A BUILDER'S GUIDE TO

FOOTINGS & SMALL SLAB FOUNDATIONS

As a professional builder and remodeler, it's not uncommon to be tasked with small foundation work. Whether you've been asked by a client to build a new shed, a new deck, or a new landing for a set of exterior stairs, it's important to get the details right. In the pages that follow, we've curated content that outlines all of the critical steps in forming and pouring footings and small slabs.

While the construction approach to these projects is largely universal, the building code is not. Frost depths vary from region to region, and are the critical element that influences the longevity of footings and slabs. Check with your local building inspector to determine the required depths of your footings, and see the "How It Works" piece on page 2 to gain crucial insights into how frost heaving can impact your work. Finally, always check with your building inspector prior to using any products or methods outlined here. It is that person who has final approval over your plans. While we outline the process of installing footings with spread bases, for example, your building inspector might not be familiar with the practice. Have these important conversations well before you put a shovel in the ground. Lastly, always call 8-1-1 to locate underground utilities before digging footing holes or excavating for slabs. A successful job is a safe job.

howitworks
THE MECHANICS OF HOME BUILDING

BY DEBRA JUDGE SILBER

Frost Heave

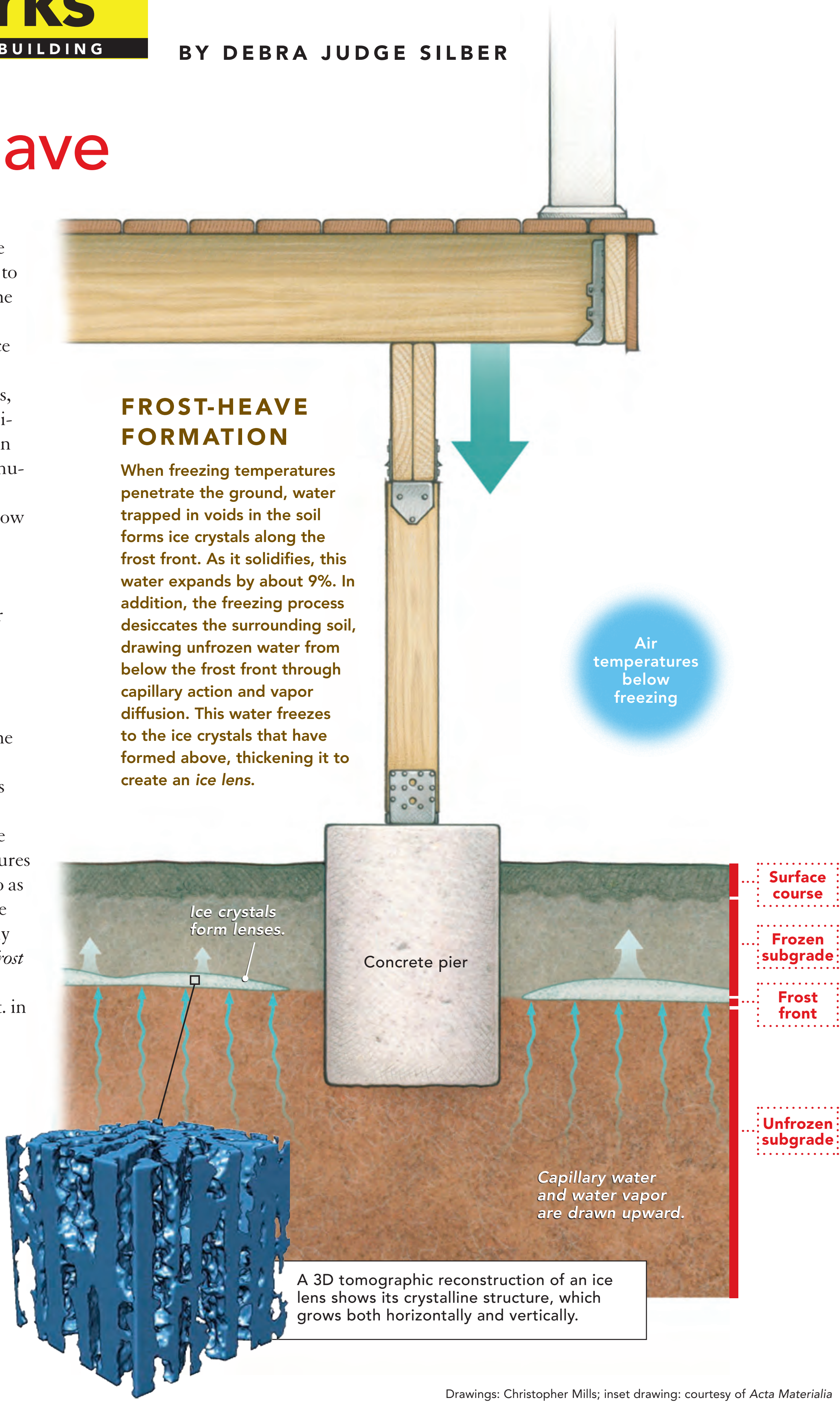
Frost heave occurs when freezing temperatures penetrate the ground, causing subsurface water to form ice structures that displace the soil along with anything that rests on or in that soil. While it was once thought that frost heave happens because water expands as it freezes, the process is actually more complicated, involving not only expansion due to freezing, but also the accumulation of additional layers of ice as liquid water is drawn up from below the frost line.

Frost-susceptible soil—fine-grained, moist soil in certain climates—is the first prerequisite for frost heave. Engineers define this type of soil as either that in which more than 3% of the grains (by weight) are 0.02 mm in dia. or smaller, or that in which 10% of the grains are 0.075 mm or smaller.

Water is another requirement, as are subfreezing temperatures that penetrate beneath the surface. The depth to which freezing temperatures penetrate the ground is referred to as the *freezing plane* or *frost front*. The depth to which they can potentially extend in any given region is the *frost line*. Frost lines range from a few inches in Florida to more than 6 ft. in the northern United States.

If not controlled, frost heave can seriously damage buildings and other structures in cold climates. Mitigation typically involves removal of one of the three elements (frost-susceptible soil, freezing temperatures, or water) required for frost heave to occur. Here's how it works.

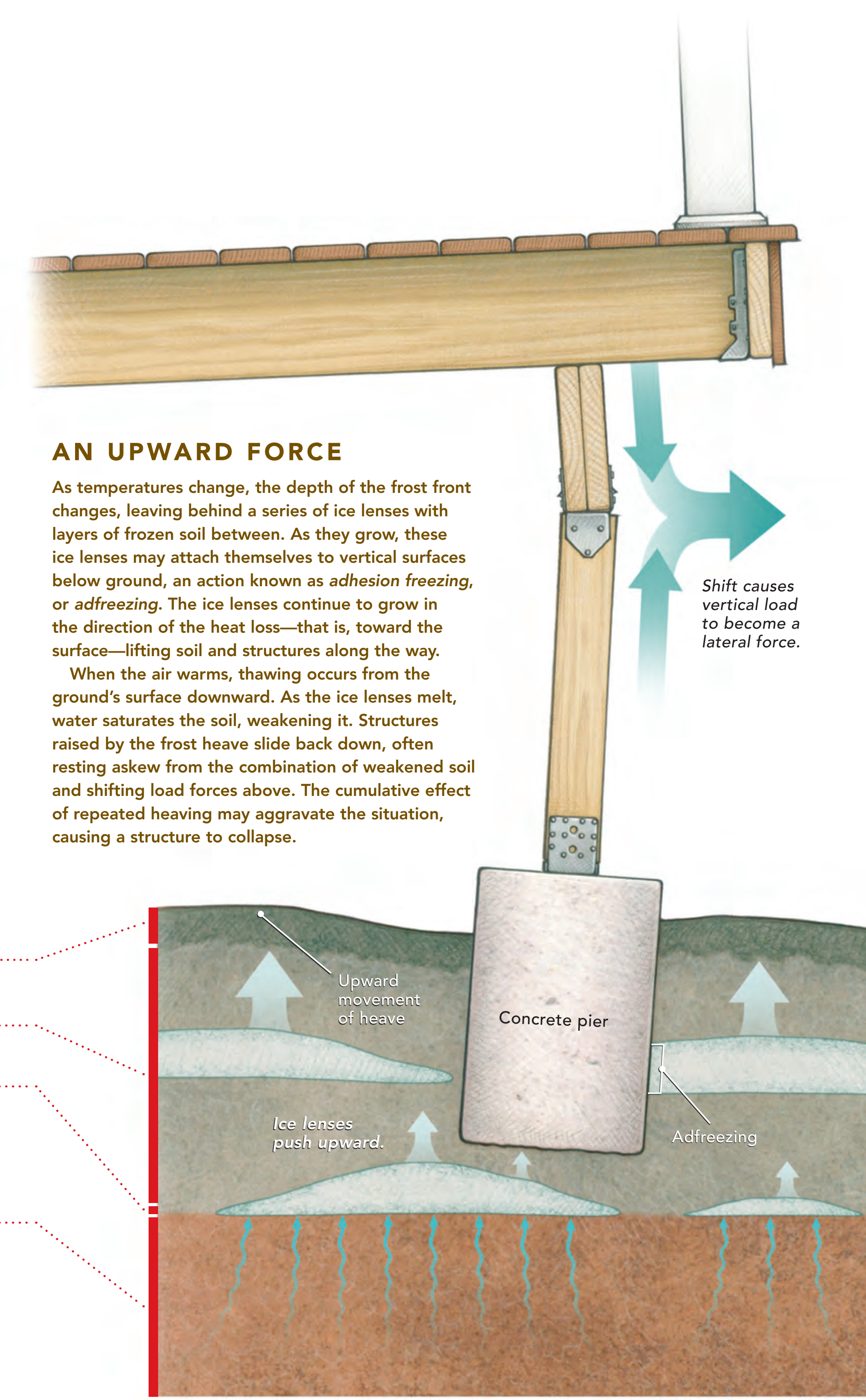
Debra Judge Silber is a former editor.



FROST-HEAVE FORMATION

When freezing temperatures penetrate the ground, water trapped in voids in the soil forms ice crystals along the frost front. As it solidifies, this water expands by about 9%. In addition, the freezing process desiccates the surrounding soil, drawing unfrozen water from below the frost front through capillary action and vapor diffusion. This water freezes to the ice crystals that have formed above, thickening it to create an *ice lens*.

A 3D tomographic reconstruction of an ice lens shows its crystalline structure, which grows both horizontally and vertically.



AN UPWARD FORCE

As temperatures change, the depth of the frost front changes, leaving behind a series of ice lenses with layers of frozen soil between. As they grow, these ice lenses may attach themselves to vertical surfaces below ground, an action known as *adhesion freezing*, or *adfreezing*. The ice lenses continue to grow in the direction of the heat loss—that is, toward the surface—lifting soil and structures along the way.

When the air warms, thawing occurs from the ground's surface downward. As the ice lenses melt, water saturates the soil, weakening it. Structures raised by the frost heave slide back down, often resting askew from the combination of weakened soil and shifting load forces above. The cumulative effect of repeated heaving may aggravate the situation, causing a structure to collapse.

Drawings: Christopher Mills; inset drawing: courtesy of *Acta Materialia*

Controlling frost heave

FOOTINGS AND PIERS

Code mandates that support structures either extend below the local frost line or be protected by insulation so that the bearing soil is not subject to freezing and, thus, heaving. Frost heave also can be controlled by backfilling around piers with gravel to promote drainage, using a sleeve to prevent ice from gripping the concrete, or pouring footing bases that resist upward movement.

DRIVEWAYS, WALKWAYS, AND PATIOS

The occurrence of frost heave can be minimized by replacing fine-grain, frost-susceptible soil with coarse granular material that is not subject to heaving. Drainage measures can reduce the presence of moisture, which also prevents heaving. Providing a capillary break is another option; interrupting the capillary action that draws water toward the ice lenses can make frost heave less severe.

BASEMENTS

Frost heave can seriously damage a basement if the ground surrounding that basement freezes to the foundation walls. When this happens, heaving soil around the house can carry the walls with it. This situation does not occur with heated basements, however. That's because a heated basement (insulated or not) loses heat to the soil surrounding it. This outward heat loss pulls moisture away from the foundation walls. Because moisture is required for adfreezing, less moisture means the frozen soil has a less tenacious grip on the foundation.

Laying Out Deck Footings

A fast and accurate way to get the holes in the right spots

BY GREG DiBERNARDO

Installing deck footings is rigorous work. Even though I use a machine-driven auger instead of digging by hand, clearing rocks and mixing and placing concrete is still hard.

The vast majority of decks are rectangular and are supported by being bolted to the house on the inside and by a built-up beam on the outside. Most deck beams are "dropped," that is, set below so that the joists rest on the beam and cantilever beyond by a couple of feet. In some cases, the beam is "flush," or set at the same level as the joists, which attach to the beam with joist hangers. In either case, the beam location determines how far the footings will be from the house. The first step in footing layout is to establish the line of the deck beam parallel to the house. I do this with stakes and string, extending the line beyond where I know the ends of the deck will be. Then I locate and lay out one side of the deck so that it's square to the house, and I use that as a reference for spacing the footing locations.

Deck footings have to be placed just right so that the posts they support land in the center of each footing. Pay attention to the framing plans. They might not call out the location of the footings, but they will at least show the centerline of the beam and the spacing of the posts.

Greg DiBernardo owns Peachtree Decks and Porches in Alpharetta, Ga., and has been specializing in outdoor construction projects for over 10 years. Photos by Andy Engel.

STRING THE LAYOUT STRAIGHT

Any deck begins with a plan, whose theoretical outline has to be transferred to the ground in order to locate the footings and begin construction. String is the right tool for establishing the straight lines and square corners of a deck. Although any string will do, braided mason's line is strong, stretches less than other string, and comes in highly visible colors.

1 Determine where the footings will go. *Measure out from the foundation to where the centerline of the footings will be. Mark the ground with paint at each side of the future deck, a short distance beyond its ends.*

2 String the centerline. *Drive a stake at each end of the deck. Stretch a string tightly between the stakes, then double-check its distance from the foundation.*

3 Set a second string square to the first. *If there's a foundation corner or jog, the easy way to square up the footings is to drive a stake tight to the foundation, sight the string so that it's parallel to the adjoining wall, and set the outer stake.*

VERIFY SQUARE WITH PYTHAGORAS

While you often can start a square layout by eyeballing a string stretched along a foundation corner, foundation corners are not always square. Because of this, square should still be verified with a version of the Pythagorean theorem. Any triangle whose sides measure 3, 4, and 5 (or multiples of those numbers, such as 6, 8, and 10) has a square corner opposite the hypotenuse. With this knowledge, it's easy to verify that your string is square to the house using only a tape measure.

1 ***Mark the wall.*** *For accuracy, use a 6, 8, 10 triangle. Mark the wall at 8 ft. from the string.*

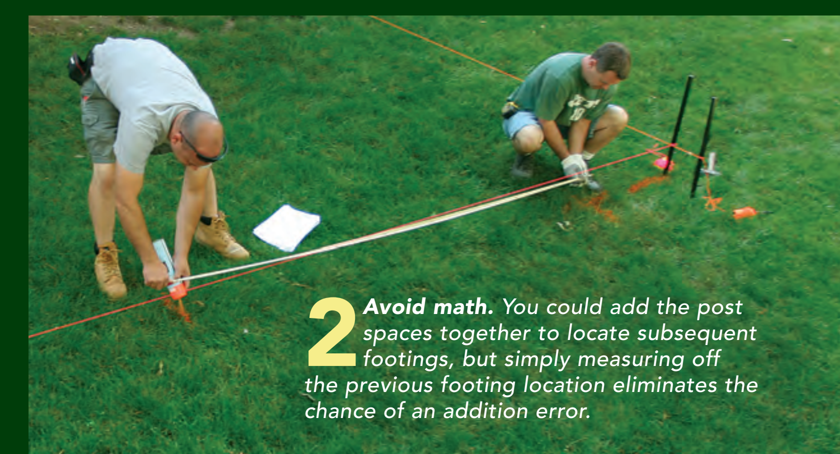
2 ***Mark the string.*** *Being careful not to stretch it, mark the string at 6 ft. from the wall.*

3 ***Verify a square corner.*** *Pull a tape from the 8-ft. mark on the foundation to the 6-ft. mark on the string. Verify a 10-ft. measurement on the tape or the stringline will need to be adjusted square.*

MARK THE FOOTING LOCATIONS

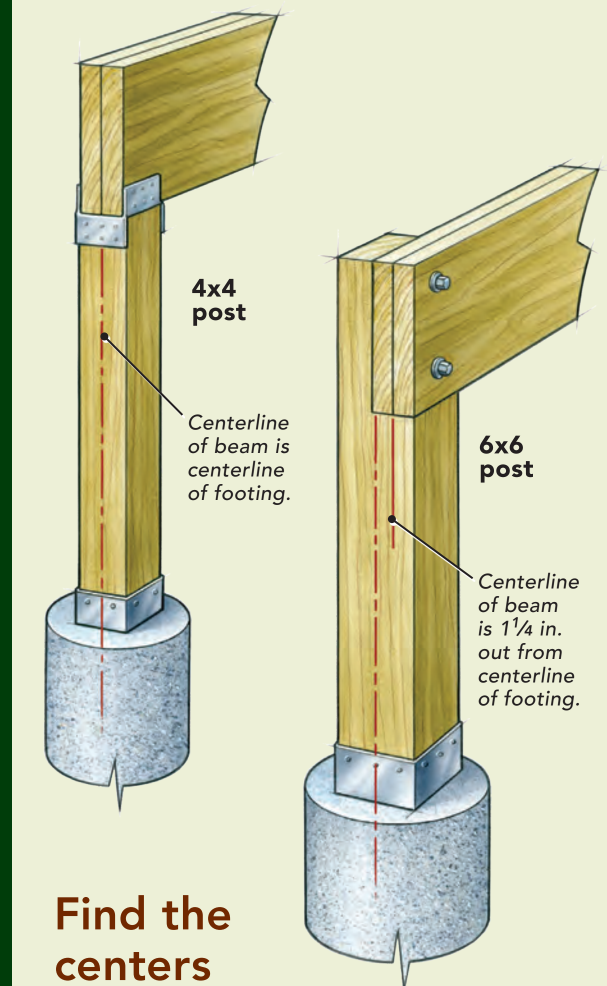
Once you've strung the line of the footings parallel to the house and measured their locations so the deck will end up square and the footings properly spaced, it's time to mark the ground. Upside-down spray paint in bright colors makes marks that won't get lost in the job-site shuffle.

1 ***X marks the spot.*** *Using the post spacing from the plans, measure from the perpendicular string and paint the center of the first footing location on the ground.*



2 ***Avoid math.*** *You could add the post spaces together to locate subsequent footings, but simply measuring off the previous footing location eliminates the chance of an addition error.*

3 ***Dig 'em out.*** *Whether you use a mechanical auger or dig by hand, an accurate layout will keep you from putting a hole in the wrong spot. (These mini-skid steers can be rented.)*



Find the centers of the footings

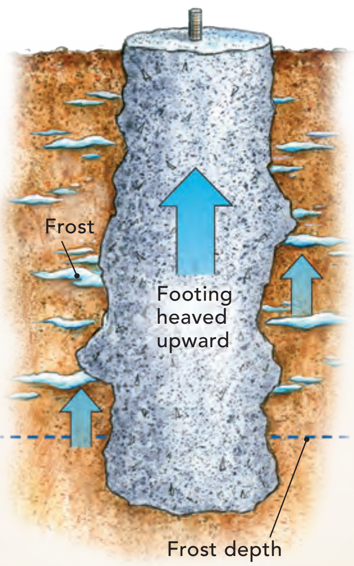
Deck posts should be centered on their footings. Depending on the post base used, the accuracy of the footing layout can be critical. Some post bases—Simpson's CBSQ, for example—require a minimum of 3 in. between the edges of the concrete and the sides of the base. If you're using a 6x6 post, that leaves very little wiggle room on a typical 12-in.-dia. footing. Other bases, such as Simpson's EPB44PHDG, require a minimum of 3 in. of concrete to the sides of the anchor bolt in the center of the base. That allows almost 6 in. of play in locating these bases on a 12-in. footing. If the deck beam is to be supported on a 4x4 post, you can use the planned distance from the center of the beam to the house as the center of the footings. However, a common detail is to support the beam on a notched 6x6 post. In that case, because the post is wider and will be offset from the beam, the footing is centered under the posts by being placed 1¼-in. back from the center of the beam.

Drawings: Don Mannes

Deck Footings Done Right

BY MIKE GUERTIN

They're no fun to dig, but that's no excuse for digging them wrong

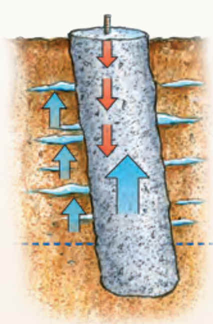


START WITH A GOOD HOLE

Building codes cover most of the basics about footing size, frost depth, and the bearing capacity of soil and concrete. Codes don't, however, tell how to dig a proper footing hole. A good hole is smooth, straight, and flat-bottomed; includes a footing form; and avoids the pitfalls below.

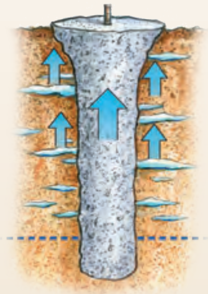
Side issues

No form: The smooth sides of a footing form minimize soil friction and act as a bond break, preventing heaving. If you don't use a form, concrete assumes the uneven shape of the soil. Frost can "grab" the rough sides and heave a footing even if the bottom is below the frost line.

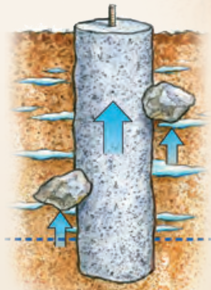


Slanted: The force on a slanted footing loads the side rather than the bottom of the footing, causing it to sink and rotate. Also, frost can heave up against the side.

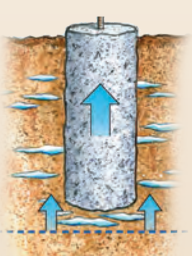
Inward taper/flared top: Footing forms prevent inverted-cone and mushroom shapes, the worst designs for footings. These shapes often have narrow bases that can sink under load, and frost pressing upward on the top can tilt the footing. Footing forms alleviate the problem even when the hole is dug overly wide at the top.



Debris: Rocks, roots, pipes, and other projections that impinge on the straight sides of footings can give purchase for frost to heave or tilt footings. They also leave defects in the footing that can lead to concrete fractures.

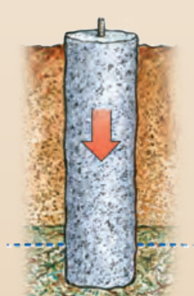


Bottom problems



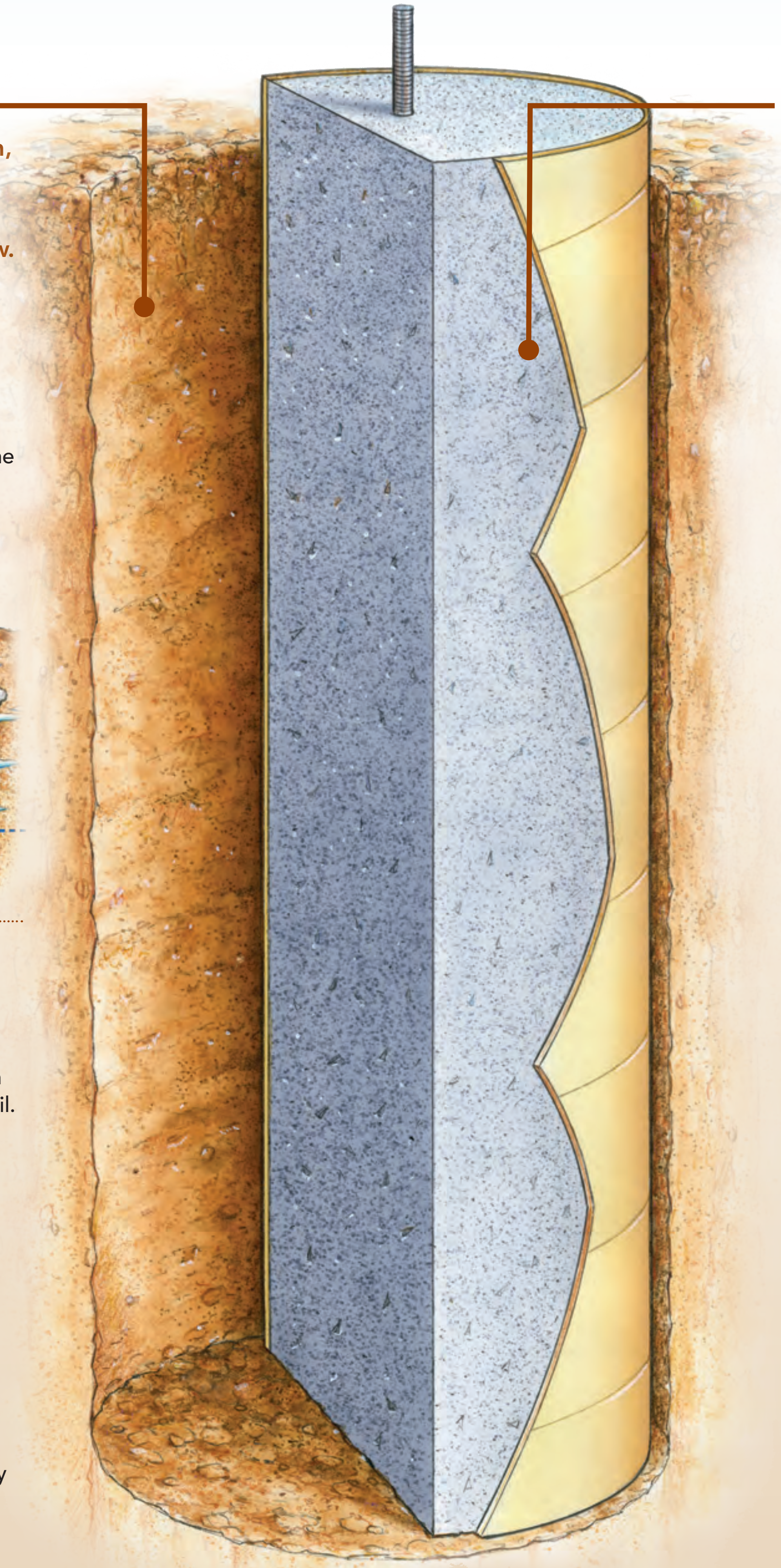
Too shallow: Decks connected to a house must be supported by footings that reach the frost line, the point below which the ground won't freeze. Otherwise, when moisture in the earth freezes and expands, it can push shallow footings upward. Frost depths vary, so check the local building department for your conditions.

Rounded/pointed base: Footings are designed with flat bottoms for a good reason. If you dig them with round or pointed bottoms, then add a load, they can act like arrowheads piercing the soil. Make the bottom of the footing hole the same size as the footing form or larger. The bottom also must be flat and close to level.



Unstable soil: Topsoil (loam) contains organic material (decayed plant matter and unclassified mineral matter) and a lot of air. Highly compressible and unstable, it can't reliably support a load. Footings must be dug through the topsoil, which can be several feet thick, even if that means going well past the frost line.

Disturbed base: Footings can't rest on earth that has been disturbed by digging, even if that excavation took place many years ago. This is especially problematic for footings dug near a foundation wall. Even the couple of inches of loose soil at the bottom of a freshly dug hole must be removed or compacted by tamping.



FINISH WITH GOOD CONCRETE

The minimum compressive strength of concrete used for footings should be 2,500 psi. Air pockets and other defects can reduce compressive strength, so the importance of properly mixing and placing concrete can't be overlooked.

Get the mix right

Too dry: A stiff, dry mix may not consolidate fully, so the footing could be left with air pockets and fracture lines that can lead the footing to crumble under load.

Too wet: Soupy concrete dilutes compressive strength. As the extra water dries away, tiny holes remain and weaken the concrete.

Just right: The concrete should be damp enough to hold together when squeezed into a ball and not crumble apart. It should keep a crown when shoveled and not spill off the edges.

Soil contamination: Soil can inadvertently fall into the concrete during placement, especially on footings poured directly into holes without forms. Soil contamination can weaken concrete and leave fracture lines. Use a footing form that's at least several inches above grade to avoid contamination.

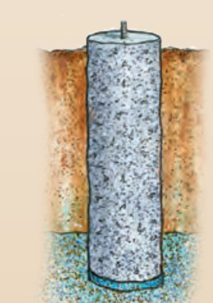
Avoid these setting mistakes

Footing top below grade: Footings poured so that the concrete is below grade invite surrounding dirt to fill over the top. This puts the post-base connector at risk of corrosion and the post itself at greater risk of decay. Pour the footing at least 4 in. higher than grade.

Uneven tops: It's hard to plumb and secure a post base properly on top of a footing with a sloped top. Make sure to screed and level off the top of the concrete before it cures.

Rocks in the mix: Avoid the temptation to toss stones into the concrete pour. Soil on the stones will prevent the concrete from bonding, and there's also a risk of creating air pockets and weak spots.

Air pockets/cold joints: This problem often occurs when using a stiff concrete mix, when a pour is interrupted and fresh concrete is placed on top of curing concrete, or when large aggregate doesn't consolidate into the mix. Don't pause for more than 15 minutes during each pour, and vibrate or rod the concrete to ensure that layers are intermixed.



Water infiltration: If you hit water as you dig the footing holes or leave rainwater in a footing hole before pouring, the concrete will be contaminated and weak. Water must be removed from the hole, or the concrete must be isolated from the water by using a plastic bag or waterproof footing form.

Drawings: Don Mannes; photos: Dan Thornton

BY SCOTT GRICE

Mixing concrete by the bag

Some people might assume that mixing concrete is an obvious task: Buy a bag of premix, dump it in a wheelbarrow with some water, and mix it up. Sounds simple, right?

As a fence and deck contractor, I have learned otherwise. I often have to mix five to ten bags in an afternoon, then have to push around wheelbarrow loads of wet concrete. This chore was a strong motivator for me to come up with an efficient, reliable mixing system.

The first step to smarter concrete-mixing is to use my truck's tailgate as a platform for emptying the concrete premix into the wheelbarrow. This setup limits the number of times I have to move the bags of concrete and keeps them at a comfortable working height. Second, I put the water in the wheelbarrow before the concrete. This step helps to keep down the dust and prevents dry pockets in the mix. Third, I use a stiff rake to mix the concrete. A rake mixes more efficiently and is easier to work with than a hoe or a shovel. Finally, to keep from straining the operator (me), I mix only one 90-lb. bag at a time. I don't think mixing two bags at once is any faster, and I know it tires me out sooner.

After I've finished, I pour any excess concrete into a compact lump to be removed once it hardens. Then I wash out the wheelbarrow so that it's ready to work another day.

Scott Grice is a fence and deck specialist in Portland, Ore. Photos by John Ross, except where noted.

STEP BY STEP

Combine water and concrete at the truck

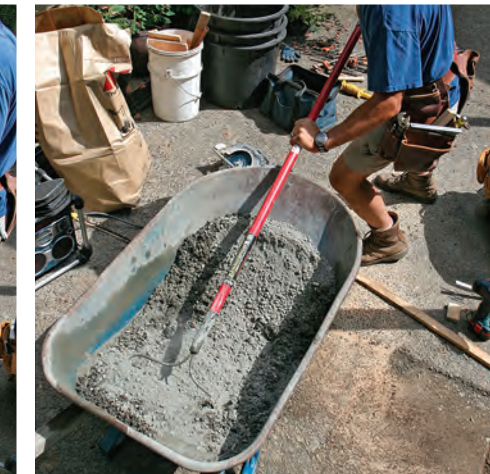
1 ***Put in the water first.*** *For this size of wheelbarrow (sidebar, pp. 11), add water to a depth of about 1 in. Too little water is better than too much because you always can add more later.*

Tip: Use a piece of dry wood as a depth gauge. The water level shows clearly.

2 ***Add the concrete.*** *Place the unopened bag in the water. Then use a utility knife to open the bag with a single cut along the end. Grab the bottom of the bag and tip it up so that the concrete slides out rather than pours out. This technique minimizes dust.*

3 ***Move the mix to where it's needed.*** *To maneuver through tight areas without hanging up the rake, put the working end of the rake in the wheelbarrow with the handle pointing ahead.*

Make a lagoon in the island of concrete



4 ***Stand in front to mix.*** *Pull the concrete to the front, and water will flow in behind it. Because I'm standing at the front of the wheelbarrow, I can now work the concrete without having the wheelbarrow move as I push back and forth. Let the water flow in after each push-and-pull stroke. Keep mixing until most of the water is absorbed.*

5 ***Add water in small amounts.*** *Too much will weaken the concrete, so add a little water at a time, then mix. Aim for the texture of dry cottage cheese.*

6 ***The final test.*** *I'm done when all the concrete is wet and I've scraped the rake along the bottom and sides to remove any dry pockets. The mix passes my personal slump test when it's all wet but still firm enough for the rake's furrows to hold their shape.*

STEP BY STEP

Sturdy, stable, and sized right

When it comes to wheelbarrows, bigger is not always better. A medium-size 6-cu.-ft. tray is large enough to hold as much wet concrete or rock as I can move comfortably but is not so big that it's unwieldy. I prefer a tray made of heavy-gauge steel that, unlike plastic, is not affected by UV-rays and won't crack if the temperature dips into single digits. Nice extras on any wheelbarrow are solid hardwood handles for easy gripping and anti-tilt-back supports on the feet to reduce the chance that I'll end up with a load of concrete exactly where I don't want it. All this adds up to a wheelbarrow that can take the abuse of a full-time professional. For more information, visit www.jacksonprofessional.com.

To see a video of former editor John Ross demonstrating this concrete mixing technique, visit FineHomebuilding.com.

Wheelbarrow photo page 11: Courtesy of Jackson Professional Tools

BY ANDY ENGEL

Placing a small concrete slab

Although the amount of concrete used is small, the forming and finishing techniques for a slab such as a deck-stair landing—or in this case, a propane-tank pad—aren't much different from those used for larger slabs. First and foremost is subgrade preparation. Get that wrong, and the slab will crack. The underlying ground needs to be compacted evenly. In most cases, slabs shouldn't be placed next to new buildings until the backfill around them has settled for several years. After digging out the slab location, compact the soil directly below so that there's no loose dirt.

Use a gravel base

One step that's called for but rarely done on small jobs is to place gravel between the slab and the subgrade. The usual explanation is that the gravel provides drainage to prevent soil saturation and the resulting frost heaving. But unless you drain that gravel somewhere with pipes, where's the water going to go?

There are two reasons to use gravel. First, concrete moves because of thermal expansion and contraction. Restricting this movement will crack the concrete. A gravel base allows the slab to move freely. Second, slabs need a flat base to ensure uniform thickness, and gravel is easier to grade than many soils.

Choosing concrete

For a slab that's 40 sq. ft. or more (about ½ cu. yd. of concrete for a typical 4-in.-thick slab), it's easiest to order truck-mixed concrete. This 3-ft.-sq. slab was small enough that mixing bagged concrete by hand made sense. At 9 sq. ft. and 4 in. thick, the project called for 3 cu. ft. of concrete. An 80-lb. bag of concrete mix makes ⅗ cu. ft., so this slab took five bags.

I used a crack-control concrete, which includes reinforcing fibers. The slab was small enough that no steel reinforcement was needed, but that little extra strength from the fibers only cost me $5. Larger slabs, say 5x5 and up, will benefit from reinforcement with rebar or wire mesh to control cracking.

Concrete needs moisture to cure. After finishing the slab, cover it with plastic and keep it damp for at least a day. A week is better, and 28 days ensures the best cure.

STEP BY STEP

1 *Prepare the subgrade.* *Dig 6 in. beyond where you want the slab edges and 8 in. deeper than where you want the top of the slab. Make sure the subgrade pitches away from the building, and tamp down loose soil.*

2 *Grade the gravel.* *Fill the excavation with 4 in. of gravel. Rake it flat, and use a level to make sure it's pitched about ¼ in. per ft. so that the slab, which will parallel the base, drains water.*

3 *Make and set the form.* *Most 4-in. slabs are actually the 3½-in. depth of standard 2x4s. Nail the corners together, and place the form on the graded gravel, making sure it doesn't rock. Drive 12-in. lengths of rebar to just below the top of the form to keep it from moving.*

4 *Mix the concrete.* *Dump two 80-lb. bags of mix in a wheelbarrow for each batch. Add 3 qt. of water per bag, and mix thoroughly with a hoe. Add small amounts of additional water if necessary to bring the concrete to a consistency that's about the same as thick cake batter.*

5 *Settle the concrete.* *After dumping the mixed concrete in the form, jab into it all along the edges with a shovel. This helps to ensure that the mix fills the form without leaving voids.*

6 *Tap the sides of the form.* *Lightly hammer the form all around the slab until you see bubbles rising from the concrete. This step makes for a smoother slab edge that won't collect water, which can freeze and spall the concrete.*

7 *Screed the slab.* *Flatten the concrete using a straight 2x4 that's about 1 ft. longer than the form width. Move the board forward with a back-and-forth sawing motion while keeping it on the form.*

8 *Tamp the surface with a rake.* *Gently tamp the entire surface of the slab. The rake pushes down the gravel that's part of the concrete mix, and brings up a mixture of cement and sand that's easier to smooth.*

9 *Smooth the rake marks with a mag float.* *Keep the leading edge of the float up. When the surface water dissipates, float the slab again. This is the final finish for exterior slabs. For a smooth interior slab, work it again with a steel float when the surface begins to lose its wet sheen.*

10 *Round the corners.* *This leaves smooth, friendly edges that are less likely to chip. Use an edger once after each mag floating; on interior slabs with exposed edges, use it after the steel float. After the slab hardens for a day or more, pry the joints apart and remove the form.*

STEP BY STEP

Andy Engel is a senior editor.
Photos by Patrick McCombe.

Concrete tools

MAG FLOAT Used in the initial tooling to bring up a creamy mix that's easy to finish. As a final finishing tool, it leaves a coarse, slip-resistant surface that's good for exterior slabs.

STEEL FLOAT A finishing tool that leaves a smooth, compacted surface that repels water but that also can be slippery when wet.

EDGER Rounds over the exposed edges of slabs, leaving a surface that's more resistant to chipping than a simple square edge would be.