

Building Stem Wall Foundations

Keeping foundations in-house can make scheduling easier and improve job quality



by Tim Uhler

[Editor's note: This is the first part of a two-part story; it provides an overview of foundation layout and describes the author's technique for building footings. Next month the story continues with the completion of the stem walls.]

While I was learning the trades in high school, the carpenters I worked with also built foundations; during one particularly busy period, we formed and poured 10 of them in a month and a half. We were working in a cul-de-sac, and would set up the footings for four houses at a time, then pour them all at once. It was tough work, but it taught me a lot about concrete. About five years ago, I began putting those skills to use again

when our company stopped subbing out our foundation work. Now we form and pour all the footings and walls for the homes we build, using the same methods as most of the foundation subs in our area.

Foundation work isn't for everybody. For one thing, it involves an investment in forms and other equipment. Over the years, the company I work for has accumulated about 120 2-foot-by-8-foot forms and an assortment of cut pieces. Currently,



Figure 1. When laying out the footings, the author determines diagonal measurements using the rise/run function on his construction calculator, then refers to those measurements to verify that corners are square. The stretched string on the right-hand side of the photo indicates the outside edge of the first set of footings.

these 1½-inch-thick MDO forms cost about \$40 each, but we also occasionally find less-expensive used forms that are in good condition — usually from contractors who have been forced out of business. We probably have about \$10,000 invested in forming materials and related equipment, though our only specialized tools (in addition to the forms) are rebar cutters, a site laser, and a few levels and trowels.

Being involved in a project from the bottom up keeps our crew busy and allows us to make sure that dimensions are accurate and earthquake hardware is in exactly the right place. This makes the carpentry much easier later on.

Layout and Excavation

The excavator and I begin each new construction project by meeting on site and staking out the hole. I depend a lot on my excavator's experience to keep me out of trouble, especially under tricky site and soil conditions. We seldom have to dig very far, since the ground rarely freezes here and our minimum footing depth is only 12 inches.

Usually we just follow the terrain using common sense when determining the depth of the excavation. If we are trying to match the elevations of any nearby houses, we'll take a number off a siding course or some other fixed point with our laser level and use that to establish a benchmark elevation. In most cases, though, we don't work from a fixed benchmark; instead, we determine wall heights and other elevations from the top of the footing — the vertical rise method.

When the excavator cuts the hole, we make sure it's large enough to fine-tune the location of the house's footprint as we're laying out forms. We stake the property corners and mark the property boundaries with strings, which we leave in place so that the inspector can double-check our setbacks.

Footings

On most projects, we can form footings and tie steel in the morning, schedule the inspection for the afternoon, and pour the footings the following morning.

Reference points. We start by rough-measuring the hole, which allows us to quickly identify most potential problems. Once we're satisfied the hole is big enough, we stake out two long lines that are exactly 90 degrees (perpendicular) to each other. These lines help us keep the footings roughly square as we build them, and serve as a reference for setbacks from the property lines.

To keep our foundations square, we calculate a lot of diagonals. I prefer to use my Construction Master Pro Trig calculator (calculated.com) rather than the 3-4-5 right-triangle method I learned as an apprentice, because it's much faster and far more accurate. I just plug in actual perpendicular wall dimensions and determine each diagonal, using the largest squares possible (see Figure 1).

If the foundation has any large odd angles, like a 135-degree or 130-degree dogleg, I ask the designer to calculate these diagonals and include them on the foundation plan. This helps us locate these corners on site, ensures that the angles are



Figure 2. Footing forms are fastened together at the corners with duplex nails; 16-inch metal spreaders keep the sides properly spaced.



Figure 3. Either metal or wooden stakes can be used to hold the forms in place. In hard ground, a metal stake can be used to “predrill” holes for cheaper wooden stakes.

correct, and reduces the time we spend in the field figuring out these details.

Footing forms. Though code in our area allows 12-inch-wide footings for single-story homes, our typical footing is 16 inches wide. We form the footings with 16-foot-long 1x6 #2 pine fastened together with 6d duplex nails, and use 16-inch metal spreader cleats to keep the footings spaced uniformly (**Figure 2**). While we have a bucket of metal stakes, most of the time we fasten our form boards to inexpensive 1x2 wooden stakes (**Figure 3**). If the ground is too hard to pound in wooden stakes without breaking them, we predrill holes by driving in a metal stake and wiggling it back and forth, then pulling it out.

During most construction projects, each subsequent trade in the process works to increasingly tighter tolerances: Dirt guys generally work to within the inch, footing workers to within the half-inch, stem-wall builders to within $\frac{1}{4}$ inch, framers to $\frac{1}{8}$ inch, and finish carpenters to $\frac{1}{16}$ inch (or less). But our goal during the foundation phase is to work within $\frac{1}{4}$ -inch



Figure 4. A single crew member can level the staked forms using a rotary laser. The receiver included with the Stabila LAR250 kit used by the author indicates distance from grade in $\frac{1}{16}$ -inch increments.

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Figure 5. Tying the rebar together on top of the spreader cleats makes it easier to get the overlaps and spacing right. Afterward, the spreaders can be temporarily removed and the rebar dropped in place.



Figure 6. Companies that do production foundation work may want to consider the Max cordless rebar tier (maxusacorp.com), which automatically makes a tie in less than a second.



Figure 7. Most contractors cut and bend rebar on site, as shown. An option in some areas is to have a local metal shop pre-cut and pre-bend the rebar.

dimensional tolerances, and to be within $\frac{1}{16}$ inch of our target elevation. When we form footings, we're aiming for perfect numbers — even though we know things will get moved around a little because of the nature of working in the dirt (or rain, mud, or snow).

Usually, we start forming with the longest, straightest run. Then two of us work from opposite ends of this run away from each other to assemble the remaining footings. Since most of our stem walls are 8 inches wide, we always add 4 inches to our measurements if the corners are “outside to outside,” and use the plan dimension if the corner is “inside to inside.” For example, if the longest foundation wall run is 40 feet, the footing will measure 40 feet 8 inches, plus the thickness of the form boards (assuming I am hooking my tape to the forms). If I have time, I try to put all these measurements on the plans themselves prior to forming.

Because 1x6 forms aren't very stiff, we stake the forms every 4 feet to keep them straight. We orient the stakes directly oppo-

site each other, with one stake at the center of all form board overlaps. We initially tack the form boards together with a single 6d duplex nail, which allows us to raise the forms to grade and pivot on that nail.

Before we get the whole footing formed, we square the largest 90-degree angle and stake the form boards so that they're straight but not level or nailed to the stakes. We use this right angle as a reference point for the rest of the footprint.

Once all the footing forms are in place, we double-check the largest diagonals, parallel runs, and lengths against the foundation plan and our calculated diagonals just to make sure we didn't make any mistakes. Then we finish staking in the entire footprint at the corners and where the forms overlap on long runs.

Shooting grade. Old-school builder's levels or transits are accurate but require two people: one to read the level and one to hold the grade stick. Instead, we use a Stabila LAR 250 self-leveling laser (stabila.com), which turns shooting grades and elevations into a one-man job (Figure 4, previous page).



Figure 8. To place the rebar at the proper depth in the footing, the author suspends it from the spreader cleats. Here, he's also used a template to accurately locate the 1-inch-diameter all-thread rod needed for an iLevel shear-wall brace.

Whenever possible, I set our laser level up in the middle of the footprint so that I have a sight line to the unit no matter where I am in the hole. I eyeball the footing to see where I think the highest spot is, and take my first reading there. If I set my stick to make sure the minimum depth — typically 8 inches — meets the engineer's or code requirements there, the rest of the footing will also be thick enough to meet code.

When shooting grade, I start with the outside forms. First I raise a corner to grade and nail one stake, then I move to all the pivot points and do the same. Another carpenter follows behind me, using a spirit level to level the inside forms with the outside forms and then tacking them off. Once the entire footing is raised to grade, we nail off the remaining stakes (one nail per stake), adding nails at the overlaps to keep the forms tight.

Bending and tying steel. When there are no engineering plans to follow, we refer to the prescriptive schedules for steel reinforcement contained in our local



Figure 9. Areas in the footings that must support point loads are reinforced with rebar following the engineer's specifications.



Figure 10. Here, the author's crew has formed footings for an interior shear wall and for several large piers that will support point loads from the roof.

code. Often, we source the rebar out to a local shop, and it arrives on site pre-cut and pre-bent. The shop tags the rebar, and we just spread it following the tags and their notations on the prints.

We tie the steel together on top of the spreader cleats, which helps us make sure it is spaced correctly (**Figure 5**). In our area, code requires overlaps to be 30 times the diameter of the rebar. Since we most often use grade 60 #4 (1/2-inch-diameter) rebar, overlaps must be at least 15 inches long.

We shoot for 20-inch overlaps so we don't have to worry about failing inspection. We use a minimum of two ties at each overlap, twisting the tie wire with lineman's pliers just enough to keep the rebar tight.

If we're using pre-cut rebar, the shop usually provides us with 30-inch-by-30-inch 90-degree bent steel for all the corners, which requires a lot of ties (**Figure 6**). If we're cutting and bending the steel ourselves (**Figure 7**), we always put 2-foot bends on full-length 20-foot sticks so that

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we have to make fewer ties. Once the bar is tied in, we drop it into the footings.

Only after the footing is raised and nailed off do we raise the rebar and tie it to the spreader cleats to keep it suspended in the forms. Then we install any necessary seismic connectors (**Figure 8, previous page**) and tie in our vertical

steel to the footing steel, leaving the rebar temporarily leaning against the forms until we place the concrete (**Figure 9, previous page**).

Next, if footings for point loads are called out on the plans, we form them to the specified thickness. Sometimes we have to dig down a little so the pads don't

stand too tall in the crawlspace. Typically, we run a wood column through the floor onto the pier pad, though sometimes we'll pour a stem wall on top of an interior footing if an interior shear wall is required (**Figure 10, previous page**). Then we drop in the steel reinforcement and brace the formwork to keep it plumb.

Placing concrete. Most of the time, we use a local line pump contractor to place our concrete. He does all the line handling, which makes our job much easier, allowing us to focus on screeding and troweling the concrete (**Figure 11**). We've used boom pumps before, but the concrete sometimes comes out so fast it can blow apart forms or even steel, and one of our crew has to man the hose.

A line pump pour is more relaxed, and I can keep my eye on the forms. While it takes a little longer — maybe an hour on a typical job — we still save a minimum of \$200 on each pour over the cost of a boom pump.

Once the footings are filled, we screed off the tops of the forms and trowel the concrete smooth with a magnesium trowel. A smooth surface helps the stem-wall forms to sit flat on the footings, eliminating gaps that might allow a wet wall mix to leak out of the forms.

Snapping layout. I like to pour in the morning so that after lunch we can snap lines for the stem walls and set the spreader cleats that will hold the underside of the panel forms (**Figure 12**). We place the clips 16 to 24 inches on-center — a spacing that helps keep the forms straight — and push 1½-inch nails through their center holes into the wet concrete to hold them in place (**Figure 13**).

Once the concrete feels firm enough, we strip the footings and break down and stack the form boards to use again for our next footing (form boards last for about 10 footings). *[Story continues next month.]*

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Figure 11. As the line pump operator fills the footing form, a crew member follows behind and screeds the concrete level. A second worker then trowels the footing smooth.



Figure 12. Workers lay out the stem walls on the footings, snapping lines while the concrete is still soft.



Figure 13. Form clips are set every 16 to 24 inches along the snapped layout lines. The author holds them in place with 1½-inch Teco nails pushed into the wet concrete; even if rain washes the lines away, the clips will still be in the right position for the stem-wall forms.