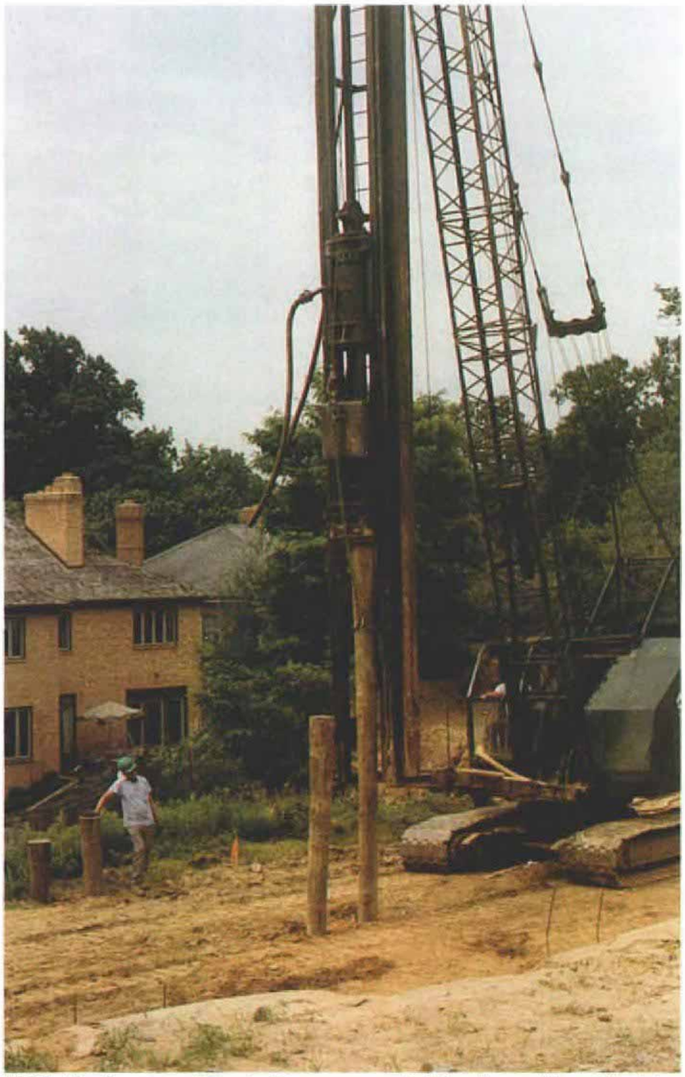
Deep Foundations

Using driven piles and grade beams to build on soft ground

by Alvin M. Sacks



If I had a hammer. **Wood piles are pounded in place with a pile driver. They're driven until they won't go any deeper (their "refusal depth"), even though the machine keeps hammering.**

Once in a while you dig a foundation footing and find the soil getting softer instead of harder the deeper you go. If by digging a few extra feet you can reach solid bearing, then the easiest and least expensive solution is to place your footings at that depth. But if the soft soil continues for several feet or more, better alternatives exist. One alternative is a steel-reinforced grade beam supported by some form of concrete or wood piles (drawings facing page).

Concrete or wood?—Concrete piles are usually placed into deep holes that have been excavated with a large auger (like the machine that's used to install utility poles). In very soft soils, drilled holes often collapse before being filled and thus need to be lined with a hollow steel pipe called a casing. The casing may be left in place after being filled, or removed during concrete placement (whether it's left or removed will depend on variables such as the character of the soil and the cost of the steel). A modification of this method eliminates the need for a casing. It consists of a special auger that injects concrete into the hole while simultaneously withdrawing from it.

Wood piles are usually driven in place with a pile driver (photo above), a technique that's especially useful in fill soils that don't contain stumps and rocks. Wood piles are driven down to a "refusal" depth. Refusal simply means that the pile won't go any deeper, even though the pile driver keeps on hammering it. The approximate refusal depth can be accurately estimated using formulas that consider, among other factors, the power of the driver and the resistance of the soil. In general, driven piles have twice the bearing capacity of drilled piles. Not only do their ends bear on underlying soil or rock, but their sides also develop friction with the surrounding soil.

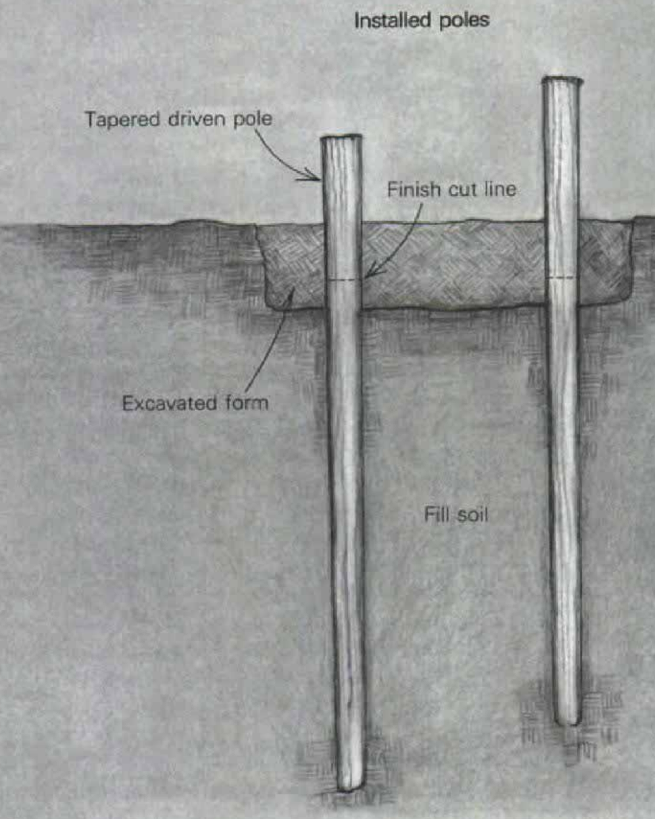
Coping with soft fill—This case involved three adjacent lots in a draw (a small ravine). Two of the lots had been filled with up to 20 ft. of spoil—dirt that had been excavated and removed from another construction site. The spoil had been trucked in about 20 years earlier and dumped without being compacted. While the fill had naturally consolidated over time, it was still too weak to support the very large, two-story homes that were planned for this site.

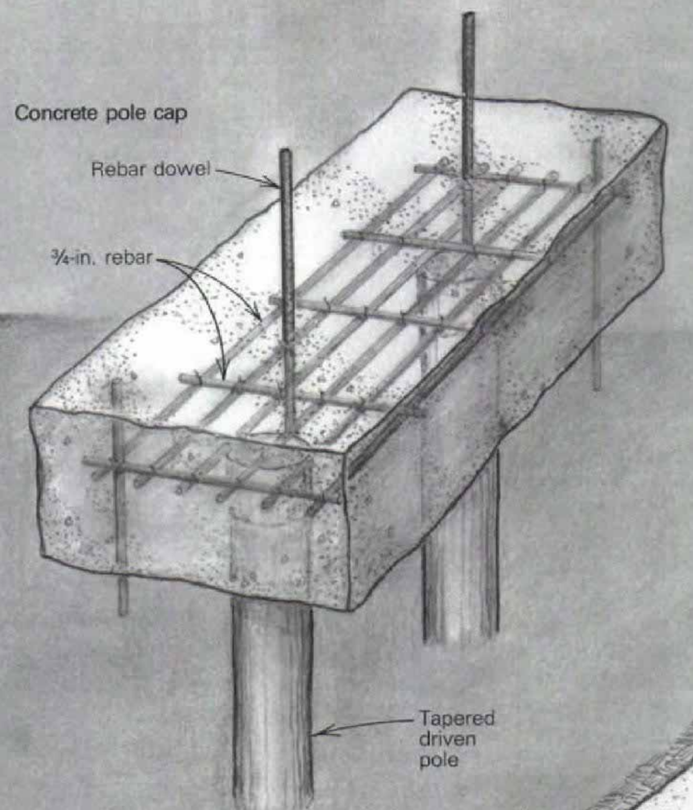
Although the underlying soil was probably strong enough to support the houses, it was much too far below the surface. A hole deep enough for two full-height basements would have been needed for conventional footings (such information can be gotten from test pits or borings, or by checking a topographic map that dates from before the fill was brought in). Construction feasibility and cost led the builder to choose treated wood piles and to span the distance between them with grade beams that doubled as wall footings.

Durability of wood—When installing wood in contact with the ground, the question of life expectancy arises. In Venice, untreated piles surrounded by seawater have survived 1,000 years. Untreated piles would not have lasted long on this job, however. Wood can last a long time under water because it's exposed to little oxygen. But these piles would be above the water table, and thus more susceptible to rot. The design called for Southern yellow pine piles treated with chromated copper arsenate (CCA). These are warranted for only 40 years, but if they prove to be as durable as creosote-treated piles they should last much longer—perhaps 75 years. The soil could consolidate and compact enough during that period to support the building, though there's no guarantee. It depends on the soil characteristics at the site. This should be taken into account before deciding whether to use wood piles.

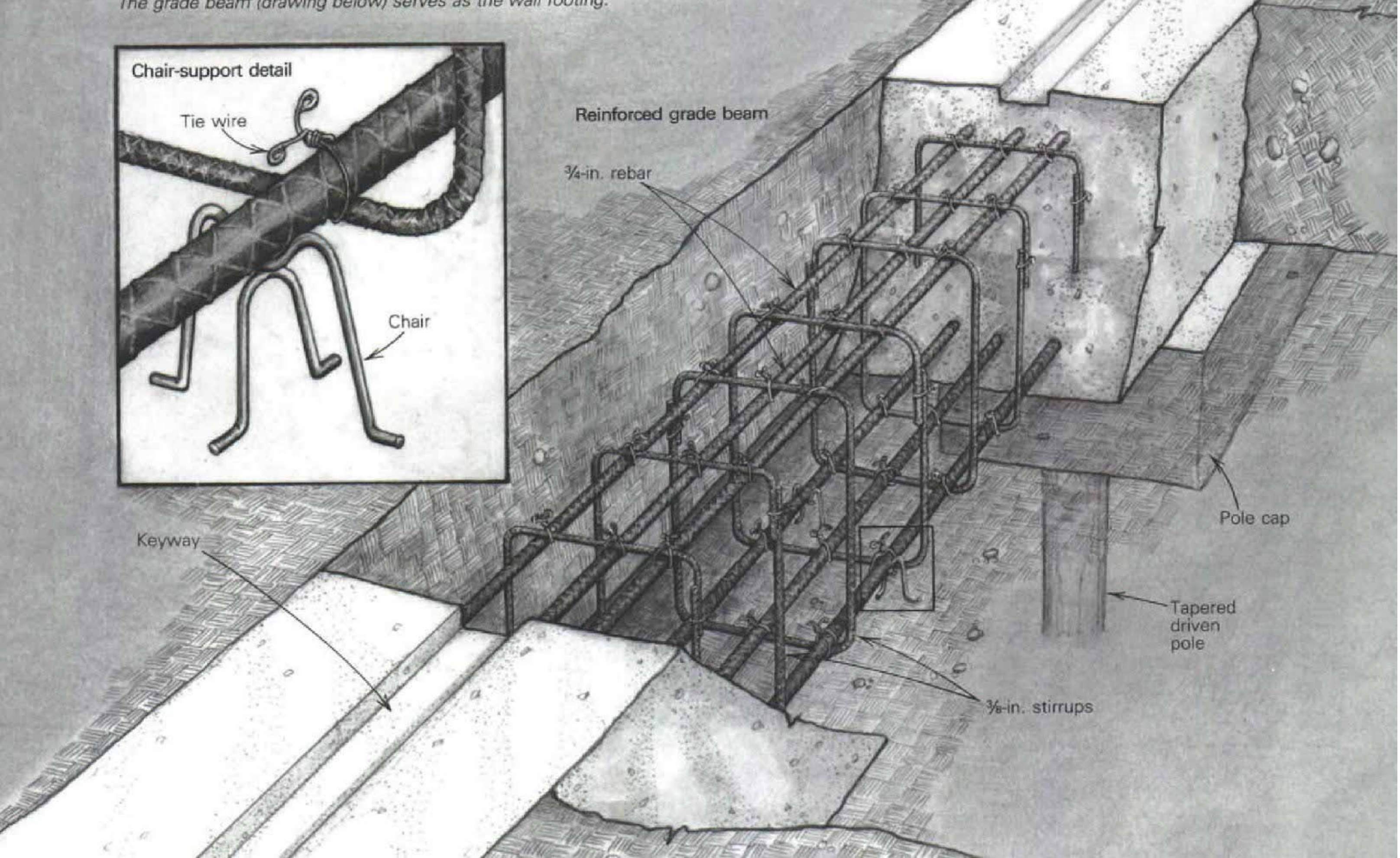
Installing the piles—The piles on this job consisted of 25-ft. long poles that tapered

Drawings: Bob Goodfellow





A three-component deep foundation
After the poles have been driven, they're cut off near the existing grade, and a form is excavated around them (drawing above left). Note that one pole is driven deeper than the other; because the first pole compacts the surrounding soil, the second pole has a shallower refusal depth. The poles are then recut to their finished height and capped with a reinforced-concrete pole cap (drawing above right). The pole cap is tied to the grade beam above with vertical rebar dowels. The grade beam (drawing below) serves as the wall footing.



Adequate reinforcement. A grade beam must resist bending forces from any direction. Forming the rebar into a cage provides reinforcement across the beam's entire cross section.

from 12 inches in diameter at the top to 9 inches in diameter at the base. Because the compressive strength of the wood under axial loads (straight down) is about 1,200 lb. per square inch, each pole could theoretically carry 52 tons. But the large number of poles that were driven under each house meant that each one supported much less than its maximum capacity. Most of the homes' weight was transferred to the soil along the sides of the poles (a phenomenon known as "skin friction"), rather than to the ends.

To provide an adequate margin of safety, two-dozen poles were driven under each house. The structural engineer decided to install the poles in pairs, with 5 ft. between individual piles and 15 ft. between pairs. This close spacing made it easy for the poles to carry the footing, slab, wall and column loads. Pairs of poles were placed under bearing walls, corners and all other concentrated loads.

In pairs such as these, the second pole has a shallower refusal depth than the first, usually by a few feet. This happens because the first pole compacts the surrounding soil as it's driven, which in turn increases the soil's resistance to penetration by the second pole.

After all the poles were driven, the builder used a chainsaw to cut them off just above the existing grade. A backhoe with a narrow bucket then excavated a trench around each pair. Next, the finish elevation of the poles was determined using grade stakes, utility poles and the street as benchmarks. Each pole was then recut to its finish elevation and capped with a concrete pole cap.

Steel-and-concrete caps—A pole cap is a reinforced-concrete pad that's placed over the tops of the poles (concrete is usually referred to as being "poured," but "placed" is the correct term). The cap helps to prevent splitting and curling damage that might result from imposed loads. It also blocks the migration of oxygen from the overlying soil that could abet decay of the pole. Each cap was 2 ft. 8 in. thick and extended a few feet beyond all sides of the poles.

Rebars were laid vertically and horizontally in the pole cap and tied together. The design called for four vertical rebars—two tall ones and two short ones (drawing, previous page). The taller ones would serve as dowels, joining the pole cap to the grade beam that would eventually be poured above it. Such attachment helps to tie all the foundation elements together for resistance to lateral shifting. (Remember that when a foundation wall is backfilled, it acts as a retaining wall as well as a foundation, so it's subject to lateral forces. The greater the backfill height, the greater the lateral force acting on the wall.) The shorter vertical bars acted as grade pegs, marking the finished height of the pole cap.

Forming the grade beams—In this project, the reinforced grade beams also served as wall footings. The engineer called for grade beams at least 12 in. wide by 16 in. to 24 in.

deep. Because they would also serve as a base for 12-in. block, the builder made them about 2 ft. wide. Although form boards were used where the grade changed abruptly, most of the beam was placed in unlined trenches and reinforced with #6, or ¾-in. dia. rebar (rebar is sized by number, as in #6; the number is always a numerator whose denominator is 8). The rebar was held in place by stirrups—⅜-in. dia. rebars that have been bent into squared circles. Tying the long bars to the stirrups with tie wire formed a cage, and guaranteed reinforcement at the top and bottom of the grade beam (bottom drawing, p. 59).

A concrete grade beam, or any other spanning member, must be designed so that the concrete and steel work together. The steel needs to reinforce the concrete against tension (stretching) and twisting forces. The concrete, in turn, should be thick enough to encase the steel and strong enough to hold it in place. To be protected from corrosion, rebars need at least 3 in. of concrete cover around them on all sides. Rebar should be elevated on chairs—small metal or plastic supports—during concrete placement. Some masons use brickbats to support rebar, but doing so is bad practice because it lowers the beam's tensile strength (see sidebar below). Where two grade beams intersect over pole caps, their rebars must be tied to each other to maintain the integrity of the reinforcement.

When grade beams double as footings, their surfaces should be roughened to improve adhesion to the foundation wall. For very tall walls or those apt to oppose significant lateral pressures, keyways (2x4s laid in the wet concrete and later removed) or vertically embedded steel dowels make good connecting devices. □

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Brickbats and freefalls

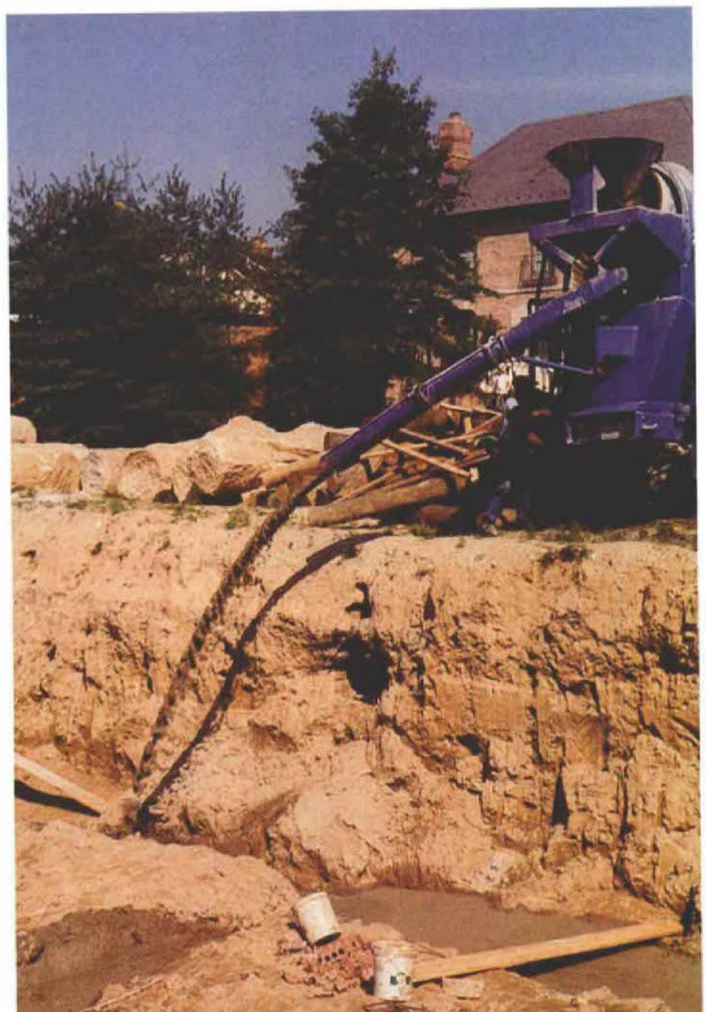
Pole and grade-beam foundations use lots of steel and concrete. Is that much strength needed for a residence? Maybe not, but the reduced quality of much of today's residential construction demands such overdesign. The design sometimes has to compensate for shoddy construction practices.

One common problem is the sloppy way many workers install rebar. To do its job, rebar must be properly located and spaced, adequately tied together, and encased far enough inside the concrete. Brickbats and other odd-sized rough chunks of brick, concrete or stone should not be used as chairs to support rebar (photo below left). Doing so may weaken the concrete.

But the most ubiquitous problem is the excessively wet concrete that's typically used when placing footings. Concrete develops strength when its components—the aggregate and the paste—are well mixed. Although most contractors want a mix that's wet enough to be poured easily from a ready-mix truck, it's important that the mix not be soupy. The problem with a soupy mix is that the aggregate tends to settle to the bottom, a form of segregation that reduces the concrete's overall strength. This might not be a problem for footings placed on well-consolidated or compacted soil, but it could prove disastrous where the concrete must span a distance, as in a grade beam. A rule of thumb is that if you can pull the concrete with a hoe and have it easily flow around obstacles, it's too loose. For lasting strength, concrete should be stiff enough to require shoveling around the ditches or inside the forms. Don't use a vibrator to move it around because that can cause segregation. Vibrators are designed only to compact concrete in place by removing entrapped air.

Concrete can also segregate and lose strength when it freefalls more than about 5 ft. (photo below right). In such cases, using portable chutes or other devices will prevent segregation of the concrete components. If concrete trucks can't be driven all around the site, wood or metal chutes, or concrete pumps equipped with long booms, can be used to deliver the mix. —A. S.

Don't do this. **Elevating rebar on brick scraps is bad—but common—practice. Rebar should instead be supported on chairs.**



...*or this.* When concrete free falls more than about 5 ft., the aggregate can settle to the bottom. This seriously weakens the mix.