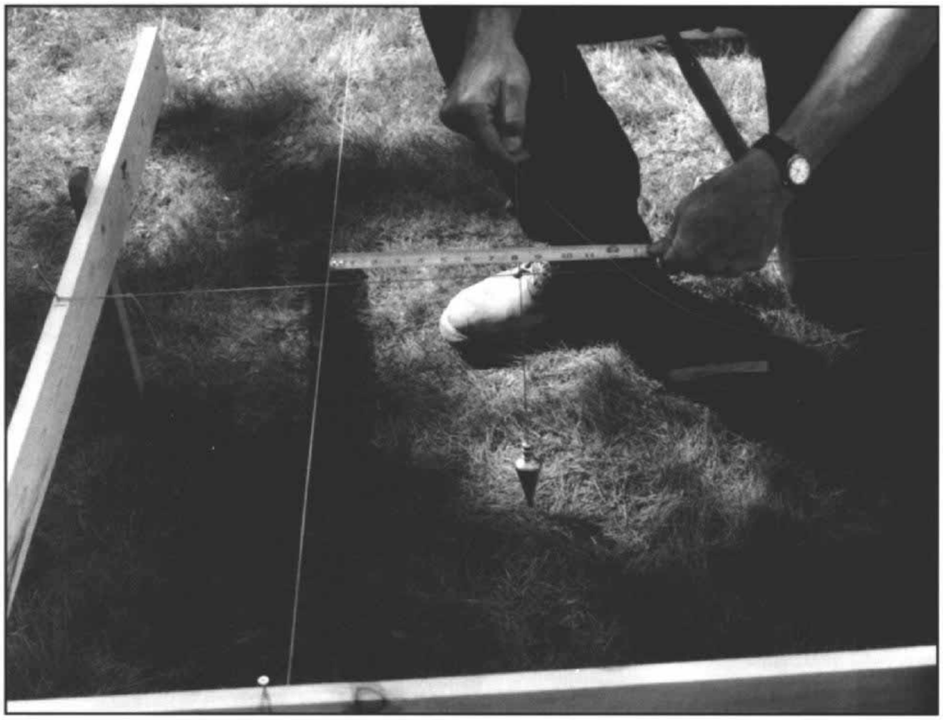
Deck Foundations that Last

Design footings and piers to match the load and bearing capacity of your soil

by Scott Schuttner



Lining them up. **Stringlines stretched between batter boards provide locations for footings and piers. A plumb bob can be used to transfer locations from the string to the ground.**

Adding a deck to a house is usually a good investment. People just plain like them. A deck is tailor-made for a Sunday afternoon cookout, and there are few better places on a summer evening to sip a cold drink. But the best of deck plans will come to grief without a foundation that is designed and built correctly.

The foundation is a deck's connection with Mother Earth. A good foundation will be strong enough to support any expected load and sized so that the soil beneath it can support its weight. The foundation must be installed so that it won't heave when the ground freezes, and it should be constructed of decay-resistant materials. Plus, the foundation shouldn't break the budget.

Unlike a house foundation, which spreads its load around the perimeter of the building, deck foundations normally concentrate loads at isolated points. At each point, part of the total load from the deck is transferred through a beam and a post above grade to a concrete pier below grade and finally to a wider, buried concrete section called a footing (drawing facing page). Alternately, a wood post may run all the way from the beam to the below-grade footing.

When designing a foundation, you must determine the number of footings and their sizes, how deeply they should be buried and whether or not to use concrete piers or wooden posts below grade. The foundation is best designed after the framing plan has determined beam locations and the number of posts that will be needed.

Sizing the footings—The first step in foundation design is figuring out the footprint of each footing (see sidebar p. 67). The footprint is the area of contact between the bottom of the footing and the earth.

The minimum footprint for each footing depends on the total load of the deck and what percentage of the total load will be transferred to each footing. To determine the footprint of each footing, first divide the total load on all footings by the number of footings. Then divide the load on each footing by the bearing capacity of the soil. Changing any of the variables in the calculation will affect the outcome.

To determine the total load of the deck, multiply the total square footage of the deck by the design load per square foot. Codes usually require that a deck support a minimum of 40 lb. per sq. ft. (psf) of live load (people and any movable items on the deck) plus 10 psf of dead load (the weight of the permanent parts of the deck) for a total of 50 psf. Some codes require 60 psf. The larger the deck, the larger the total load, which will mean larger footings, assuming all other variables are held constant.

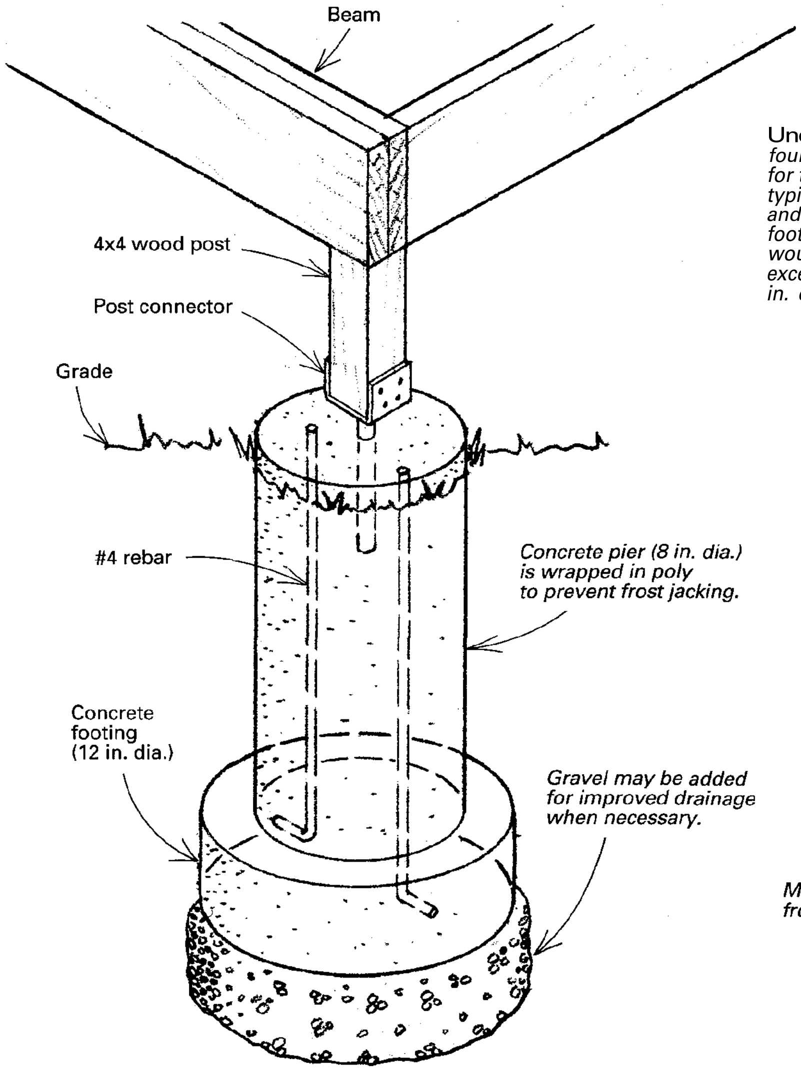
A simple deck has a beam near one end that supports half the total load, and a ledger on the house that supports the other half. So the total load on the footings will be half the total load of the deck. If the deck has multiple beams or large cantilevers (when floor joists extend beyond the supporting beam beneath), the footings may not carry the same percentage of the total load.

A word of caution about cantilevers: They increase the load on the beam. For a simple deck with a ledger on one side, a beam on the other and only a slight cantilever, you can figure the size of the footings as if there were no cantilever. For large cantilevers—let's say anything more than 10% of the span—you may want to consult an engineer. The weight on the beam does *not* increase proportionally as the beam is moved toward the ledger. As a rough guide for estimating loads only, under normal conditions the beam will bear about half the load between itself and the ledger, in addition to all the load on the cantilevered side.

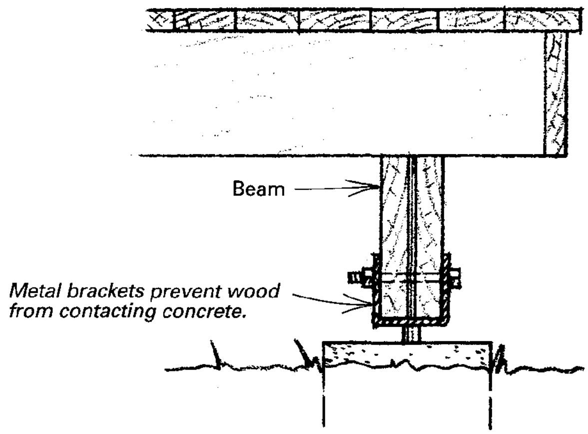
Calculating the bearing capacity of the soil also can be tricky. Soils composed mainly of inorganic silts and inorganic clays, or soils that are sandy or high in gravel content, will usually have a bearing capacity of 1,500 psf or more. A deck foundation built on this kind of soil could exert 1,500 lb. on each 12-in. by 12-in. footing. As the bearing capacity of the soil falls below 1,500 psf, as in soils with high amounts of organic clay, silt or peat, larger footprints will be needed.

Typical footing footprints for normal loads and good soil are 12 in. to 14 in. for square footings and 14-in. dia. to 16-in. dia. for round ones. Footings can be made bigger to compensate for soil types that have a low bearing capacity. But there are practical limits to how big footings should get. Footings over 20 in. on a side, for example, need special engineering. When loading gets too high, one option is simply to increase the number of piers and footings.

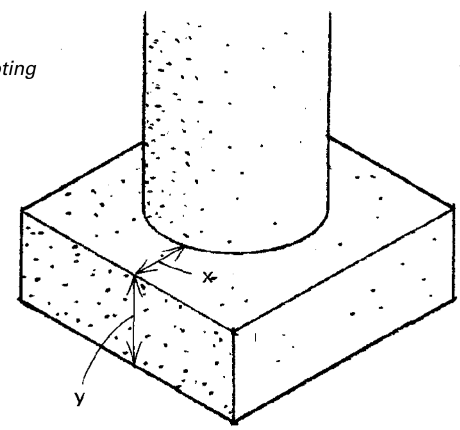
For most decks, 6-in. thick footings are adequate, but with heavier loads or footings over



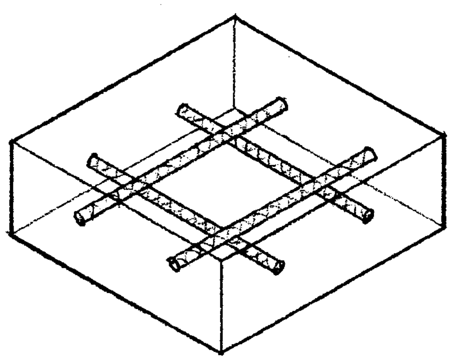
Understanding a pier foundation. *A good foundation begins with a footing that is sized correctly for the load and the soil type. An 8-in. dia. pier would typically include one or two pieces of L-shaped rebar and extend several inches above grade. For small footings with typical deck loads, no steel reinforcement would be needed in the footing unless distance x exceeded y (below left). In very wet conditions, put 12 in. of gravel below the footing.*



Rebar is generally not needed in the footing if y is greater than x.

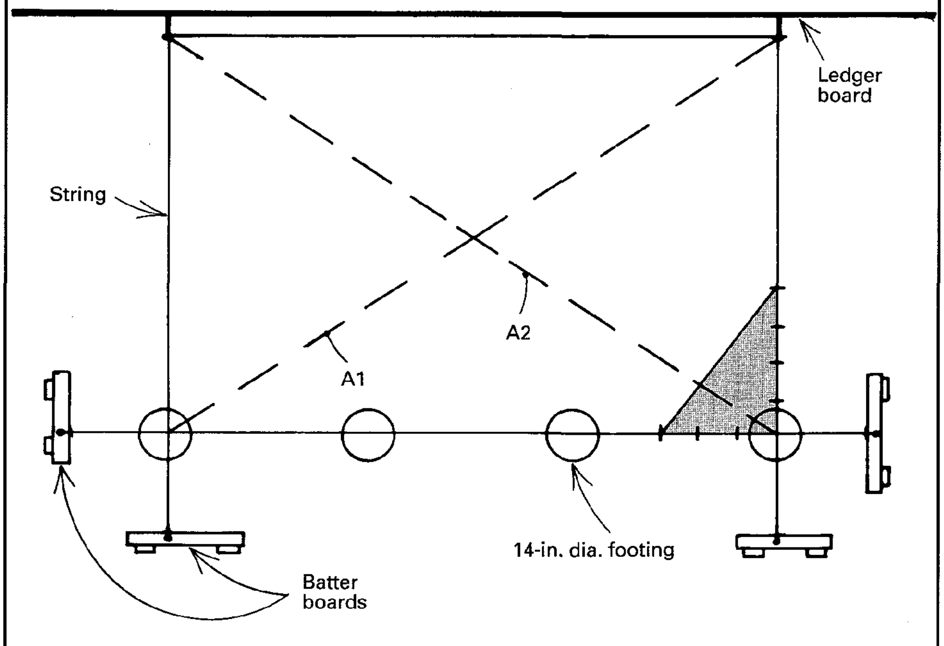


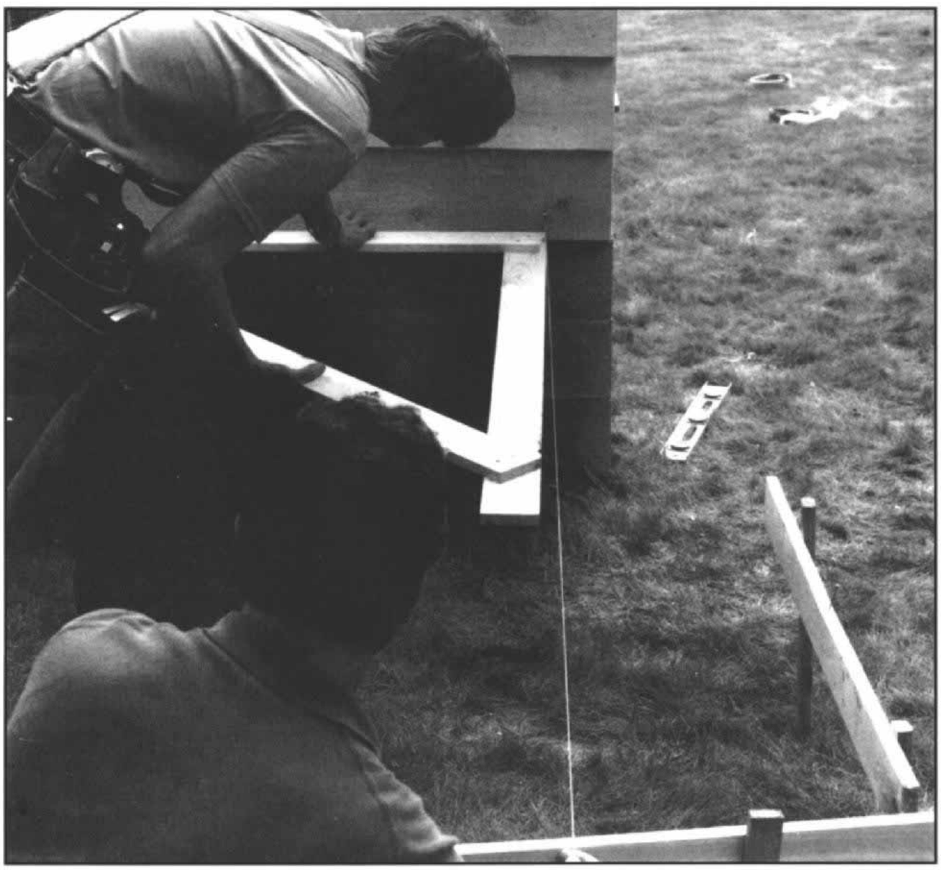
If rebar is needed in the footings, place #4 bars 12 in. o. c. in both directions. The ends should not be exposed.



Drawings this page: Vince Babak

Make sure it's square. *There are several methods for making sure the layout of the foundation is square. One way is to establish the corners of the layout with stringlines and batter boards, and then measure the diagonals. Assuming that opposite sides are the same length, if A1 and A2 are the same length, all four corners must be square. You can also use the 3-4-5 rule to check that an individual corner is square (see shaded area below). Mark 3 ft. on one string, 4 ft. on the other and then measure the distance between the two points. If it's 5 ft., the corner is square.*





Checking for square. **In setting the string to find the comers of the deck foundation, a big, site-built square can be helpful. One leg of the square is held against the ledger board on the house, and the other acts as a reference for attaching the string to the batter board.**

16 in. on a side, footings should be 8 in. thick. Footings will not require rebar as long as the distance from the pier to the edge of the footing does not exceed the thickness of the footing. If rebar is needed, a grid with #4 bars laid horizontally 12 in. apart should be enough, although you should verify this with an engineer.

The information here is not meant to replace a professional engineer's design, but it should give you a good guide for understanding and estimating the usually straightforward load and sizing requirements of the foundation. Your building department or state geological survey office should be able to help you determine what type of soil you have. If all else fails, you can have core samples taken by an engineer.

Beware of frost—The foundation design must address the potential for frost heave, which varies from region to region. Frost heave is a function of temperature, water and soil permeability. When water in the soil freezes, the soil expands with a force that's more than strong enough to lift a deck foundation. To avoid freezing conditions, the footing must always be placed below the frost line, the usual depth at which the ground will freeze in winter. This depth can be just a few inches, or it can be as much as 4 ft., as it is where I build here in Alaska.

You can also minimize frost problems by allowing for good drainage below the footings. If the soil doesn't retain water, then it can't heave. Keep gutter downspouts from emptying near footings, and make sure the ground is sloped away from them. If you know the soil is likely to be wet much of the time because of a problem such as a high water table, it might be necessary to run a perforated drainage pipe surrounded by gravel along the bottom of the footings.

If you suspect that water will get to the footings, improve drainage by removing 12 in. of soil underneath them and replacing it with a compacted mixture of sand and gravel.

In some regions, frost jacking is a problem. Frost jacking is different from frost heaving. Frost heave is caused by frozen soil pushing up on a footing from below; frost jacking occurs when frozen soil grabs a buried pier above the frost line and forces it upward. This may shift the pier only a small amount each year, but inch by inch it adds up. Breaking the bond between the column and the frozen soil will minimize frost jacking. One way to break the bond is to wrap the pier with several layers of polyethylene sheeting.

Getting to ground level—After sizing the footings, you must decide how to bring the foundation above grade. There are several ways to do this. You can pour concrete piers, which is what I almost always do, you can run wooden posts from the footings up to the deck, or you can use precast concrete-pier blocks.

Concrete piers are decay-proof, strong and required by codes in many areas. In most cases they can be cast integrally with the footings (this is my preferred method, and I'll explain how that's done a little later). Piers can also be formed and poured later if the footings are large or complicated, but this requires two concrete deliveries

Drawing this page: Michael Hiotakis

Calculating the footings and concrete for a sample deck

Calculating the load on each concrete footing is a critical step in designing a deck foundation. Let's suppose you have decided to build a 12-ft. by 20-ft. (240-sq. ft.) deck on your house, and the soil has a bearing capacity of 1,500 lb. per sq. ft. (psf). That would be typical for good soil.

The load is a combination of the weight of the structure (the dead load) plus the weight of the people and the objects that will be on it (the live load). Using a standard design load of 50 psf (40 psf for the live load and another 10 psf for the dead load), you know the foundation must support a total of 12,000 lb. That is simply the square footage of the deck multiplied by its design load (240 sq. ft. x 50 psf).

In this plan, half the load (6,000 lb.) will be carried by a ledger board attached directly to the house. The other half will be carried by a single beam. According to the framing plan, 4x4 posts every 6 ft. 4 in. will support the beam. So there will be a total of four posts with a 6-in. overhang at each end of the beam.

Divide the 6,000-lb. load on the beam by the four posts required in the framing plan. You now know that each footing must support 1500 lb. In typical soils, that would require a 12-in. by 12-in. footing that is 6 in. thick. If you decide to make a round footing (by using the bottom of the hole as your form), then a 14-in. dia. footing would provide 154 sq. in. of ground contact—more than adequate for the 1,500-psf load that each post will produce.

A good choice for this plan would be 8-in. dia. concrete piers between the footings and the posts. Let's assume the piers will be 42 in. high, putting the bottom of the footing 48 in. below grade.

But let's suppose the design load is a little heavier, or the deck a little larger, and each footing is to bear 1,700 lb. What then? Divide the load by the bearing capacity of the soil (1,700 ÷ 1,500 = 1.13). The result, 1.13, is the square footage of each footing, or about 163 sq. in. That's a square footing that measures 12¾ in. on each side.

The 1.500-psf assumption for the soil's load-bearing capacity is conservative. But some softer soils might require larger footings. Your local building office should be able to help you determine what kind of soil you have. When in doubt, consult an engineer.

***Ordering the concrete*—You'll need another bit of math when it's time to order, or mix, the concrete. The formula for determining the volume of a cylinder is πr^2 x h (3.14 x radius squared x height). The volume of a square pier would be determined by depth x width x length. It helps to know that there are 1,728 cu. in. in 1 cu. ft.; 27 cu. ft. = 1 cu. yd.**

To calculate the volume of concrete needed for this foundation, first determine the volume of the 8-in. dia. by 42-in. long piers. That is 3.14 x 4^2 x 42 = 2,110 cu. in. per pier. Then, 2,110 cu. in. ÷ 1,728 cu. in. = 1.22 cu. ft. per pier.

Next, calculate the volume of a 12-in. square footing that is 6 in. thick (12 in. x 12 in. x 6 in. = 864 cu. in.). Now divide 864 by 1,728 to learn that you will need 0.50 cu. ft. per footing/The total for each footing and pier combination is 1.72 cu. ft. If you were using the bottom of a 14-in. dia. hole for the footing form, a 6-in. thick footing would require 923 cu. in. of concrete (3.14 x 7^2 x 6). That's the same as 0.53 cu. ft.

Multiply that number by the total number of piers and footings to get the total volume of concrete needed (but add a little extra to account for spillage and error): 4 x 1.72 = 6.88 cu. ft. (or, for the round footing, 4 x 1.75 = 7 cu. ft.). That's about 0.25 cu. yd. *—S. S.*

instead of one. Piers should protrude above grade several inches to help keep water away from the ends of the posts they support, even if you're using decay-resistant posts.

Concrete piers that support 4x4 posts are usually 8 in. dia. if round or 8 in. by 8 in. if square. Larger posts require larger piers (10 in. to 12 in. for 6x6 posts). Piers can be formed by using tubular fiberboard forms—Sonotube is probably the best known brand—or by forms built with lumber. Building codes may require steel reinforcement. A typical 8-in. pier might require one or two pieces of #4 L-shaped rebar that run vertically from the footing through the pier. If the pier is less than 8 in., a straight piece of rebar can usually be used.

When building on particularly good soils or rock, the footing may not need to be any larger than the pier. In that case the pier form can simply be run to the bottom of the hole. But you still need to take precautions against frost heaving and frost jacking.

Sometimes it may make sense to run concrete piers all the way up to the beam. This eliminates short posts on low decks, but it requires that the metal bases that anchor the beam to the pier be set at precisely the right height. There will be little room for adjustment after the concrete is poured.

Instead of a concrete pier, you can use a pressure-treated wood post. This post would extend from the footing to the beam, eliminating the joint at grade level. This can make for a more rigid structure and may be required in earthquake country or on decks that are more than

***Digging the holes.* Holes can be dug in several ways. The author paid the owner of a chain-link fence company to bring in this Jeep-mounted rig. It made short work of a backbreaking job.**

***Form cutting made easy.* One advantage of using round fiberboard forms is that they are easily cut to length. Just use a handsaw, but try to make the cut square.**

***Concrete the fast way.* Ordering ready-mix concrete may cost a little more, but it saves a lot of work. Here, a wheelbarrow is used to ferry concrete to the forms.**

8 ft. tall. Additional stability can be provided by surrounding the post with concrete up to grade level, but be sure to slope the concrete to encourage drainage.

When using this method, place the uncut, factory-treated end of the post on the footing and keep the end grain protected from dampness by placing it on an asphalt shingle or sealing it with roofing tar. Six in. of compacted gravel placed under the footing also will help keep the wood dry. I don't favor this method because posts going all the way to the footing are harder to repair or replace, and many customers worry that wood posts in direct contact with the ground will rot, even if they're pressure treated.

In warmer climates, where the frost line isn't very deep, inexpensive precast pier blocks may be all you need for a foundation. These 12-in. to 18-in. tall by 12-in. to 24-in. square blocks often come complete with a cast-in-place metal post base. But avoid the type with a block of wood cast into the top. The blocks are too small and often split when you nail into them.

Laying out the foundation—With all of the framing and foundation decisions worked out and indicated on a set of plans, laying out the foundation becomes a simple matter of using basic geometry to transfer the drawn plans to the deck site (drawing p. 66).

In all cases, one side of the deck should act as the reference line for the rest of the layout. Typically, this will be the ledger, which is attached to the house. I prefer to install the ledger before doing the layout.

It's important to remember that all dimensions on the plans represent horizontal distances. So whenever you use a tape measure at the building site, keep it as close to level as possible. This is particularly tricky on a sloped site where measurements can become severely distorted if you follow the slope of the ground.

Once the ledger is set, the rest of the deck is located with strings that are attached to batter boards. A batter board is a 3-ft. or 4-ft. piece of 1x4 lumber attached about 1 ft. off the ground to a pair of 1x2 stakes in the ground. Stringlines are then stretched tightly between batter boards to represent the sides of the deck or the centerlines of the foundation footings (photo p. 64). The strings are tied to screws or nails fastened to the top of the batter boards.

Each corner of a deck without an existing solid reference like a ledger will need a pair of batter boards placed at right angles to each other. Corners are established where two strings cross. For complicated decks with a number of connected shapes, additional pairs of batter boards might be needed for layout.

The batter boards should be located so that the strings will be approximately centered on them, allowing plenty of room for adjustment. Keeping the batter boards 18 in. to 24 in. away from the intersecting strings will make them less likely to get bumped and knocked out of position while digging the holes. Layout work is best done with two people because there's a lot of string stretching, measuring, adjusting and marking that must occur simultaneously.

The first string, which runs parallel to the ledger board, locates the common centerline of the footings for a simple, rectangular deck (see drawing on p. 66). Measure from each end of the ledger out to the string and make sure the distances are the same. Then secure the string to the batter boards.

Next, establish each side of the deck by stretching strings from each end of the ledger to two more batter boards placed parallel with the ledger. If the deck is to be square, it is critical that these strings run square to the ledger and are exactly parallel. The stringlines should be roughly level. If the ledger is higher than the batter boards, you can use a plumb bob to set another string below the ledger and use it to measure out from the house. Or measure out from the ledger, keeping your tape level, and use a plumb bob to find the location of the string parallel to the ledger.

Carpenters traditionally check for square corners by applying the Pythagorean theorem, which is better known on the job site as the 3-4-5 rule: It means that a triangle with sides measuring 3 ft. by 4 ft. by 5 ft. will contain a perfect right triangle. You can measure 3 ft. along one string, 4 ft. along the other and make reference marks with a felt-tip pen. If the distance between the reference marks is 5 ft., the corner is square. Another trick is to measure the distance between opposite corners (the diagonals) if you're laying out a rectangular deck. When the lengths of these diagonals are the same, and opposing sides are of equal length, the angles within will be 90°.

I like to establish square corners by using a big site-built triangle (photo p. 66). I usually make one of these at the start of a job, and I find many uses for it before the deck is finished. I make the triangle out of straight 1x4s and check it with a framing square. To use it, I just rest one leg against the ledger (or any other reference surface) and run the Stringline out parallel with the other leg.

With the sides of the deck and the footing centerline laid out, you can now mark on the ground the exact locations for the outermost footings. Mark the string where the posts should go, then transfer the measurements to the ground with a plumb bob and flag the spots with colored tape held to the ground by a nail (photo p. 64).

Once the footing locations have been marked, you can remove the string. But leave the batter boards and nails in place so that you can check the location of the forms for the piers before concrete is poured.

Digging the holes—If you've ever dug a 48-in. deep hole by hand, you know that it can be hard work. And if you run into some large stones or bedrock, it can become a nightmare. If you've only got a few holes to dig, or if you're trying to cut costs wherever you can, the trusty, old post-hole digger will probably get the job done. But you might want to investigate the price of drilling the holes. I found the president of a local chain-link fence company was willing to bring in his Jeep-mounted hole driller for a very reasonable price (photo p. 67).

Post connectors. **There are several types of metal connectors that can be used to attach wooden posts to concrete piers. This one is placed in wet concrete.**

Another option is to rent a hand-held gasoline-powered auger. Available in one-person and two-person models, these rigs can generally dig holes only up to about 12 in. in diameter, maybe a little wider in soft soil. It's hazardous and brutal work, especially if the soil is rocky. But it's still quicker than the post-hole digger.

Installing a foundation—After digging the holes, it's time to construct a form system to contain and shape the concrete for the footings and the piers. Using the sides of the hole as the form for the footing is expedient and works in most soil types except those that are loose or sandy, where it may not be allowed by local codes. If the hole is significantly larger than that required for the footing, a square form can be constructed out of 2x6s or 2x8s. This form should be held level and in the proper location by attaching it to 1x2 stakes driven around the form's perimeter.

Because the hole is usually wider than the pier diameter, the pier requires its own form. I like to pour footings and piers in one step, which is easy to do when you use tubular fiberboard forms. These forms are widely available, lightweight, cheap, leak-proof and easy to cut to length with a handsaw (top photo, facing page). They come in 12-ft. lengths, and the 8-in. dia. size cost me about $1 per ft.

The tubes should extend from the top of the footings to several inches above grade. Your code may stipulate just how much (I usually shoot for 2 in.). It's not important that the tops of all the piers end up being level with each other. The wood posts can be cut to different lengths to compensate for differences in distance between pier brackets and the bottom of the beam. Cut the forms as square as possible. To mark the cut, wrap a piece of paper around the tube.

If you're building on particularly good soil, your footings may not have to be any wider than the piers. But in most cases you'll need to suspend the tubes off the bottom of the hole so that concrete can spread out and form a larger footing. The bottom of the tube would then determine the height of the top of the footing. The tube can be held up by attaching it with screws or nails to a pair of staked 2x4s that span the hole. Use a level to make sure the forms are plumb. Vertical rebar in piers can be inserted into wet concrete when just enough has been poured to provide support. Grids for footings will need to be tied with wire and suspended above the bottom of the hole on rocks.

Handling concrete—You can purchase sand and gravel with bags of cement and mix them together yourself, or you can buy bags of premixed concrete to which you just add water. Premixed bags yield only about ⅔ cu. ft. each and cost enough to make them practical only for very small jobs. You can also rent a mixer, but if you need more than 1 cu. yd. of concrete, and your time means anything to you, consider calling the ready-mix people. Just make sure you are completely prepared for the pour by the time the truck arrives (bottom photo, facing page).

The strength of the concrete (or its compressive strength), which is measured in pounds per square inch (psi), is determined by the amount of cement in the mix. The standard mix uses five bags of cement per cubic yard and yields a compressive strength of about 2,500 psi, which is adequate for most deck foundations. A mix of 5½ bags per cubic yard yields a strength of 3,000 psi, which may be necessary to handle a heavier load.

When you order a delivery of ready-mix concrete, you'll need to specify the quantity, the compressive strength and perhaps the slump. Slump is a measure of how much concrete will sag in a standard test, and 4-in. slump would be a common specification for concrete.

Concrete is sold by the cubic yard, which is 3 ft. by 3 ft. by 3 ft., or 27 cu. ft. Often, ordering less than 5 cu. yd. will result in a delivery surcharge. Estimating the quantity of concrete needed is a simple matter of figuring out the amount needed for each footing and pier. Then you multiply that figure by the total number of footings and piers (see sidebar p. 67). Using tubes on deck jobs makes estimating concrete needs much easier. Forms are regular geometric shapes, unlike the irregular sides of the hole.

There are three or four types of galvanized connectors used to secure posts to masonry piers. After pouring concrete, strings can be put back to ensure accurate alignment of brackets, then immediately place connectors or bolts in the still-wet concrete. Simpson Strong-Tie Company (P. O. Box 1568, San Leandro, Calif. 94577; 800-999-5099) is one manufacturer that makes many types of connectors. Metal bases come in different styles, strengths and sizes. The sturdiest of them can be cast directly into the footing or pier (photo above), and others are attached with bolts or anchors after the concrete hardens. □

Scott Schuttner is a home builder and woodworker in Fairbanks, Alaska. This article is adapted from his book Building and Designing Decks, *which will be published this spring by Taunton Press. Photos by Jeff Beneke.*