Better Deck Piers

Part 1: Base the footing design and spacing on the deck's size, expected loads, and local soil conditions

by Mike Guertin

On my last two deck rebuilds, the concrete supporting the existing framing was inadequate, and the decks had suffered for it. The footings were too small and too shallow and the piers were too misshapen, which led to settling and frost heaving that weakened the ledger connections (a safety issue) and to sagging beams that left the deck surfaces wavy. Unfortunately, this situation isn't unusual, as many deck builders rely on rules-of-thumb to size their footings and piers, then hand off the digging, forming, and pouring tasks to the least skilled laborer on the crew. But a solid

foundation is critical for the stability and long-term durability of a deck, so I take the time to make sure my footings and piers are sized and installed properly (**Figure 1**).

Poured concrete piers aren't the only foundation option for decks, of course. Other choices include pinned piers, helical piles, or even precast concrete pier blocks with built-in brackets, for those lucky enough to live in areas without frost (see "Footings From New England to California," May/June 2007). And even in cold climates like mine, many builders just use PT posts set on (or

embedded in) concrete footings at the bottom of the hole. But to prevent decay and problems with anchoring the post to the footing, I prefer to support a deck with continuous columns of concrete that extend from the bottom of the hole to above grade.

Digging deep holes and filling them with concrete is labor-intensive work, though, so I like to do the job as efficiently as possible. In Part 1 of this article, I'll describe how to design footings that are adequate, but not oversized. In Part 2 (scheduled for the next issue), I'll show you how to install them.

Guess, Calculate, or Use a Table?

The number of footings needed to support a deck beam is dictated by the beam's size. Unless the deck requires engineering, I refer to a beam span table as I design the framing. There's one in DCA6, the American Wood Council's *Wood Deck Construction Guide* (awc.org), though I've found that the 2015 IRC's new span table is a bit more generous (**Figure 2**). Once I've determined exactly how many footings I'll need, I can determine how large each one needs to be.

Footing size. Some deck builders use rules-of-thumb to size footings that may or may not be adequate. Others err on the side of caution and dig unnecessarily oversized footings. A third option for math-averse (but cautious) deck builders is to refer to DCA6's prescriptive footing sizing table, which supplies footing sizes based on the beam span and joist span (**Figure 3, page 26**). The footing sizes are conservative—the assumed soil bearing capacity is 1,500 pounds per square foot (psf)—and not all beam and joist spans are listed, so often you have to move up to the next larger span. Unless your soils are really poor, you can't go wrong using the prescriptive method.

Figure 1. When a pier is angled, deck loads are transferred to the pier's side rather than its bottom, which can cause it to sink. Also note the voids—a result of too many large rocks in the concrete mix—that have weakened this pier.

TABLE R507.6
DECK BEAM SPAN LENGTHS[a,b] (ft. - in.)

SPECIES[c]	SIZE[d]	DECK JOIST SPAN LESS THAN OR EQUAL TO: (feet)						
		6	8	10	12	14	16	18
Southern pine	2 – 2 x 6	6-11	5-11	5-4	4-10	4-6	4-3	4-0
	2 – 2 x 8	8-9	7-7	6-9	6-2	5-9	5-4	5-0
	2 – 2 x 10	10-4	9-0	8-0	7-4	6-9	6-4	6-0
	2 – 2 x 12	12-2	10-7	9-5	8-7	8-0	7-6	7-0
	3 – 2 x 6	8-2	7-5	6-8	6-1	5-8	5-3	5-0
	3 – 2 x 8	10-10	9-6	8-6	7-9	7-2	6-8	6-4
	3 – 2 x 10	13-0	11-3	10-0	9-2	8-6	7-11	7-6
	3 – 2 x 12	15-3	13-3	11-10	10-9	10-0	9-4	8-10
Douglas fir-larch[e], hem-fir[e], spruce-pine-fir[e], redwood, western cedars, ponderosa pine[f], red pine[f]	3 x 6 or 2 – 2 x 6	5-5	4-8	4-2	3-10	3-6	3-1	2-9
	3 x 8 or 2 – 2 x 8	6-10	5-11	5-4	4-10	4-6	4-1	3-8
	3 x 10 or 2 – 2 x 10	8-4	7-3	6-6	5-11	5-6	5-1	4-8
	3 x 12 or 2 – 2 x 12	9-8	8-5	7-6	6-10	6-4	5-11	5-7
	4 x 6	6-5	5-6	4-11	4-6	4-2	3-11	3-8
	4 x 8	8-5	7-3	6-6	5-11	5-6	5-2	4-10
	4 x 10	9-11	8-7	7-8	7-0	6-6	6-1	5-8
	4 x 12	11-5	9-11	8-10	8-1	7-6	7-0	6-7
	3 – 2 x 6	7-4	6-8	6-0	5-6	5-1	4-9	4-6
	3 – 2 x 8	9-8	8-6	7-7	6-11	6-5	6-0	5-8
	3 – 2 x 10	12-0	10-5	9-4	8-6	7-10	7-4	6-11
	3 – 2 x 12	13-11	12-1	10-9	9-10	9-1	8-6	8-1

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa, 1 pound = 0.454 kg.

a. Ground snow load, live load = 40 psf, dead load = 10 psf. L/Δ = 360 at main span, L/Δ = 180 at cantilever with a 220-pound point load applied at the end.
b. Beams supporting deck joists from one side only.
c. No. 2 grade, wet service factor.
d. Beam depth shall be greater than or equal to depth of joists with a flush beam condition.
e. Includes incising factor.
f. Northern species, incising factor not included.

SOURCE: INTERNATIONAL CODE COUNCIL

Figure 2. Footing locations are determined by the size of the deck beam and its permitted span. As shown above, the maximum span for a double 2x8 beam supporting 14-foot joists is 5 feet 9 inches.

Beam Span	Joist Span	Round Footing Diameter	Square Footing (X" by X")	Footing Thickness
6'	≤ 10'	18"	16"	7"
6'	≤ 14'	21"	18"	8"
6'	≤ 18'	24"	21"	10"
8'	≤ 10'	20"	18"	8"
8'	≤ 14'	24"	21"	10"
8'	≤ 18'	27"	24"	11"
10'	≤ 10'	23"	20"	9"
10'	≤ 14'	27"	24"	11"
10'	≤ 18'	31"	27"	13"
12'	≤ 10'	25"	22"	10"
12'	≤ 14'	30"	26"	13"
12'	≤ 18'	34"	30"	15"
14'	≤ 10'	27"	24"	11"
14'	≤ 14'	32"	29"	14"
14'	≤ 18'	37"	33"	16"
16'	≤ 10'	29"	26"	12"
16'	≤ 14'	35"	31"	15"
16'	≤ 18'	40"	35"	18"
18'	≤ 10'	31"	27"	13"
18'	≤ 14'	37"	33"	16"
18'	≤ 18'	42"	37"	19"

Figure 3. Footings can be sized based on beam and joist spans, rather than on deck loads. According to the DCA6 (which this chart is based on), the 16x20 deck shown in Figure 4 would require 24-inch-diameter, 10-inch-thick footings.
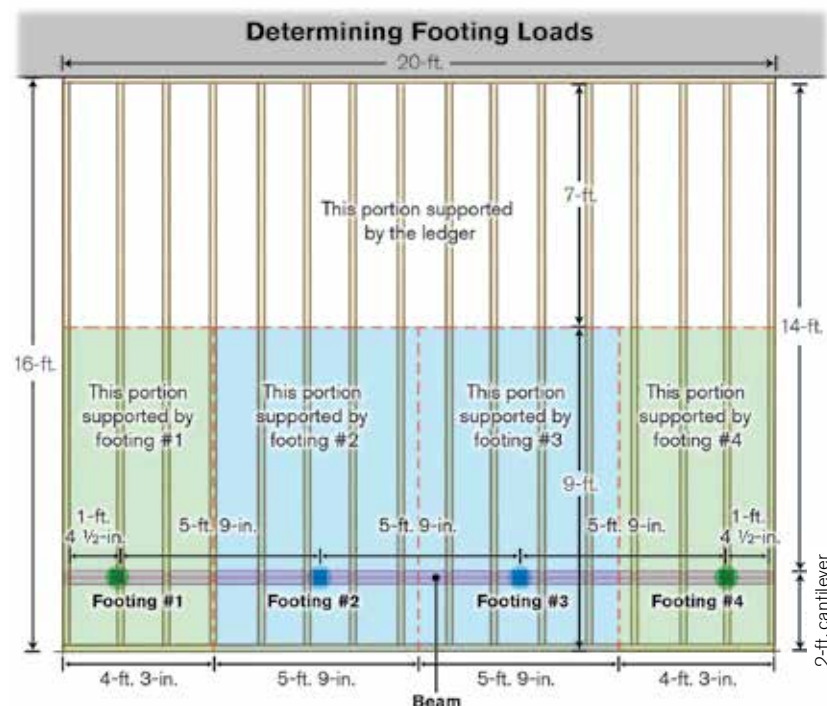

Figure 4. To size footings based on actual deck loads, first determine the tributary area that each footing will have to support, as shown above. Then multiply each tributary area by the anticipated deck load (typically 50 psf).

I've tried all three approaches at different times in my career, but for the last dozen years I've calculated the size of each footing during the deck design process. The calculations take only a few minutes and they assure that I'm following best building practice without going overboard. If the soil is dense, with a higher bearing capacity than 1,500 psf, for example, I've found that I can greatly reduce the footing size—and save quite a bit of concrete—by determining the tributary load on each footing and assessing the soil's bearing capacity.

Tributary load. All versions of the International Residential Code (IRC) from 2000 through 2015 call for decks to be designed for a 40-psf live load (which accounts for the owners, their guests, and their furniture and other portable stuff) and a 10-psf dead load (to account for the weight of the deck itself); add the two together for a total load of 50 psf. The weight of snow also comes into play in areas where the snow load is greater than 40 psf; if you're in one of those areas, substitute the snow load for the live load to determine the total load. There's no need to add live and snow loads together, since it's assumed that the owner will shovel off the snow before using the deck. You should also check the live load requirements of your local jurisdiction, which may substitute a greater live load for the 40-psf figure. If a hot tub is planned, total loads can be closer to 100 psf (see "Getting Started With Hot Tubs," Jan/Feb 2014).

At 50 psf, the total load on a deck measuring 16 feet deep and 20 feet wide would be 320 sq. ft. x 50 psf, or 16,000 lb. A tributary portion of that load is distributed to the beam (and then to the footings), and a tributary portion to the ledger board, as shown in the drawing (**Figure 4**). In this example, there are two different-sized tributary deck load sections:

END SECTIONS
9 ft. x 4 ft. 3 in. = 38.25 sq. ft.
MIDDLE SECTIONS
9 ft. x 5 ft. 9 in. = 51.75 sq. ft.

Figure 5. A penetrometer has a spring-loaded piston that retracts into the tool when it's pushed down; when released, the tool relaxes to full extension leaving a friction indicator ring at the maximum level of compression. Here, the scale reads 2.25 tons, indicating a soil bearing capacity of 2.25 tons—or 4,500 pounds—per square foot. Because it's difficult to take measurements at the bottom of footings deeper than arm's length, the author tapes the penetrometer body to a stick and uses a mirror mounted to another stick to view the penetration scribe mark.

What About the Weight of the Footing?

The dead load figure (10 pounds per square foot) in the IRC covers the weight of framing, decking, and railings, but generally doesn't include the weight of the footings. But should it? Some argue that this weight can be ignored, since the soil removed from the hole is close to the mass of the concrete filling the hole. Others argue that the full weight of each footing should be included in sizing calculations. A third argument is that the net difference between the mass of the concrete and the mass of the soil removed should be added to the tributary load on each footing.

I actually weighed the silty gravel subsoil from a couple of footings and found that it weighed about 110 pounds per cubic foot. Cured concrete weighs about 150 lb./cu. ft. Adding the full weight of a 12-inch-diameter footing tube that has an overall height of 4 feet—which holds about 3 cubic feet of concrete and has a total mass of 450 pounds—to a tributary deck load of 1,912.5 pounds yields a total load of 2,362.5 pounds. Meanwhile, the net difference between the soil and the concrete is 40 lb./cu. ft., so the net difference between the concrete footing mass and mass of soil removed from the hole is 120 pounds. Add the net difference to the tributary load for a total of 2,032.5 pounds (1,912.5 + 120). (Note: The 12-inch-diameter footing is a guess at this point. The actual base of the footing may need to be greater or may be smaller.) In practice, since the actual weight of the framing and decking materials often don't add up to 10 psf, there's probably enough prescriptive dead load capacity left to handle the difference in the weight of the concrete and the excavated soil for many decks. —*M.G.*

To find the total load bearing on each footing, multiply the area of each section by the total load per square foot (50 pounds).

END FOOTINGS:
38.25 sq. ft. x 50 psf = 1,912.5 lb.
MIDDLE FOOTINGS:
51.75 sq. ft. x 50 psf = 2,587.5 lb.

Soil Bearing Capacity

You can guess at your soil's ability to resist those loads—or bearing capacity—by comparing it to the five soil types listed in Table R401.4.1 of the 2012 IRC. They range from 12,000 psf (crystalline bedrock) down to 1,500 psf (for soils composed of a mix of clay, sand, or silt). If you aren't comfortable grading your soil this way, you can check with the local building department, which may have soil maps that can be used to guide the soil-bearing-capacity determination.

I actually measure soil density using a simple penetrometer, which is much more accurate than basing the soil's bearing capacity on its type (**Figure 5**). Often I find that the soil is stronger than the soil type would indicate, and that footing sizes can be reduced significantly. More importantly, I've found in some cases that the soil's bearing capacity was less than what would be expected based on local soil maps or soil types.

There are a variety of penetrometers on the market, from simple pocket versions (like the one I use) that cost as little as $60 to engineering-grade models—called cone penetrometers—with digital readouts, which can cost more than $1,500. To take a reading I dig a footing hole down to virgin soil below frost level, carefully removing loose soil from the bottom of the hole. Without tamping or otherwise disturbing the soil, I press the penetrometer into the earth in five to 10 spots, trying to avoid stones. I record each reading, reject the anomalous ones, and average the similar ones together. Because the scale on the model I have reads in tons, a quick conversion to pounds is needed.

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Always check with your local building official before using a penetrometer. He may or may not take your word for the readings you take. I've been lucky that most of the officials in communities where I work know my work and trust my readings.

Size the Footings

To find the necessary area of a footing, I divide its tributary load by the soil's bearing capacity. For convenience, let's assume a bearing capacity of 1,500 psf. And while it's probably not necessary, for this example I'll add in the net mass of the concrete to the total tributary load for each footing (see "What About the Weight of the Footing?," page 28). To make it easier to translate the result into a square or round footing, I usually convert it from square feet into square inches.

Footing area. The formula I use to calculate footing area is (tributary load + net concrete) ÷ soil bearing capacity. Here, I'll use 1,500 psf for the soil bearing capacity.

END-FOOTING AREA

(1,912.5 lb. + 120 lb.) ÷ 1,500 psf = 1.355 sq. ft. or 195.12 sq. in.

MIDDLE-FOOTING AREA

(2,587.5 lb. + 120 lb.) ÷ 1,500 psf = 1.805 sq. ft. or 259.92 sq. in.

Round footings. To find the diameter of round footings, I take the area I calculated above and plug it into the formula $2 \sqrt{(area \div \pi)}$, where $\pi = 3.14159$.

END-FOOTING DIAMETER

$2 \sqrt{(195.12 \text{ in.} \div \pi)} = 15\frac{3}{4}$ in.

MIDDLE-FOOTING DIAMETER

$2 \sqrt{(259.92 \text{ in.} \div \pi)} = 18\frac{3}{16}$ in.

Square footings. For square footings, I need to calculate the length of the sides rather than a diameter, so I simply find the square root of the area I found above.

END-FOOTING SIDE LENGTHS

$\sqrt{(195.12 \text{ in.})} = 14$ in. by 14 in.

MIDDLE-FOOTING SIDE LENGTHS

$\sqrt{(259.92 \text{ in.})} = 16\frac{1}{8}$ in. by $16\frac{1}{8}$ in.

Figure 6. Footings that are sized based on actual deck loads and soil conditions are usually smaller in diameter than when they're sized using prescriptive methods. This makes digging holes for them much easier, especially when frost depths are more than 3 feet below grade.

Even though my calculations are based on a minimal bearing capacity of 1,500 psf, these footing sizes are still considerably smaller than if I had used Table 4 in DCA6 (**Figure 6**). To start with, the closest table listing for a 16-foot-deep deck with 5-foot-9-inch beam spans is an 18-foot-deep deck with 6-foot beam spans. According to Table 4, round footings for this deck would need to be 24 inches in diameter and 10 inches thick for the middle footings, and $21\frac{5}{8}$ inches in diameter for the end footings (Footnote 2 permits a 0.9 reduction for end and corner footings: 24 in. x 0.9 = $21\frac{5}{8}$ in.).

In part two of this article, I'll dig deep into the actual footing installation. Look for it in an upcoming issue of *PDB*.

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