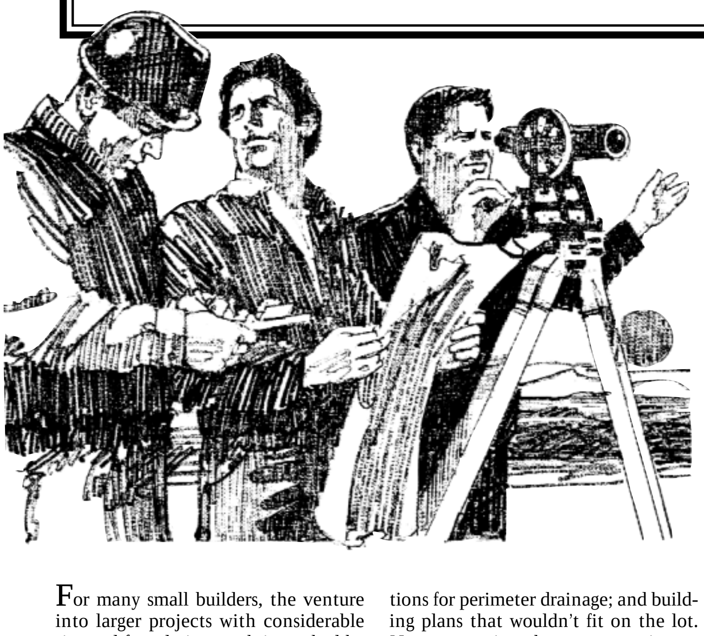
STARTING OUT SQUARE & LEVEL

by Richard Cooper

Careful measurement and good site management will yield a true foundation



For many small builders, the venture into larger projects with considerable site and foundation work is marked by many unknowns. There is much to learn about what takes place before the more familiar framing stage. As the builder's role is basically supervisory through the excavation and foundation work, knowing what to expect from your subcontractor is essential. This overview of building layout should help you get a well-sited square and level foundation on which to build.

Checking out the Site

The condition of the site itself will affect the success of your foundation. With fewer quality building sites available it is even more important to check out the site for potential disasters. For example, in the course of the last two years we've encountered situations requiring blasting or pinning springs in the foundation hole; inadequate elevations for perimeter drainage; and building plans that wouldn't fit on the lot. Not to mention that every septic system we installed seemed to require an uphill pumping system. With these experiences in mind, we check out new sites carefully.

Besides the septic system design and approvals, the most important site considerations are the oil and water conditions. Preliminary septic test borings should inform you generally about soil conditions, the likelihood of encountering ledge, the groundwater table, run-off, and so on. Preliminary transit readings of the building lot, particularly of its lowest elevation in relation to your building's planned basement elevation should tell you a gravity drain is possible. (In one town I know, the building code requires that a house be built on a slab if the foundation cannot be gravity-drained. However, sewage pumps are allowed there — you figure out the logic on that one.) Depending on your local codes, this can be an important item to determine.

This initial site information should help you with the following decisions. Can your site accommodate a full foundation? Will blasting be needed? (For blasting, expect a bare minimum charge of $2,000 to $3,000.) What should the elevation of the foundation and footing be in relation to the contours of the lot? What drainage systems will be necessary?

The elevation of the footing and foundation are especially crucial, because once soil is excavated it is no longer "undisturbed" - which is the general code requirement for placing a footing. Often, playing it safe and raising the level of a building a foot or two will protect you from many potential problems with drainage, grading water table, ledge, marine clay, or other site troubles. It is a lot easier to add fill to come up to a high foundation than it is to grade a site away from a foundation that's too low. Of course, hindsight in such cases is always easier than foresight (the voice of experience here), which is why I advise being conservative in evaluating your building elevation.

The Foundation Plan

Before we can proceed with laying out the building and excavation, we need one simple item, a benchmark, and one complex item, a good foundation plan. Your foundation plan is capable of providing either minimal or substantial information to your excavation and foundation subs. Basically, what they see is what you get.

Ideally, the foundation plan should include the following information:

- Elevations — location of benchmark (elevation customarily established at 100 feet), bottom of footing, top of footing, top of foundation wall, stepdowns, basement slab.
- Locations and sizes — foundation perimeter, stepdowns, basement windows, bulkhead, utility drainage and radon abatement, bond-outs, beam pockets, pads for posts and chimney, sub-slab plumbing if applicable, Lally column locations and sizes, any special anchor bolt locations or omissions (for doorways, etc.)
- Sections and details — typical footing, typical foundation wall, rebar details, interior and exterior drainage systems, radon abatement system, slab/footing detail.

Perhaps this sounds fairly fundamental, but omissions in the foundation plan (elevations, bond-outs, or beam pockets for instance can cause considerable effort and expense later. Unfortunately, concrete doesn't rework quite as easily as wood. Also, the foundation plan is your main document for communicating with our excavation and foundation contractors, so it you want it done right, spell it out in detail.

In the foundation plan, there are two ways of designating your vertical distances. The first, which we'll call the benchmark method, uses a benchmark that is established arbitrarily (customarily at 100'0"); the second, which we'll call the vertical rise method, is simply working with the heights specified (for example, 7'5" wall) without reference to any fixed site benchmark.

The benchmark method. In this method, all your elevations are predetermined in relation to the benchmark, which is a fixed point on the site . This is an advantage, because the excavator and foundation contractor always has a constant reference point, against which all work is compared. Unforeseen problems, such as ledge or marine clay, may necessitate changes in your elevations, but hopefully, your dig will be uneventful.

Figure 1 (see next page) shows part of a foundation plan for a light-commercial wood-frame building including some of the items listed above. Note that all the elevations refer to a benchmark elevation of 100'0", in this case, the top of a nearby fire hydrant. There are bottom-of-footing elevations (B.O.F.) for various sections of the foundation and for pads. The area marked B.O.F. 85'6" for instance, would be 14'6" below the benchmark of 100 feet, and so forth. There are also top of footing (T.O.F.) elevations. The difference between T.O.F. and B.O.F. foundation wall elevations gives the depth of the footings or pads. For example, B.O.F. 88'4" minus T.O.F. 89'2"=10'0" deep footing.

The foundation wall elevations are also given in relation to the benchmark. This makes the excavation and foundation contractor work in direct reference to the benchmark, so there are no excuses for wrong elevations.

Vertical rise method. Figure 2 (see next page) shows the second method, using only the heights specified, without reference to a benchmark on the site. This portion of a residential foundation plan gives elevations, as the note in the square box says in reference to the top of footings being designated as 0'0". Looking around this plan, you see foundation wall elevations at 7'10", 7'6 1/2", and 7'5" above the footing, plus notes on beam pockets, pads with rebar notes, locations of basement windows, and other relevant details. Thus the foundation crew knows how high to pour the walls, but the original footing grade will have to be established during the excavation. This method can lead to

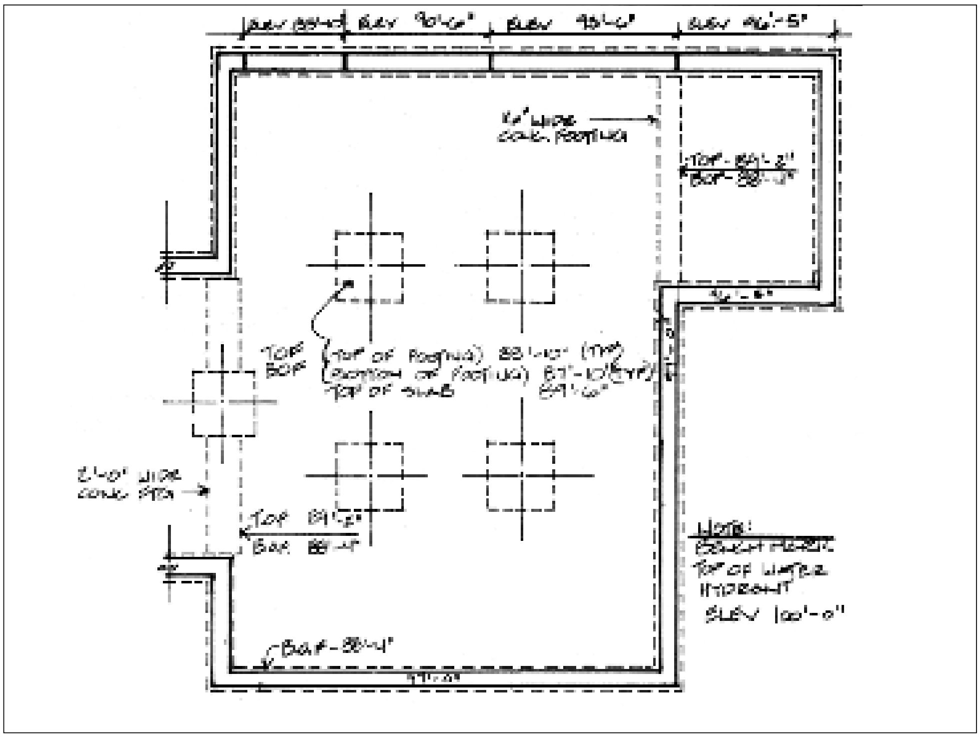


Figure 1: ***Benchmark method.*** *In this method, all elevations are pre-determined in relation to a fixed point on the site. In this case, the benchmark was a nearby fire hydrant. (This is a portion of a foundation plan for a light-commercial wood-frame building.)*

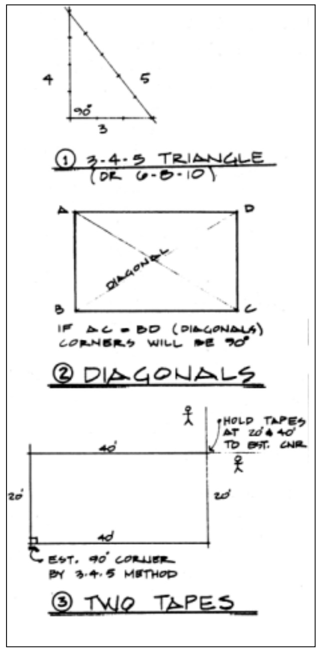


Figure 3. *When staking out the foundation for excavation, there are three simple ways to determine right angles: the 3-4-5 triangle approach (top), measuring the diagonals (center), and using two tapes (bottom).*

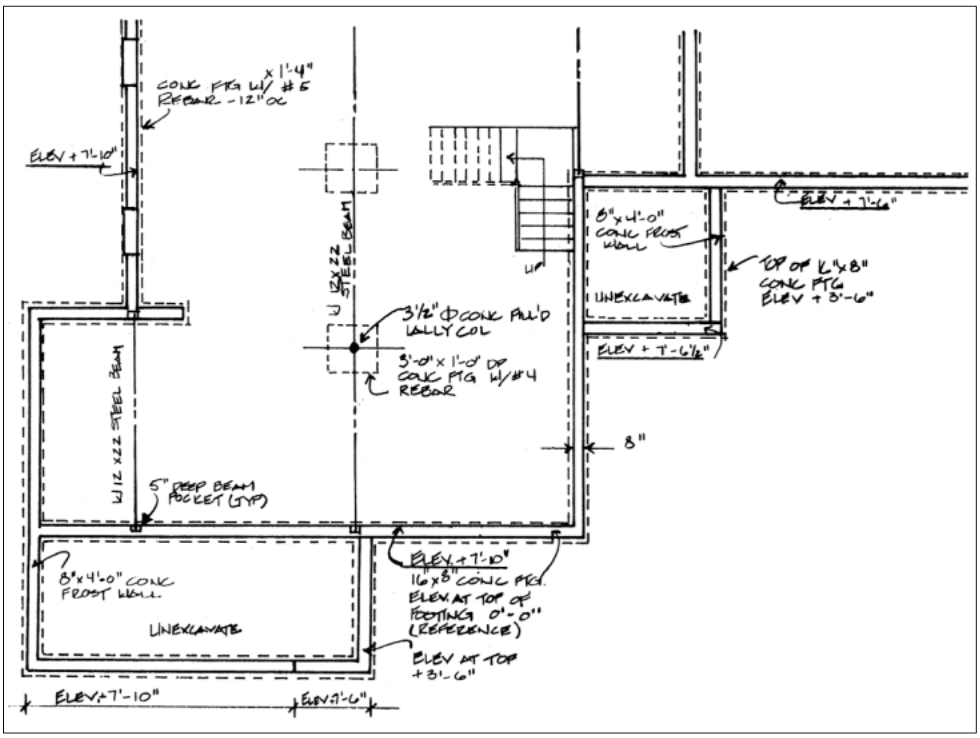


Figure 2: ***Vertical rise method.*** *In this method, no fixed point is used. This portion of a residential foundation plan references elevations to the top of footings being designated at 0'0". With this method, however, it is easy to misjudge a building elevation.*

error because it is easy to misjudge a building elevation when it is determined by the eye, or even building level, on a site filled with piles of excavated dirt and the general mayhem, noise, and confusion of excavation.

Foundation Layout and the Builder's Level

After determining a point for a benchmark (for example: a stump, the center of a paved road, or the top of a property boundary monument), arbitrarily notated as discussed earlier as 100'0", you proceed with your layout. The way to deal with this in the field is with a field notebook. Each time you reset your level, you first determine the reading of the benchmark and note it in your journal, then proceed with all your other readings. If, for instance, the reading of your rod when set on the benchmark is 3'6", you then subtract this amount from all your other readings to adjust them to benchmark reference elevation of 100'0". An advantage of using a field journal is that this addition and subtraction work can then be done later back at the office or at home in, I hope, more peace and quiet.

A word at this point about the measuring rod itself: The standard rods come in either inches divided into quarter inches, or inches divided in tenths. Since no one I know carries around a tape measure marked in tenth inches, to be consistent I stick with the strange but accepted sixteenth-inch system. This 1/4-inch scale sacrifices some accuracy but does not lead to the confusion of using a mongrel 1/10-inch system, which I have dubbed either the "footimal" or the "inchtric" system. For more accurate readings when working on the building itself we sometimes use the tape part of a ruined tape measure — a fairly common object at construction sites — taped or tacked to a piece of strapping. That way measurements with an accuracy of 1/16 inch can be easily read with your builder's level. When taking elevations, another practical piece of advice is to keep the same person looking through the instrument during a day's work, as the interpretation of what they are seeing on the rod is somewhat subjective and can vary with the individual.

What you are doing at this stage in the building layout is determining the basic lay of the land on your site, getting some idea of the differences in elevation that exist, and determining the elevations that you feel will work best for your footings, foundation walls, and basement slab. If you have a fully surveyed site plan, much of this work is already done for you, but chances are you will only be working with a boundary survey with no elevation contours. These elevations are then included on your foundation plan, and you're ready for site work.

Staking Out

Now you are ready to stake out the foundation in preparation for excavation. We have found it most convenient to stake all the corners, usually using the 3-4-5 right triangle

Transit Terminology

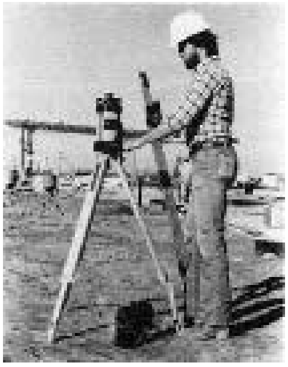
Builder's Transit: only reads horizontally. This is the type of level most contractors own.

Transit Level: can also tilt up and down, allowing one to sight down to the ground and place points on the ground.

Full Scale Transit: turns 360 degrees on both horizontal and vertical axes.

Spirit Vials: small tubes of fluid with bubbles, usually mounted in a length of wood or metal; levels with a long spirit vial (as on a carpenter's level) need to be leveled exactly, as there is no compensating mechanism inside the level.

Automatic Levels: usually have a round leveling bubble, have an internal pendulum that uses prisms and mirrors, and levels the line of sight according to what gravity tells it. The bubble does not have to be exactly centered to achieve a level sight line.



Lasers are now common on bigger construction sites. The Beam machine by AGL Corp. (Jacksonville, Ark.) comes in a manual model that can be upgraded to self-leveling or dual guide.

State-of-the-Art Levels

Surprisingly, state-of-the-art equipment for leveling is headed in two opposite directions, the basic and high tech. On the primitive end, we have the re-emergence of the water level or the "you-can't-fool-gravity" system. With the water level, one end of a transparent hose is mounted at the height desired, and the other end is carried around to check other locations. This is especially useful for masons who can't get far enough away or high enough to use a regular level. Water levels can be found at masonry supply shops.

The high-tech end of the spectrum is covered by electronic levels and all types of lasers. An electronic level functions like a laser, but uses infrared light, which is picked up by detectors mounted on a measuring rod. This allows one person to run the entire operation since the reading is done at the rod.

Construction lasers come in many types designed for various uses. Laser, an acronym for "light amplification by stimulated emission of radiation," uses a helium-neon light source and emits a visible beam of light. Like the electronic level, the laser beam is read at the pole with a detector that can emit either a visible or audible signal. Current construction uses range from slabs, foundation walls, and raised computer floors to drywall and piping. Not only can lasers produce level beams of light, but they can also establish grades, even compound grades, similar to making compound miter cuts. The AGL MCS (Machine Control System) can even be attached to a bulldozer to automatically control the dozer hydraulics to create the desired grades. As a final high-tech example, the EDM or Electronic Distance Meter can shoot a beam of light, that when reflected back to the meter, can tell you the distance to the object and the slope and difference in elevation. As residential builders, we encounter little of this high-tech world, but it's all out there, and only a matter of time before it works its way down to even the smallest job. - R.C.

formula to establish at least one or two of the primary right angles of the building. After the foundation boundary is established we then string lines between the stakes, and spray paint the ground on either the building lines themselves, or approximately 2 to 3 feet outside of the building lines for the size of the actual excavation hole. In either case, inform your equipment operator as to what your lines represent.

Other than the 3-4-5 triangle method, there are two other techniques to establish square corners. One is measuring the diagonals of rectangular areas to see if the diagonals are equal. Also you can use two tapes that intersect to determine the remaining points of the layout. These methods are shown in Figure 3.

If considerable excavation is required, as is often the case where we work in coastal Maine, it is a good idea to extend one of the primary building lines (see Figure 4) with stakes set well away from any excavation work. These stakes can then be used to re-establish your primary building line after the foundation hole is dug.

Excavation

It is important to thoroughly go over the site and foundation plan with your excavation contractor — preferably first in your office where you can better express your special concerns and specifications. Strongly request (I hesitate to say demand) quality, experienced equipment operators and make sure they understand the plans. Also it helps to keep the same operators throughout the job for consistent quality and more important, for familiarity with the specific job. This should be understood with your excavator.

During the excavation it is necessary to spend time observing the work and the soil conditions being encountered. You should make changes quickly if you see problems arising. Don't hesitate to stop the bulldozer in mid-stream if you feel you need to check a measurement or set up your level to check their work. You're paying for their time — and it sends the message that you're not afraid to check their work and demand quality. It is important to check that the footing excavation is level so you don't end up with a footing pour 3 inches deep at one end and 12 inches deep at the other. Either set up your level or ask the excavator to check with his level. I also strongly feel that anyone, from the boss on down, must be willing to get down in the muck and mud and find out what's going on. If you're not willing to do this but are just trusting that everything will come out right, you're in the wrong business.

Another item that should not be slighted is providing adequate ramps for the concrete trucks. Make sure that they are built wide enough, long enough, high enough, with solid packing gravel, and with the entire foundation accessible. Again, dealing with problems such as stuck concrete trucks on inadequate ramps can lead to inferior work because valuable manpower is spent in the wrong place.

During the excavation itself is when water or bedrock problems will force their presence on your consciousness, often in the form of cries for help from an excavator. If problems occur, the options at this point include: relocation of the building away from the problem, raising the building elevation above the water or ledge, or more likely, dealing with the problem as it exists.

We recently encountered ledge on a site. We didn't blast. The ledge was scraped clean by hand after the backhoe did what it could, the foundation perimeter was laid out, and then holes were drilled every 2 feet for pinning the foundation to the bedrock with short pieces of rebar. Where bedrock intrudes only slightly into a basement area, it is advisable to skim it with concrete, rather than endure the delays and expense of blasting to remove rock.

At another site we encountered a considerable spring (see Figure 5). Situations like these demand creative, on-the-spot, and cost-effective solutions.

Using the Transit

At this point, before we climb into the excavated foundation hole to lay out our building lines for the second time, a discussion of the transit is in order. If you are trained as a carpenter, you know that you should treat your instrument carefully, you know how to set up and level it, you assume that it gives correct readings, you use it, and that's about it. (See "Transit Terms,"). But how do you know if your instrument is reading accurately, and why does it seem to disagree with the foundation contractor's level? Most people don't field test their levels, or have them shop-adjusted very often.

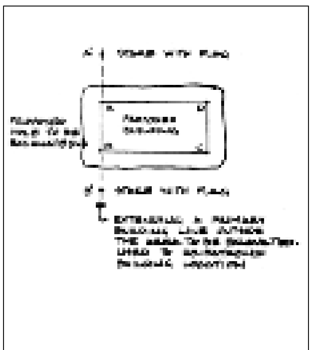


Figure 4. *When considerable excavation is required, it is a good idea to extend one of the primary building lines with stakes set well away from any excavation work. These stakes can be used later to re-establish your primary building line after the foundation hole is dug.*

Figure 5. *Too late in the excavation, Design Extension and Builders discovered a spring in the daylight basement area of a foundation. The solution was to backfill both sides of the frost wall with crushed stone for continual drainage, create several bond-outs through the footing to equalize inside and outside water pressure, and provide a permanent 6-inch drain pipe to direct the spring water away from the building.*

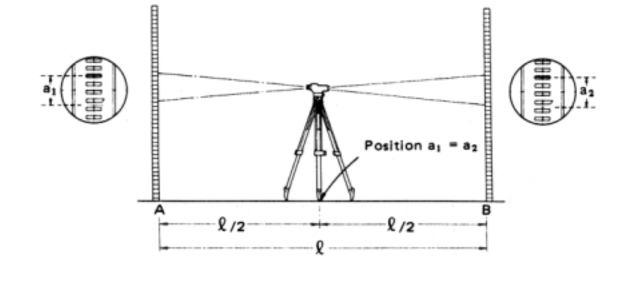


Figure 6. *For maximum accuracy, "mean out" errors by taking transit readings from the center of your work. If this isn't possible, take readings both ends of the work, and take the average of the two readings.*

GENERAL PRECAUTIONS

1. Be sure to carry the instrument to the job site in the plastic case
2. Handle with care.
3. Do not place the instrument directly on the ground.
4. After taking the instrument and accessories out of the plastic case, be sure to close the case over to keep out dust and dirt.
5. Use both hands to hold the instrument when carrying it at the job site. When carrying the instrument mounted on the tripod, do not bang it against obstacles.
6. If the instrument is left mounted on the tripod for any length of time, cap the objective lens and cover the entire instrument with the vinyl cover provided.
7. Be careful not to expose the instrument to direct sunlight and rain. If it gets wet, wipe it with a dry cloth before putting it back in the plastic case.
8. Store the accessories in the specified places in the case.

Figure 7. *The manual for the Lietz automatic level lists precautions that may seem excessive, but according to the author are necessary to keep your level working true.*

According to Jeff Whiting of Maine Surveyors (Yarmouth, Maine), probably only 10 to 15 percent of the instruments in the field are accurately adjusted. This may sound pretty discouraging, but before you revert to using the water-in-a-hose method, listen to this statement from Jeff: "Surveying instruments are designed to mean out errors. Technique is everything. You can use a completely unadjusted instrument to do perfect work so long as the correct procedures are followed." The secret of these "correct procedures" is disarmingly simple. It all has to do with meaning (or averaging) out errors. To do this, you set up your instrument whenever possible in the center of the area to be measured or leveled. In that way, any out-of-adjustment factor will be equally compensated (see Figure 6). Conversely, shooting from one end of the site will only magnify the error, the further away you take your reading. If it is not possible to position the instrument in the center of your work, take readings from both ends of the work, and take the average of the two readings.

Maintenance of your leveling instrument is crucial. Figure 7 shows the precautions listed in the Lietz Level operation manual. If you think these precautions are excessive, catch this final quote from Jeff Whiting, "The way I look at it is, if most of these builders were hunters and they treated their guns the way they treated their transits and levels, the things would blow up in their faces every time they pulled the trigger."

> "If most of these builders were hunters and they treated their guns the way they treated their transits and levels, the things would blow up in their faces every time they pulled the trigger."

Jeff recommends repair and adjustment of your instrument every six months. This check-up should cost in the $20 to $40 range. Procedures for field adjustments are contained in your owner's manual should you care to do it yourself.

This leaves only the most crucial factor, the foundation contractor. Reputation will usually precede a good foundation crew, and they will be well worth hiring if you can schedule them to fit your needs. Good foundations, a well-prepared and excavated site, on-site presence and availability of your company's supervisor, preliminary office meetings, a good contract, and finally, prompt payment, will help get you on a good foundation contractor's "A" list. Assuming you have laid out some corner markers in the excavation and have provided a level surface on which to form footings, everything should proceed without problems.

The footing layout is usually done using your corner stakes and checking for square as described earlier. I have not seen the use of strings and batten boards staked beyond the foundation corners for quite some time. Foundation crews don't have the time to do this type of setup and are comfortable with checking their footing forms as they install them. Setting the footing forms, inspection by a code officer before pouring concrete (required in many towns), and the pour itself, are normally all done in one day.

After the footings are stripped, usually the next day, the foundation crew will chalk out their wall lines on the footings. I have rarely seen the use of the transit at this stage to determine or "turn" corners; much more common is the use of the 3-4-5 triangle, measuring diagonals for equal distances, and cross-taping as previously illustrated.

The aligning of the wall forms is usually done by setting the forms on lines chalked on the footings, then straightening the forms with the use of strings blocked off at the top of the form corners. This is exactly the same method as used to straighten wood framed walls. Check the form work yourself by sighting down the forms, or checking 90-degree corners by the 3-4-5 method. The foundation crew may give you a hard time about checking their work but they'll know you're expecting accuracy.

Setting the elevation of the pour inside the forms is usually done with a transit- and by nailing finish nails inside the forms every few feet at the correct elevation. Here is where the previous discussion of the use of the transit is relevant. Most foundation crews will set their transit location arbitrarily and take all readings from one point. This is fine if the instrument is accurate; if it is not the readings may be off. You can ask when their instrument was last adjusted, suggest re-checking the readings with the instrument set in a location opposite from where it was first set, or check it yourself. If you set up your instrument to double check, depending on the foundation crew, they'll either get nervous or tell you to get lost, or words to that effect. But don't forget, you're paying the bills. Another way to try to ensure accuracy would be to specify your criteria (for example, level within 1/4 inch in 50 feet) in your contract, with a penalty clause for substandard work.

Ready for Framing

Throughout the process of preparing a site for building, communication and careful observation are my most effective tools. I don't pretend to know the tricks of every trade involved in a project, so I watch and ask questions. This, of course, helps avoid problems, but it also provides me with an exciting opportunity: to watch the foundation pour. And if you take the precautions described in this article you can be assured that your carpenters will find a square and level foundation on which to start framing. ■

Richard Cooper is a project manager for Design Extension and Builders, Inc., a custom design-build firm located in South Freeport, Maine. He has been working in construction for over 20 years, in renovation, custom housing and light commercial work.