Designing Pier Footings

How to excavate, lay out, and pour concrete pier foundations

by Robert Hatch

I've built lots of masonry pier foundations. I used to either stack cinder blocks or pour concrete into site-made wooden forms. Then, a few decades ago, the job got a lot easier with the invention of the Sonotube pier form, which is now an industry standard. In this article, I'll give some basic tips for working with tubes, along with some unusual ways of using them that I've learned over the years.

Some Rules of Thumb

Before laying out a run of piers, I determine the required diameter, the size and depth of the footing, and the spacing between the piers. After fixing several sagging decks, I've developed a few rules of thumb, based on an old piece of Yankee logic – when in doubt, bigger is better.

Pier diameter. My rule of thumb for pier diameter is "1 inch per foot of span." Thus, a deck that spans 8 feet will stand comfortably on 8-inch-diameter piers, while a deck that spans 10 feet requires 10-inch-diameter piers. For spans longer than 12 feet, I always add a second row of piers and a second girder at the center of the joist span. (I use No. 2 or No. 3 grade pressure-treated lumber, so I don't trust it for spans longer than 12 feet.) Reducing the span also cuts material costs by letting me use 2x8 joists rather than 2x12s.

Footings. A lot of builders install piers without footings. But I've found that footings help keep the structure from settling; to leave them out risks having a railing or rim joist that looks like a roller coaster. Generally speaking,

WORKING IN WINTER

Setting Sonotubes in midwinter is difficult at best. When the frost is set hard in the ground, it's tempting to load the truck with a pickax, a crowbar, a flamethrower, and some dynamite. Luckily, there's an easier way.

We remove any snow from the excavation area, and put an empty gallon-sized metal paint can everywhere there will be a pier. We start a good kindling fire in each can, and keep these fires going throughout the day. Every couple of hours we lift the cans, scrape away any willing soil from the excavation, and reset the cans into the holes. We use the excavated dirt to build a berm around the cans, which helps hold in the heat.

This goes slow at first – it can take five or six hours to get the cans set to their rims, but after that, the process gets easier. Before we leave for the day, we put a good bed of coals and a perforated lid on each can. We also place a rock or a brick on top of each one; the heat tends to draw water out of the frost, so unweighted cans are apt to float up in the hole. We keep the rim of the can above grade so that any melted snow or ice will drain away rather than submerging the can and putting out the coals.

We can drive 3 feet of frost out of the ground overnight with this method. A paint can will typically melt a 12-inch-diameter cylinder of soil, which is easily dug out by hand. And though we can't get a box footing into the frozen ground, we take a spade and "bell" the bottom of the hole to act as a footing. Even stony hardpan is easier to dig after using this method. – *R.H.*

a pier footing should be as thick as the pier's diameter, with sides that measure twice that much. So an 8-inch pier should rest on a footing that's 8 inches thick and 16 inches square, while a 12-inch pier should rest on a footing that's 12 inches thick and 24 inches square.

The key factor in determining how deep to place the footing is the local frostline. Here in the White Mountains of New Hampshire, we typically set the top of the footing 4 feet deep. For critical applications, however, we go down to 8 feet. These include structures that will support a lot of weight, and piers that are close to a plowed driveway (where the lack of an insulating blanket of snow means a deeper frostline).

To ensure that you're on undisturbed soil, it's also wise to go deep when setting piers near an existing building. The backfill of an existing building might just contain a 6x6 wood scrap that's below your footing depth. When the 6x6 later decomposes, the resulting void will collapse under the weight of the tube.

Spacing. How closely we space our piers depends on the load they will carry, and the number and size of the girders. On a simple deck with a built-up triple-2x8 girder, an 8-foot spacing is fine. This spacing also works for most single-story additions. If the piers will have to support a two-story addition or a cantilevered deck with a hot tub, the spacing will have to be closer. When in doubt, it's best to call an engineer.

Digging the Holes

I hear that power augers can make quick work of soft soil. However, I know too many guys who hit a rock with a power auger and then went flying across the yard. We avoid power augers, opting instead for either a backhoe or a pick and shovel, depending on the number of tubes and the access to the work site. We dig by hand when there are only a few tubes to set, or at well-landscaped homes, where we don't want a backhoe tearing up the yard. When working on existing homes, we spread the excavated dirt over the inside perimeter of the deck. We also set aside all the sod and some of the topsoil so that we can use it to dress up the perimeter when we're done. This is more work than just digging holes, but it makes for a cleaner job and puts a feather in our cap with the owners.

Regardless of the digging method, the footings should rest on good, undisturbed soil. Every good foundation specification requires the soil under foundation footings to be compacted, and pier footings are no different. You can't get a compactor down into the hole, but

FIGURING CONCRETE FOR TUBES

You can quickly figure the amount of concrete needed to fill a tube by multiplying the following factors by the height of the tube in feet:

- 8-inch pier: .013 cu. yd. (0.6 80-pound bags of concrete mix per lin. ft.)
- 10-inch pier: .02 cu. yd. (0.9 bags per lin. ft.)
- 12-inch pier: .029 cu. yd. (1.3 bags per lin. ft.)

For rectangular footings, use these amounts per footing:

- 8x16x16-inch footing: .044 cu. yd. (2 bags each)
- 10x20x20-inch footing: .086 cu. yd. (3.8 bags each)
- 12x24x24-inch footing: .15 cu. yd. (6.75 bags each)

As an example, say you have four tubes that are 8 inches in diameter and 4 feet deep. With a total lineal footage of 16 feet, the tubes will require 9.6 bags of concrete mix (0.6 bags per foot). The four 8x16x16 footings will require a total of 8 bags (2 bags per footing). So you'll need 18 bags to complete the job. – *R.H.*

Figure 1. Saturating the pier hole with a garden hose helps compact the soil at the base to keep it from settling later.

Figure 2. The author makes pier footing forms from scrap lumber and plywood, and lowers them into the hole with a hoe.

running a garden hose into it for three or four minutes will help the earth settle (**Figure 1**).

Setting the Forms

We make square footing forms from scrap one-bys and cap them with a plywood lid (**Figure 2**). The lid has a hole cut into it that's 1/2 inch smaller in diameter than the tube. We lower this form into the hole with a hoe, then plumb up to the dry line to center it. We don't add rebar to the footings unless it's specified by an architect.

The most accurate way to align a row of tubes is to stretch a line across where their outside edges will be, rather than across their centers (**see photo on page 1**). This is also easier than centering the string — you just set the tubes against the string, rather than having to measure from their centers. On level lots, we set the line a couple of inches above grade, then cut the tubes off just below the line. This is just a personal preference, as I don't like to see a lot of concrete sticking out of the ground. (On a slope, where the grade falls away from the line, we place a level against the outside of each form and level up to the reference line.)

If the piers must protrude above grade to directly support a rim joist, we install the tubes high, then cut them all at once. There are two easy ways to do this. One is to use a story pole and a transit to mark the elevation on each tube; the other is to level out from the house to the two end tubes, then snap a chalk line from these two points across the remaining tubes. There is no need to cut the tubes at exactly this elevation. Once they're marked, we cut off the tubes a little high, poke a nail through the side at the reference mark, then pour concrete to the nail.

We tie our reference lines to stakes or batter boards driven outside the perimeter of the layout. We temporarily remove these lines while digging, and reset them after the holes have been roughed in. We then carefully backfill around the footing form by hand, and tamp it to keep it in place. One person then centers the tube on the hole in the form's lid while another backfills with a shovel.

SIZING THE FOOTING

Deck footings can be called upon to support thousands of pounds each, even without considering the hot tub that may one day be added. The International Residential Code has specific requirements for pier footings, which most decks rest on. The size of a footing depends on two conditions: load and soil bearing capacity.

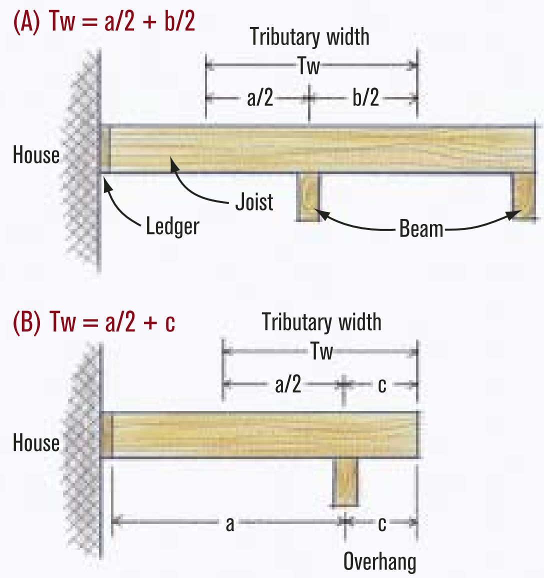
Calculating Load

Load is calculated by multiplying the tributary area on each footing by the deck's design load.

The tributary area is the section of the deck that bears on the footing. To calculate area, you need to find length and width. So, first identify the beam that's supported by the footing. Then measure halfway to the next beam on each side, and add the two distances together **(A)**. If there's no intermediate beam, measure halfway to the ledger on the house. And if there's a cantilever to one side of the footing, add in its length **(B)**. Call the resulting figure the width.

Calculating the length is similar to finding the width, only this measurement is made perpendicular to the first. Measure halfway to the nearest pier on one side of the footing and halfway to the pier on the other side, and add these two distances together **(C)**. Then, multiply this number (length) by the width to get the tributary area.

Multiply the tributary area by the deck's design load to find the load the footing must be able to support. A common design load is 50 pounds per square foot (40 psf live load plus 10 psf dead load), although some jurisdictions require 70 psf (60 psf live load with 10 psf dead load). Snow loading can be even higher, so be sure to check locally.

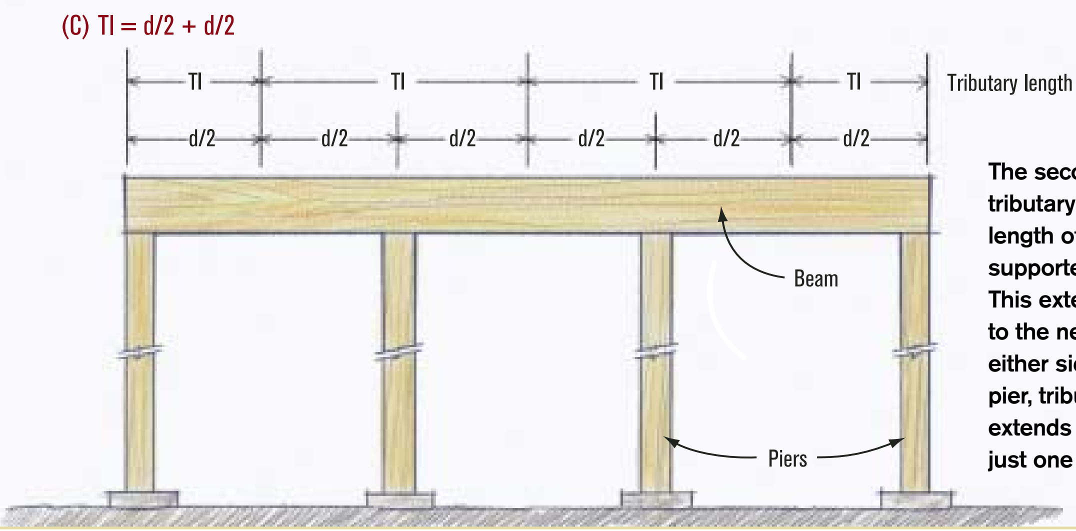


The first factor in calculating the tributary area is the length of joist that bears on the beam that's in turn supported by the pier. Tributary width extends halfway to the next beam or ledger, plus any cantilever.

Establishing Soil Bearing Capacity

The next factor you must consider is soil bearing strength. The following is excerpted from *JLC Field Guide, Volume 1* (www.jlconline.com):

It's hard to identify soils precisely in the field. A preliminary soil investigation may give enough information to go on, but sometimes an engineering soil report will be required. Some rough



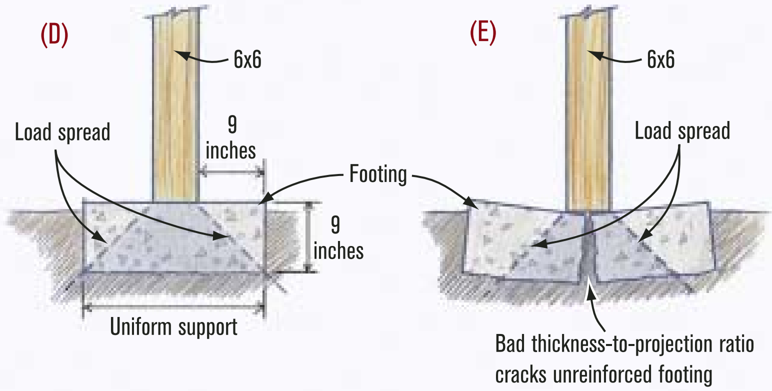
The second factor in tributary area is the length of beam that's supported by the pier. This extends halfway to the next pier on either side. On an end pier, tributary length extends halfway to just one pier.

SIZING THE FOOTING

information about soils can be learned from simple on-site tests:

- *Dirt-ball test: To assess soil cohesiveness, squeeze a moist double handful of soil into a ball, then drop it from a height of about 1 foot. If the soil will not form a ball or if the ball readily fragments when dropped, the soil is relatively non-cohesive and granular, with a low proportion of fine clay. However, if the soil forms a ball that holds together when dropped, it likely contains a high percentage of cohesive clay.*
- *Water suspension test: Drop a scoop of soil into a large jar of water. Gravel and sand will settle to the bottom of the jar almost immediately. Finer silt particles will take fifteen minutes to an hour to settle. Clay particles will remain suspended in water for a day or longer. So, if the water remains very cloudy for a long time, the soil probably contains a high percentage of clay.*
- *Noodle test: Roll a small quantity of soil into a thin noodle or string shape between your palms. If the soil can be rolled as thin as 1 in. without breaking apart, it is probably a cohesive soil with a substantial percentage of clay.*

A Footing Can Be Too Wide



Loads spread through a footing at 45 degrees. If unreinforced footings project farther than their thickness beyond the sides of the pier they support, they will be subject to cracking due to shear loading.

Soil Bearing Capacities

Material	Loadbearing Value (pounds per sq. ft.)
Crystalline bedrock	12,000 psf
Sedimentary rock	4,000 psf
Sandy gravel or gravel	3,000 psf
Sand, silty sand, clayey sand, silty gravel, and clayey gravel	2,000 psf
Clay, sandy clay, silty clay, and clayey silt	1,500 psf

Loadbearing values indicate the amount of force that undisturbed, native soils can support.

2000 INTERNATIONAL RESIDENTIAL CODE

Putting Them Together

As an example, consider a deck that spans 14 feet from the ledger to the main beam, with a 2-foot cantilever beyond. Half of 14 feet is 7 feet, to which is added the 2-foot cantilever: 7 feet + 2 feet = 9 feet. Assume the piers are spaced 10 feet apart. The tributary area on the corner piers would be only 5 feet x 9 feet, or 45 square feet. On center piers, it's 10 feet x 9 feet, or 90 square feet. Let's figure a center pier's design loading: 90 square feet x 50 psf load = 4,500 pounds.

On clay soils, the footing for that pier would have to be at least 3 square feet (4,500 pounds/1,500 psf). If the footing is square, that's 21 inches across. If round, the diameter's about 2 feet.

The IRC specifies that spread footings must be at least 6 inches thick and project at least 2 inches beyond the loaded surface. In addition, the projection must not exceed the thickness. So, if the pier is a 12-inch concrete column and the footing is 24 inches in diameter and 6 inches thick, you've met code. The footing projects 6 inches around the pier, exceeding the minimum 2-inch projection, and just meeting the maximum projection-to-thickness ratio.

You could also land a wooden column directly on a concrete footing. Let's use a nominal 6x6. It measures 5 1/2 inches square, so the footing would project 9 1/4 inches beyond the 6x6. The projection exceeds the minimum 6-inch footing thickness, so to satisfy the IRC, this footing would have to be at least 9 1/4 inches thick. The reason is loads spread through a footing at 45 degrees in a cone shape **(D)**. Concrete supported by the soil outside of this cone imposes a shear load on the footing, and such an unreinforced footing is likely to crack down the middle **(E)**. – *Andy Engel*

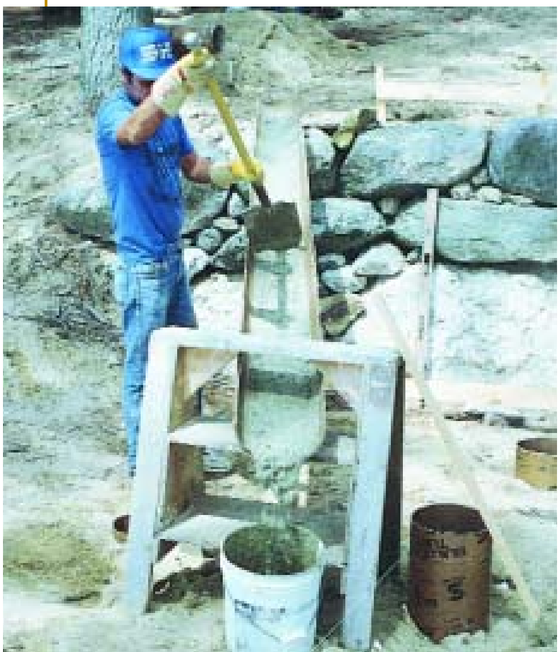


Figure 3. When mixing concrete by hand, a tube ripped in half with a circular saw makes a convenient chute (left).

Figure 4. Rebar goes in when the tube is partially full of concrete (right). The bend at the end of the rebar ties the pier to the footing.

Figure 5. Tamping throughout the pour gets rid of voids in the pier. The nail in the side of the tube marks the finish concrete elevation.

Pouring the Concrete

Redi-mix isn't cost-effective for small jobs, so when setting fewer than a dozen piers, we mix the concrete by hand. If we have to haul the concrete any distance from the mixer to the forms, we use a wheelbarrow, then shovel the concrete into the tubes. On steep grades, we make a handy cement chute by using a circular saw to slice a tube lengthwise into a pair of half-cylinders (**Figure 3**).

To eliminate voids and make sure the concrete fills the entire footing, we place the concrete slowly and tamp it vigorously with a stick or a paddle as we go. When the tube is half-full of concrete, we insert a length or two of rebar into the center, making sure the bend in the rebar extends well into the footing (**Figure 4**). We then continue pouring and tamping until the concrete reaches the reference nail we use to mark the finished elevation (**Figure 5**). Before the concrete sets up, we install whatever strap ties, anchor bolts, or stirrups the job requires. A dry line stretched across the row of tubes makes a good centering reference for the anchors. ❖

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