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Squaring and Leveling Mudsills

If you assume the foundation is accurate, you may end up custom cutting each rafter and fussing with every miter in your trim

by Rick Arnold and Mike Guertin

Sill width determines baseline. After a rough check to verify the overall dimensions of the foundation, a baseline is established by measuring in the width of the sill from the edge of the concrete.

Parallel walls are lined up from the baseline. The two crew members in the background mark the same measurement from the baseline on the wall behind them. The crew member In the foreground moves the chalkline until it lines up with the marks determining the sill location for the garage wall.

On one of our first framing jobs, the lead carpenter installed the mudsills by just lining them up with the outside edge of the foundation. It wasn't until the first-floor deck was framed and sheathed that we realized the foundation was 3 in. wider at one end, which made the whole platform miserably out of square. We battled problems from this little oversight all the way through the roof, and soon after we began looking for a new lead carpenter.

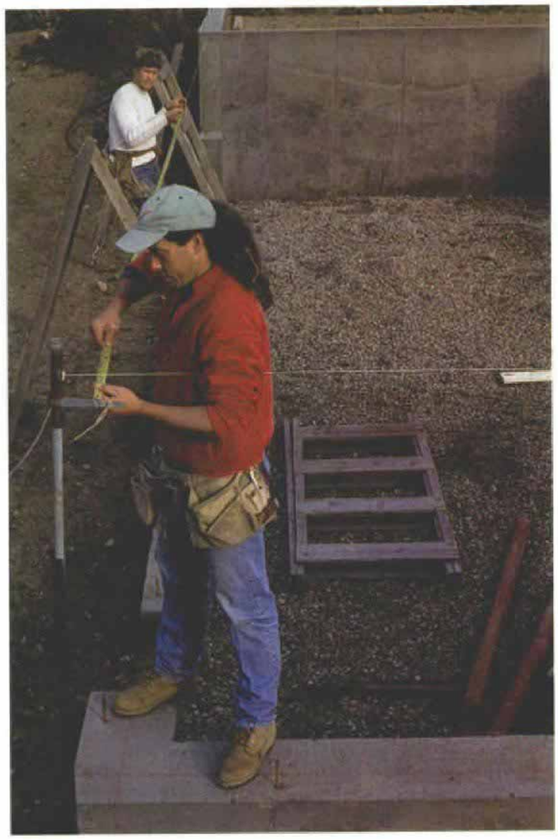
In the 15 or so years since that project, we've become a little fanatical about squaring and leveling our mudsills regardless of the scale or price range of the house. The reward for being finicky is a first-floor platform that is square, level and built to the exact dimensions called for on the plans. This extra care that is taken at the beginning saves us time and headaches throughout the project.

Crew members must communicate at all times to get accurate measurements- Measuring foundations is almost always a two-person job and may even involve three people, if more than one measuring tape is being used at one time. Constant communication between all crew members involved in a measurement is of utmost importance to the success of squaring and leveling.

We have an unwritten rule that the person on the beginning, or dummy, end of the measuring tape always calls out the measurement he is holding to the line as well as the color of that line—"$5\frac{5}{8}$, blue line," for instance. The person on the business end of the measuring tape always acknowledges his partner's call before recording the measurement.

To maintain the highest level of consistency and accuracy, we also insist that crew members never switch ends of the tape or switch jobs with anyone else on the crew during the entire process. On past projects we wasted hours trying to figure out why dimensions didn't jibe only to discover that a crew member merely held the

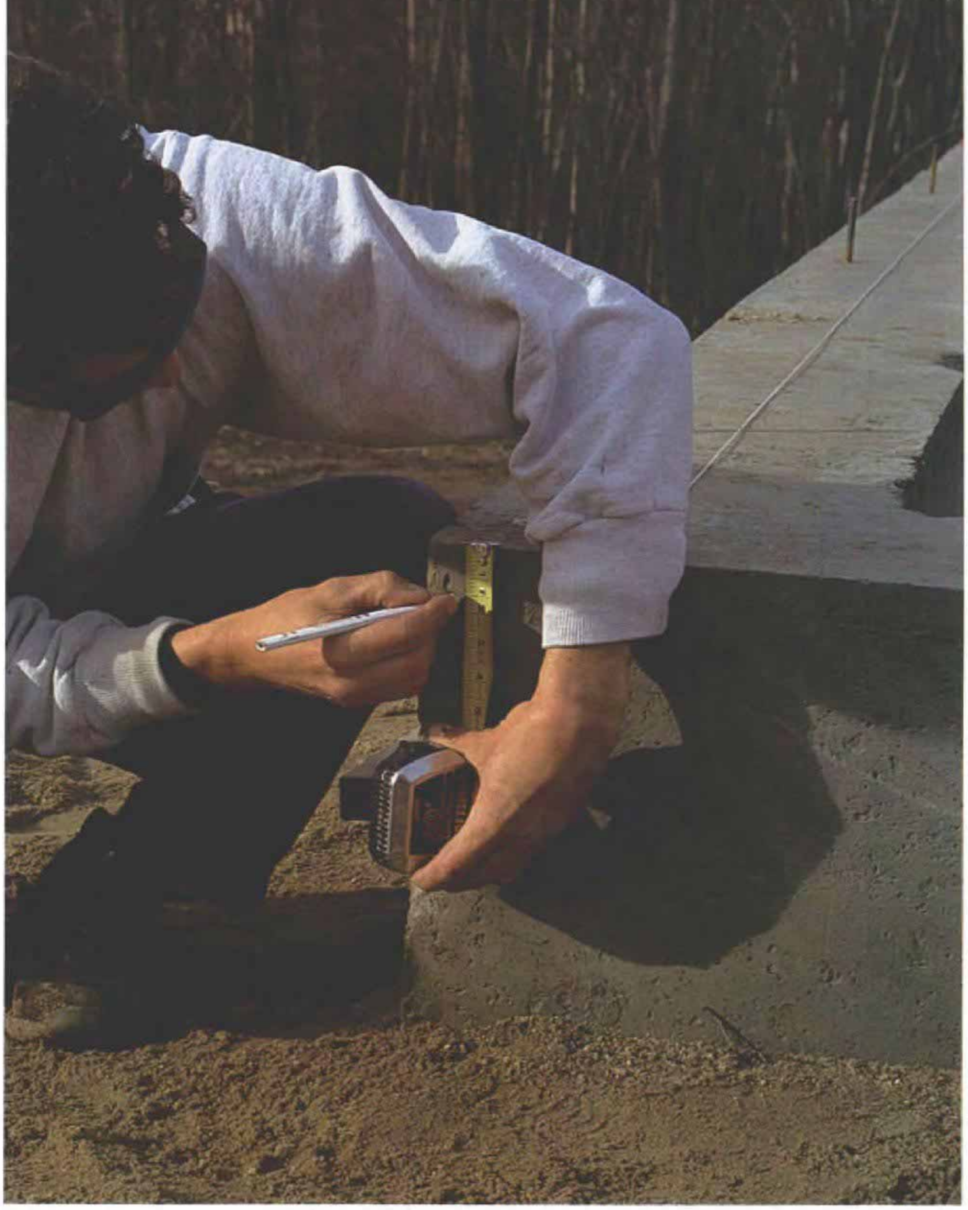
Two tapes locate the midpoint. A crew member crosses two tapes that are being stretched from the ends of the baseline. A small piece of twine is tied on the dry string where the two tapes meet at exactly the same length. This point marks the center of the rear wall.



Dry strings are used where the foundation drops. To guarantee square mudsills on the dropped foundation, the crew projects the measurements to dry strings held at the same level as the rest of the foundation. The homemade device for holding the dry strings has an angle iron that is nailed into the foundation and a telescoping pipe to allow the crew to adjust the height of the strings.

Diagonal measurements are the final check for square. After the corners are located on the rear wall, the crew measures between them and the baseline corners. If the measuring procedures have been followed carefully, the two diagonal measurements should be within $\frac{1}{8}$ in.

A plumb bob transfers the corner point to the wall below. The intersection of the two dry strings is the exact corner of the sill layout. That point, as well as any others needed to snap chalklines, is found by dropping a plumb line from the dry string.



Leveling the foundation begins with a reference point. A crew member makes a mark 1½ in. down on one corner of the foundation. From this point the crew uses a water level (photo facing page) and marks every corner. A level line between the marks will help locate places in the foundation that might be out of level.

tape in the wrong spot and that his partner failed to check him.

Check the foundation right away—We always square the foundation and snap lines for our mudsills right after the forms have been stripped (and before the foundation contractor is paid), even if we know that we won't begin framing for a while. Although totally unworkable foundations are rare, we have seen some foundation pours that were out of level as much as 3 in. in 40 ft. and some foundations that varied up to 12 in. from the specifications on the plan. Our crew can work comfortably with foundation tolerances that are within ¾ in. of square and ½ in. of level, and overall dimensions that are within ½ in. of the foundation plan.

We also double-check the foundation plan against the first-floor plan before lines are snapped. Simple features such as shelves for exterior brick veneer can have a way of throwing off foundation dimensions. Any deviation from the plan or discrepancy that exceeds our tolerances adds cost to the project and needs to be addressed before we begin. The foundation that we will use to illustrate our methods is 40 ft. long and 30 ft. wide with an 8-ft. by 20-ft. breezeway that connects the house to a 24-ft. by 24-ft. garage. The rear foundation wall of the house is dropped 7 ft., and the gable-end foundation wall steps down with the grade.

After inspecting the foundation for any obvious problems, such as a large bump-out or a severe crown or dip, a couple of crew members check the overall foundation measurements. At the same time other crew members sweep dirt or concrete debris off the top of the walls.

We install a double-2x6 mudsill system common to this part of southern New England, using pressure-treated lumber for the lower sill. With the double-mudsill system, leveling shims are inserted between the two layers, giving us a nice,

A water level is quicker, easier to use and more accurate than a transit. Having tested many kinds of leveling devices, including builder's transits, this crew's tool of choice is a water level. The tool requires no calibration and holds up well under the rigors of house framing.

tight seal against the concrete while providing a flat surface for the first-floor deck. We always check the width of a few pieces of the pressure-treated stock to determine the exact distance to set our chalkline back from the edge of the concrete. Most often this measurement is 5⅝ in.

Having inspected our foundation and found that it is close to the plan specifications, we choose the longest grade-level wall and mark 5⅝ in. from the outside of the concrete on each end (left photo, p. 46). We snap a line between these marks in blue chalk to serve as a baseline.

We snap our lines in blue chalk initially. Then, if the line needs to be adjusted for any reason, we switch to red. The crew has been instructed that a red line always supersedes a blue one.

The rear sills are lined up parallel to the front—The next step is establishing a rear-wall line parallel to our baseline. Foundations that are poured all on one level are the easiest and quickest to deal with because lines and measurements can be made directly onto the foundation. One crew member holds the dummy end of the tape at 5⅝ in. over one end of the baseline while the other member with the business end of the tape marks the planned width of the house minus 5⅝ in. on the rear wall. The process is repeated at the other end, and a line is snapped on the rear wall between these marks.

As mentioned before, the rear wall of this particular foundation is 7 ft. lower than the front wall, and the end wall is stepped, which complicates the procedure slightly. We've devised a fixture that is nailed to the lower foundation corner and that holds a dry string (in place of the chalkline) at the height of the grade-level portion of the foundation (center photo, p. 47). Instead of marking and snapping a chalkline on the rear foundation wall, we run a dry string at the same elevation as the front wall. This string is positioned 29 ft. 6⅜ in. from the baseline (30 ft. for the width of the house minus 5⅝ in. for the width of the sill). Because the rear wall of the garage happens to be in line with the rear of the house foundation, we extend the dry string all the way through to the gable end of the garage and drive a nail into the concrete there to anchor the string in position. This dry string will remain in place as a reference line until we've finished installing the sills.

We establish the parallel line for the front wall of the garage by measuring 6 ft. from our baseline on the two walls that run perpendicular to the front wall (right photo, p. 46). We extend a chalkline from the 6-ft, mark on the end wall of the house across the front wall of the garage. The line is then moved until it aligns with the 6-ft, mark on the intermediate perpendicular wall. Before the line is snapped, we secure it and verify that it is parallel to the dry line at the rear wall of the garage by measuring between the two. If our measurements are off slightly, we tweak the line at the end of the garage to compensate. When we're satisfied, we snap the line for the garage wall in blue. We can now locate and snap any other parallel lines, such as the front wall of the breezeway, by referencing one of the snapped lines or the dry string.

Perpendicular lines are located by simple geometry—We have just established the lines for our front and rear walls. The distance between these lines is the length of our perpendicular walls. Next we locate the corner points that will give us the lengths of our front and rear walls as well as the placement of perpendicular walls, and we can begin to square the foundation.

When we made a rough measurement of the foundation earlier, we determined that the actual length of the front wall along our baseline was close to the specified length of 40 ft. So next we mark 5⅝ in. in from the outside of the concrete at one end of our baseline. One crew member holds the tape at 5⅝ in. on that mark while a second pulls the tape along the wall and marks the baseline at 39 ft. 6⅜ in., or 5⅝ in. back from the total length of the wall.

Our next step is establishing a perpendicular line for the gable end of the house exactly 90° to the baseline. In the past we tried the 3-4-5 right-triangle method, which got us close but not perfect. We used right-angle prisms, but we found them to be slow and hard to work with. The Pythagorean theorem also works fine, but the calculations have to be precise. Also, figuring in the 5⅝-in. setback on top of all that will befuddle even the most mathematically inclined. Our latest method has outperformed all others in simplicity and speed.

Three people + two 100-ft. tapes = one square foundation—There are actually two variations to our method. The first and most efficient method requires three people and two 100-ft. tapes.

Two crew members hold the 2-in, line of their tapes on the corner marks at each end of the front-wall baseline. We use the 2-in, mark because it is usually the first whole-inch mark on a 100-ft. tape; it also gives the crew member plenty to hold on to when the tape is being stretched tight. The third person holds the business end of both tapes near the middle of the line or, in this case, the dry string on the opposite wall. This person crosses the two tapes and moves left or right along the line until the measurements on the two tapes match exactly (top photo, p. 47). This point indicates the exact center of the rear wall, and it's marked either with a pencil line on the foundation or a piece of twine tied around the dry string (an alligator clip from an electronics-supply store also works well to mark a point on a dry string).

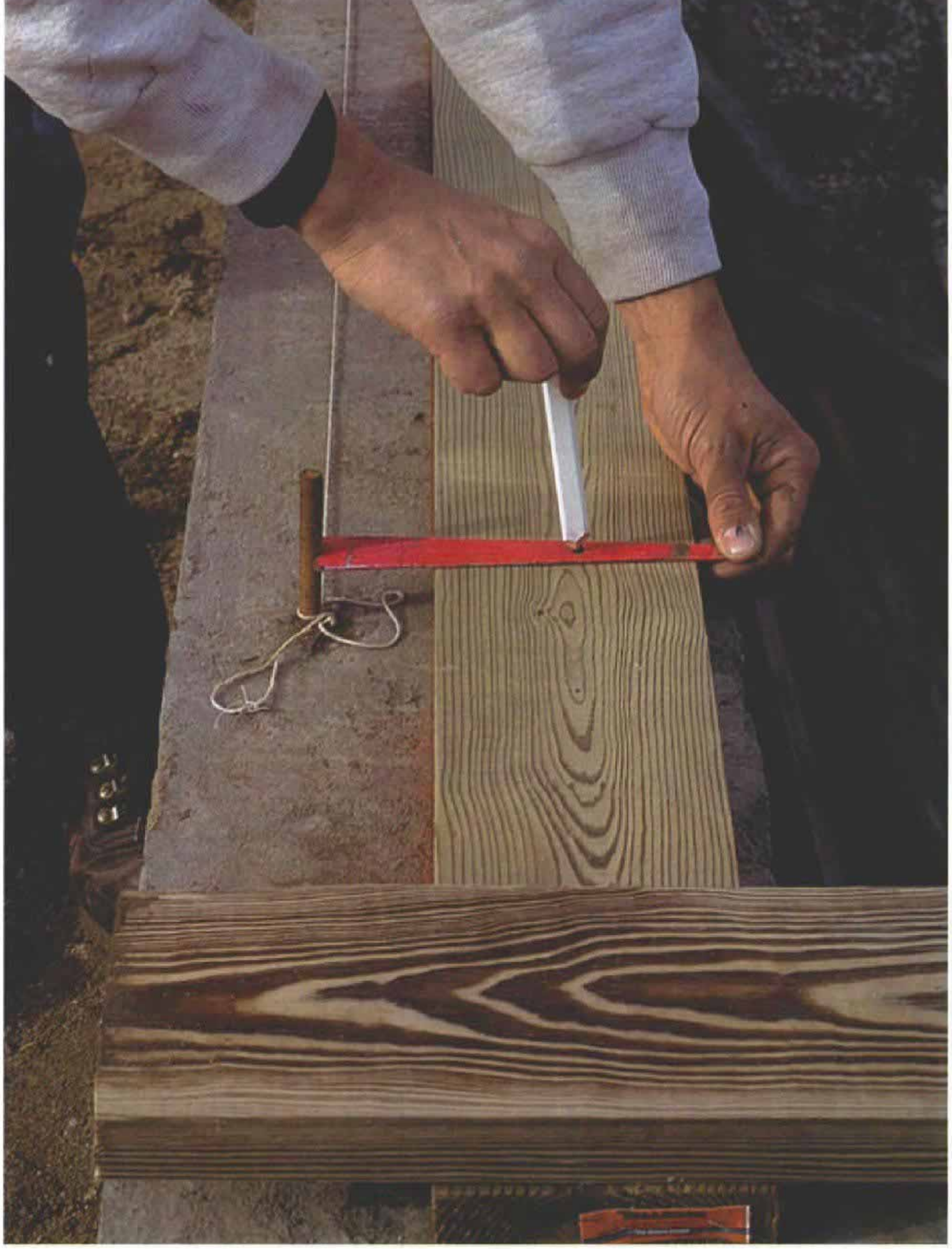
From the midpoint we measure half the length of the wall minus the width of the sill in each direction to get our inside-corner marks (center photo, p. 47). For insurance we double-check the overall length of the rear wall. Now, as a final check for square, we measure diagonally from corner to corner on the foundation (bottom photo, p. 47). If we've done our job properly, those measurements should be within ⅛ in.

Two crew members and one tape take a little longer—If there are only two crew members or just one 100-ft. tape available, we use a modified method that's a little slower but works just as well as the first system. We mark the length of our baseline just as before. Then one person holds the tape at 2 in. on one end of the line.

Instead of crossing two tapes, the guy on the business end stretches the single tape across the opposite parallel line near the midpoint and picks the closest 1-ft. increment on the tape. For our purposes we'll call that measurement 42 ft. The crew member on the business end then moves the tape along the line and marks where the 42-ft. mark on the tape intersects with the chalkline or dry string. The dummy end of the tape is then moved to the mark at the opposite end of the baseline, and the tape is held at the same 2-in, point. The business end again marks the point where the 42-ft. mark on the tape intersects with the line. The midpoint between these two marks should be the midpoint of the wall. Just as before, we measure to the left and to the right of this midpoint half the length of the wall, again minus the width of our sills, to locate our corner points, and again we confirm overall squareness with diagonal measurements.

With both methods, once we're sure that we have a perfect rectangle, we snap lines for the perpendicular walls between the corner points on our front and rear walls. From those lines, we can measure and snap any other lines that are perpendicular to our baseline, including the gable-end wall of the garage.

Both rear-corner points of this foundation happen to be "in the air" because of the drops in the foundation. On the corner where our dry-string fixture is mounted, we indicate the line of the gable-end wall using another dry string instead of a snapped line. The intersection of the two dry strings tied to our fixture is our exact comer point (left photo, p. 48). Starting at this point, we drop a plumb bob down to the lower foundation walls at enough locations to let us snap lines. But on a windy day even the tightest dry string will tend to move a bit. And even the slightest breeze can make using a plumb bob impractical. If the wind turns our plumb bob into a pendulum, we reluctantly use a 4-ft. level in its place.



A simple jig locates the bolt holes. With the sill stock lined up on the inside of the chalkline, a jig with a U-shaped end is held against the bolt. The bolt-hole location is marked through a hole **5⅝** in. from the U.

Water levels are the most accurate tools for leveling sills—For years we used a builder's transit to set our sills level, and it worked fine most of the time. We still use one occasionally if it is the best-suited tool. However, transits are delicate and vulnerable instruments, particularly around framing crews on job sites. Invariably, the transit gets knocked over or ends up bouncing around in the back of someone's pickup. Consequently, our transits seemed to spend more time in the shop being adjusted than they spent out in the field.

The tool we've come to depend on for leveling our mudsills is the good, old-fashioned, low-tech water level. (For more on building and using water levels, see *Fine Homebuilding* #85, pp. 58-60). We've been accused of being too cheap to buy a transit, and skeptics doubt the accuracy of our water-filled plastic hose. But our water level consistently outperforms the transit for both speed and accuracy. In fact, we have used our water level to inform the foundation contractor that his transit needs calibration.

We first pick a corner of the foundation and mark 1½ in. down from the top of the concrete (right photo, p. 48). After checking the plastic hose for air bubbles and making sure the fluid level in both ends is equal, one crew member, designated as the lead person, raises or lowers the hose until the water level matches his starting mark while another crew member on the other end of the hose marks the level of his comer at the lead's command (photo p. 49). For the sake of consistency, we always make our mark at the bottom of the meniscus (the concave shape of the water surface inside the hose).

We try to mark as many corners of the foundation as our length of hose allows from a single reference point. If a comer is beyond the reach of the hose, the lead person repositions himself at the farthest mark, and the process resumes.

On some foundations it is necessary for the lead person to move four or five times to catch all

Shims correct an out-of-level foundation wall. If there are dips in the foundation, the two sills are pried apart with a flat bar. The nails used to tack the upper sill in place now serve to hold the two sills apart while shims are Inserted beneath the future joist layout.

the corners of the foundation. We mark the entire grade level of the foundation and always work our way back to our starting corner to check ourselves. We are usually within ⅛ in., which is an acceptable tolerance.

If there is a drop or a step in the foundation, we mark the level on the wall just before the drop. Next we measure the drop and round to the nearest inch. We then measure that distance down from the upper-level mark and make a new lower mark on the dropped wall. We continue the leveling process from this point, marking all the dropped foundation walls at each corner until the wall elevation returns to the original level. At this point the measurement between the upper and lower levels should be within ⅛ in. of the original drop measurement.

After making level marks around the entire foundation, we go back and snap lines between our marks. Sometimes we have to scrape off excess concrete at the form-panel seams if it interferes with the chalkline. After the level line is snapped, a crew member takes measurements from the top of the concrete to the chalkline at random points around the foundation. This process gives us an idea of any areas where we'll have to adjust the level of the sills.

Nuts on foundation bolts start out only linger-tight—Once all of our lines are snapped, we can install the sills. We cut the lower sill stock to length for each section of foundation and line it up on the inside of the chalkline (photo facing page). Next, we locate the bolt holes with a homemade tool made from a piece of metal with a U-shape on one end and a hole drilled 5⅝ in. back from the U. We butt the U against the bolt with the tool squared to the sill stock by eye and mark the bolt location through the hole on the other end of the tool. The holes we drill in the mudsills are oversize so that we can adjust the sills to the chalklines once they're in place.

We roll out sill seal just before dropping the sills over the bolts. The lower sill is held in place with masonry nails until the upper sill can be marked, drilled and set on top. We cut the upper 2x6 sills so that the corners cross lap the lower sills. We also try to overlap any butt seams in the upper and lower sills by at least 4 ft. to make straightening bowed sill stock an easier job. We avoid landing seams over windows or bulkhead openings. We extend upper sills beyond any foundation drops by at least 4 ft. to tie into the kneewall below.

In most cases the kiln-dried lumber we use for the upper sill is narrower than the pressure-treated sill on the bottom. In order to maintain the proper outside dimensions of the house framing, we keep the inside of the bottom sill flush with the chalkline on the foundation, and we keep the outside of the upper sill flush with outside of the lower sill. We tack the upper sill in place with a couple of nails every few feet, and we put the nuts and washers on the foundation bolts only finger-tight at first in case shimming is necessary.

Shims between the sills bring them up to level—Most of the foundations we work on are within ¼ in. from the highest point to the lowest point; and by the time we lay the sills on top of the sill seal, these differences are negligible. When we do encounter a more significant dip in the foundation, we use flat bars to pry the sills apart, and we insert shims between the sills to bring them up to level (photo above). The nails we used to tack the two sills together now hold them apart while we slip in the shim shingles. We try to place the shims directly beneath the joist location for the best support of the platform.

If we find that an entire wall is low by ¼ in. or more, we rip 5½-in. strips of the appropriate thickness plywood and sandwich them between the two sills. Occasionally, we encounter a hump in a foundation. Rather than shim all of the sills up to this level of the hump, we make the adjustment later by scribing the rim joist and notching the joists slightly as long as the hump isn't huge. This procedure is preferable to shimming the sills around the entire perimeter of the foundation.

Once the shimming is complete, we tighten the nuts, but only snug so we don't create additional dips in the sills. We complete the installation by nailing the top and bottom sills together according to the local code.

As a final note, the entire process of squaring and leveling a foundation usually takes three crew members about two hours. It takes the same three guys another two hours to drill, shim and nail the sills in place. Expect these methods to take a bit longer at first, but with practice they'll become quicker and easier. Also, that level line snapped around the foundation will come in handy later on for orienting the siding. □

Rick Arnold and Mike Guertin are partners in Midcor Construction, a building company, as well as U. S. Building Concepts, a construction consulting business in East Greenwich, R. I. Photos by Roe A. Osborn.