which still gave a 1.6 safety factor. The load on the central bearing point was yet a little higher, so we specced two pin piles there.

The beams were engineered in a conventional manner with four "threads" of #6 rebar and a lot of stirrups to handle shear (Figure 2). We also had to design for an extra 25% load from the weight of the concrete beam itself.

Our first plan was to form the grade beams from 2x8s and 24-inch-wide sheets of 1 1/8-inch plywood. This proved impossible, though, because the width of the pin piles (outside diameter of 3 1/2 inches) plus two pieces of 3/4-inch (#6) rebar didn't allow enough concrete coverage in a 7 1/4-inch beam. So we used 2x10s below, and tapered the beam to 7 1/4 inches at the top to accommodate standard-size window bucks.

The concrete was placed carefully. Since this was a structural application, we poured some test cylinders to ensure that we got the proper cured strength.

Hindsight

This foundation wasn't perfect. The soil was softer than anticipated, and the pin piles had to go more than 40 feet to refusal. The job turned out to be pretty expensive, and used up all of the available 3-inch pipe in the city on just two duplex units. On the other hand, the two foundations were built in two days with minimal fuss and excavation.

We recently discovered another piling system, which uses large auger-like screws to get bearing and anchorage. The torque required to put in the screw piles is the indication of load-bearing capacity. According to a local contractor who uses this proprietary system, the screws are about 20% more expensive than the pin piles per foot, but they can do the job with about one-third the depth. ■

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