Designing Forms for Tall Concrete Walls

Site-built panels that hold up under stress

by William Doran

"Stop the pour!"

The words echoed through the basement, loud enough to be heard over the transit-mix truck's engine and the grinding pulse of the pumper.

"I've heard that before," said the driver to nobody in particular. "That's the cry of panic."

The problem started when a snap tie snapped at the wrong time. My friend Charles, a builder who specializes in remodeling, was used to building his forms with plywood and snap ties. He'd never had a problem with the system and didn't bother sizing the ties or spacing them to suit different circumstances. He used what he had on hand, and it always held together.

But this time the concrete dispatcher did him a favor by sending three truckloads of concrete in quick succession (he wanted to make up for a year's worth of late deliveries, and it was a slow day at the yard). Filled quickly to their tops, the forms strained against the weight of the soupy concrete. One of the ties popped, and the forms bulged outward. The adjacent ties, already at their limit and now having to pick up the load of the failed tie began to pop in quick succession. In the blink of an eye, the form unzipped, engulfing the laundry room, the water heater and the new furnace in 20 yards of fresh concrete.

Why did the forms fail? Was a tie left out? Were they too far apart? Or was the wall poured too fast? Would stronger ties have made a difference?

In my experience, most carpenters have good instincts when it comes to working with concrete. They know how to build forms and how to brace them against the imposing loads brought to bear by truckloads of fresh transit mix. But I don't know many carpenters who understand the criteria that govern form designs. Few carpenters know what the proper pour rate is or how to proportion the forms to achieve economy in material. Most carpenters overbuild the forms and hope that they'll hang together. Using a form that is significantly overdesigned is almost as bad as pushing an underdesigned form to failure. Both practices waste money, and in the case of failure, somebody might get hurt.

I work for a large general engineering firm in Los Angeles, California, and along with several other engineers, spend a portion of my time designing site-built concrete forms, some of which are very complex. But you don't have to be an engineer to size the forms for straightforward pours—even the 8 ft. to 10.ft. walls that are typically cast for basements or retaining walls. What is necessary is an understanding of what a form should do, what forces are going to be acting on it, what materials are available for building the form and the limitations of those materials. Once you've got a handle on those variables, you can use the table below to design your own forms.

The drawings on the facing page show the two kinds of site-built forms that I recommend. Both use plywood form panels braced by studs or by horizontal members called walers (usually 2x4s or 2x6s). And both use form ties to hold opposing forms together against the pressure of the fresh concrete. I'll talk about these two systems in greater detail, but before I do, let's look at the materials and the hardware used to build them.

Forming materials—In theory, any plywood designed for exterior use can be used in a concrete-forming application. The smoother the face, the better, especially if you plan to use the plywood as forming material more than once. That's because wet concrete will get into the crevices in the face veneers, and when you pull the panels away from the wall, some of the wood fibers will stay with the wall. Soon you will have a ragged, weak panel. Interior plywood is not suitable for forming because it delaminates when wet.

A product called Plyform is produced by various mills that are members of the American Plywood Association (APA, P. O. Box 1170, Tacoma, Wash. 98411; 206-565-6600). It is designed specifically for concrete-forming applications. Its veneer is limited to certain species and grades that provide greater uniformity and strength.

Plyform is available in various thicknesses, but we rarely use anything other than ¾-in. unless we are forming curved walls. It costs about 60¢ per sq. ft. Plyform panels are sanded on both sides and have a coating of form oil applied at the mill (form oil is a release agent used to prevent concrete from adhering to forms). If the panels have been idle for some time, however, it's a good idea to re-oil them before use. Also, the APA recommends that the panel edges be sealed before their first use. A book I have on concrete forming says to use aluminum paint, chlorinated rubber-based paint, oleoresinous paint or

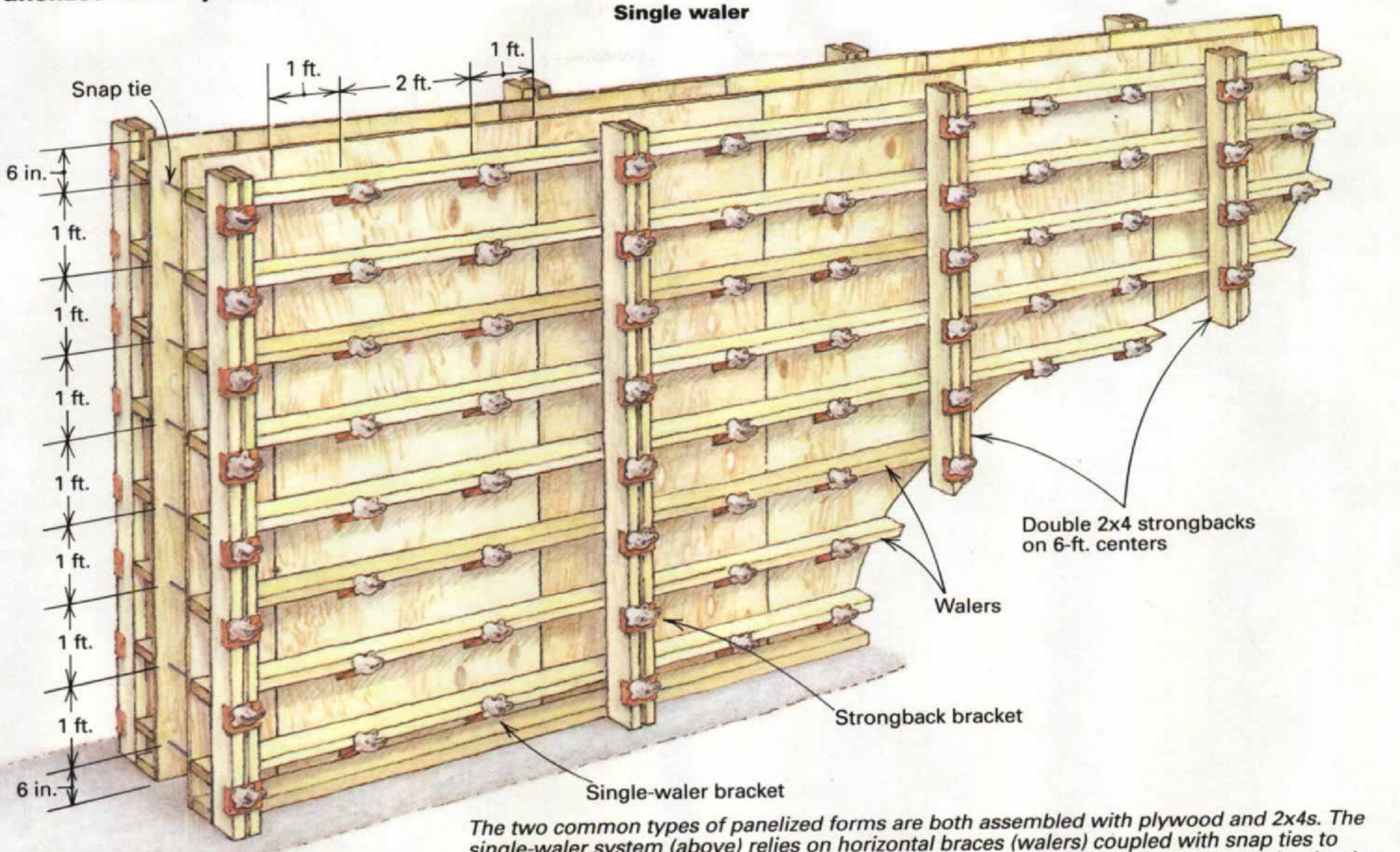
DESIGNING STUD-AND-WALER FORMS

Form thickness	Plywood orientation	2x4 stud spacing	Max. concrete pressure	Max. waler spacing	Horiz. tie spacing	Snap tie required	Concrete temp. and rate of placement (ft./hour) 40°	50°	60°	70°	80°	90°
¾ in.	Paral.	6 in.	1,200 psf	29 in.	16 in.	5,000-lb. snap tie	FLH	FLH	FLH	FLH	FLH	FLH
⅝ in.	Perp.	8 in.	1,200 psf	24 in.	16 in.	4,000-lb. snap tie	FLH	FLH	FLH	FLH	FLH	FLH
¾ in.	Perp.	9 in.	1,000 psf	24 in.	16 in.	4,000-lb. snap tie	3.8	4.7	5.7	6.6	7.6	FLH
¾ in.	Paral.	8 in.	900 psf	29 in.	16 in.	4,000-lb. snap tie	3.3	4.2	5.0	5.8	6.7	7.5
¾ in.	Perp.	12 in.	732 psf	24 in.	24 in.	4,000-lb. snap tie	2.6	3.2	3.9	4.5	5.2	5.8
⅝ in.	Paral.	8 in.	633 psf	36 in.	16 in.	4,000-lb. snap tie	2.1	2.7	3.2	3.8	4.3	4.8
⅝ in.	Perp.	12 in.	576 psf	29 in.	24 in.	4,000-lb. snap tie	1.9	2.4	2.8	3.3	3.8	4.3
¾ in.	Paral.	12 in.	492 psf	33 in.	24 in.	4,000-lb. snap tie	1.5	1.9	2.3	2.7	3.0	3.4
¾ in.	Perp.	16 in.	412 psf	31 in.	24 in.	3,000-lb. snap tie	1.2	1.5	1.7	2.0	2.3	2.6

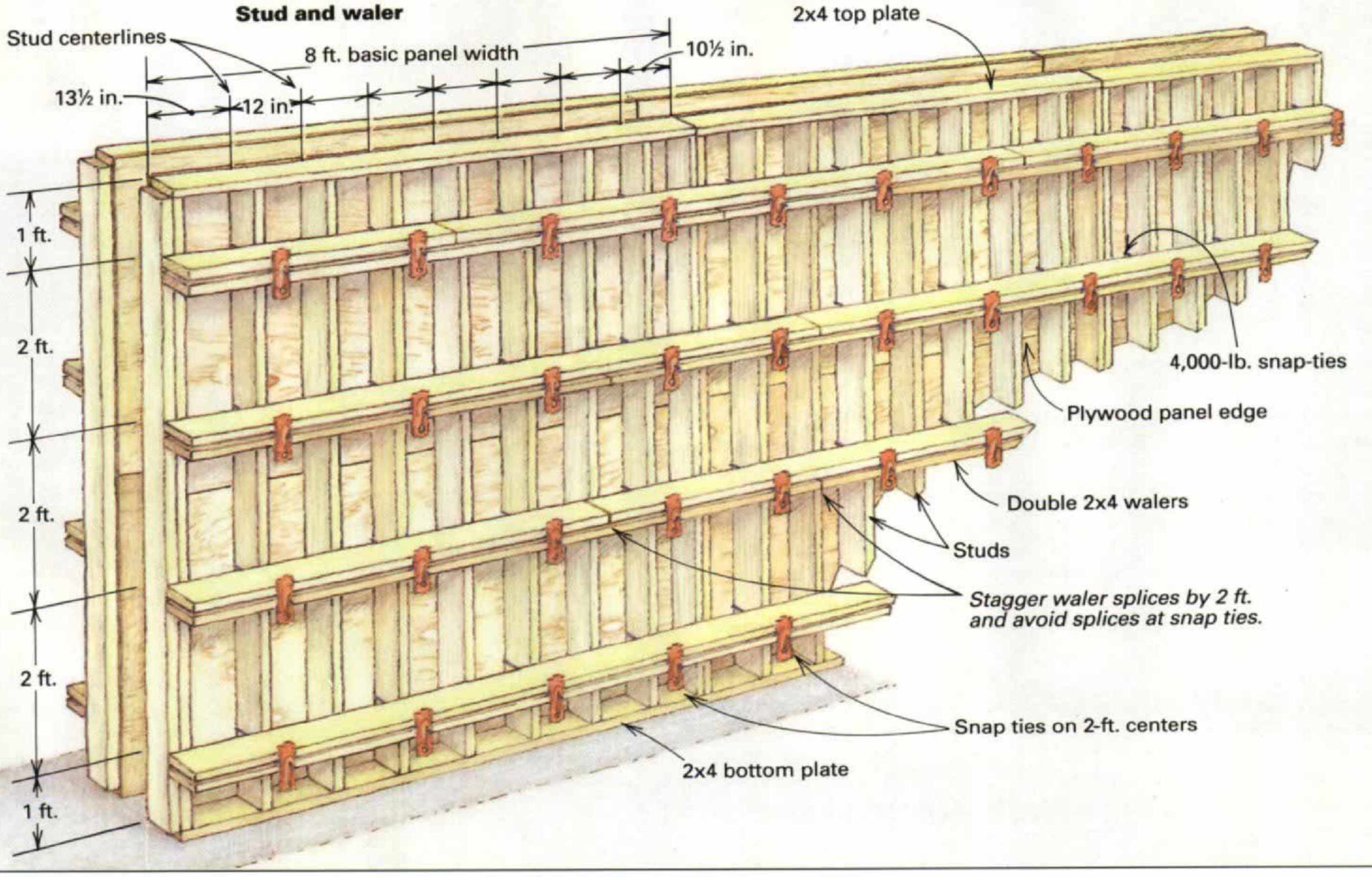
Paral.=Face grain parallel to studs; Perp.=Face grain perpendicular to studs
FLH=Full liquid head (see sidebar p. 52)

This chart shows how you can vary the thickness of the form material, its orientation and the spacing of the studs and the walers to accommodate different concrete temperatures and pour rates. Waler and stud allowable stress is based on #2 Douglas fir, and the forms are a maximum of 8 ft. tall. Walers should be no farther than 1 ft. from the top and the bottom. You can increase the spacing between the top two walers, but no more than 1½ times the normal spacing.

Panelized form systems



The two common types of panelized forms are both assembled with plywood and 2x4s. The single-waler system (above) relies on horizontal braces (walers) coupled with snap ties to resist the force of the wet concrete. The stud-and-waler system (below) uses more lumber but fewer snap ties. It can be designed to take heavier loads than the single-waler system. Note how the plywood is oriented perpendicular to the lumber to resist deflection.



Drawings: Christopher Clapp

urethane coatings for this purpose. But we never seem to have any of those on hand, so we use silicone caulk to seal the edges. It works fine.

According to the APA, it is common to get 5 to 10 uses from a sheet of Plyform, though in my experience the wear and tear of assembling and stripping the forms often take their toll before the face veneer wears out. For purposes of comparing costs with other form materials or rental form systems, I would assume four uses.

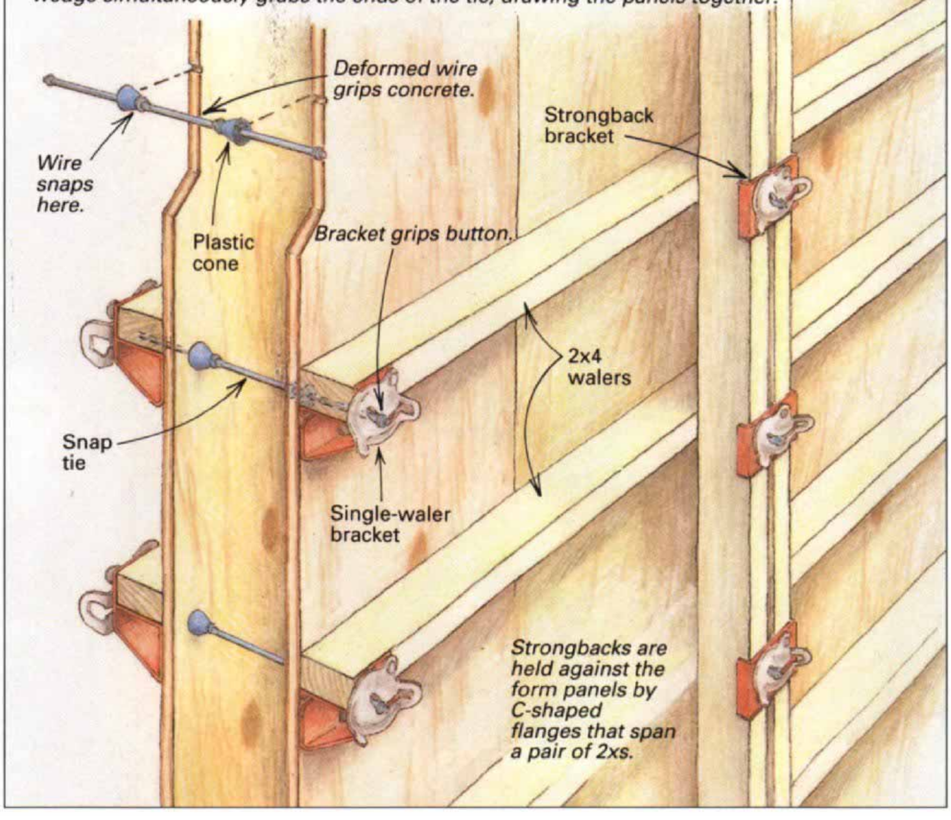
Plyform is also available with a special overlay of resin-impregnated material. It's called High Density Overlay Plyform, or HDO. This overlay makes the panel more resistant to moisture and abrasion. It is also smooth, so knots, plugs or wood grain don't show up in the finished wall. According to the APA, 20 uses are not uncommon, and in my experience this is a fair statement. But because it costs 50% more than Plyform, you've got to have a steady diet of upcoming concrete pours to justify its expense.

Formwork lumber should be relatively light, take nails without splitting, be easily worked and readily obtained. Here on the West Coast we use Douglas fir, but in other parts of the country, the typical formwork lumber may be southern pine, eastern spruce and hem fir.

For formwork, #2 lumber is adequate. Its product classification is called "structural light framing." It is cheaper than #1 but relatively close in strength, and it is considerably stronger than #3. Inspect your formwork lumber and reject any that is badly split or has large knots.

Snap ties and single-waler bracket

The most common form tie is the snap tie. Spanning the inside and outside forms, its plastic cones keep the forms the correct distance apart while the single-waler bracket's wedge simultaneously grabs the ends of the tie, drawing the panels together.



Form-tying hardware—In its plastic state, concrete would much rather be a floor than a wall. It wants to escape whatever constrains it and get as close as possible to Mother Earth. The constraint applied by a wall form is supplied by either external bracing or by devices called form ties, which link the opposing forms to one another and prevent them from moving outward. Form ties fit through holes drilled in the forms.

The most common form tie is called a snap tie. It consists of a high-tensile steel wire with a bolt head or button protrusion on both ends. Two plastic cones on the wire, held a fixed distance apart, control the thickness of the wall by bearing against the forms. Snap ties typically come in 2-in. increments. Hence, you buy 6-in., 8-in., 10-in. or 12-in. snap ties depending on how thick you want your concrete wall.

Snap ties can be used as part of a forming method called the single-waler system that includes triangular steel brackets designed to cradle 2x4 walers while holding the end of the snap tie (drawing left). Another U-shaped bracket can be used to fit over pairs of 2xs. They are used to secure double walers and strongbacks.

The bracket designs vary a bit depending on the maker, but they all use some type of a wedge to apply tension to the end of the snap tie. Jahn brackets (Dayton Superior Corp.), for example, are equipped with an eccentric cam for this purpose. The cam has a takeup of ⅝ in. to secure the waler in place and to take into account the variations that occur in lumber sizes.

In the stud-and-waler system, wedges are used to secure the ends of the snap ties. The wedges used with snap ties have a key-hole slot that fits over the end of the tie. As the wedge is driven with a hammer, the head of the tie pushes the wedge against the waler, which in turn pushes the face of the form against the plastic cones. This correctly spaces the two faces of the form and aligns the faces with the walers.

To strip the form, the wedge or cam is driven the opposite direction. Once the forms are pulled, you twist the ends of the ties. Each tie has a nick in the wire near the plastic cones, which causes it to break inside the plane of the wall. Hence the name snap tie. If the tie has a bolt head, you can twist off the ends with a socket wrench. If not, you can use a pipe placed over the end of the tie. Bend it about 75°, then rotate the pipe until the tie breaks. Incidentally, one of the advantages of the bolt head is that you can break off the ties before you strip the panels. This makes stripping easier because you don't have to pull the panel over the tie.

The cones at the end of the ties are free to move outward and to rotate, which allow them to be removed after the form is stripped. The

Sources of supply

Atlas SCA, P. O. Box 30, San Diego, Calif. 92112; (619) 277-2100.
Wide selection of hardware geared to commercial or large residential projects.

The Burke Co., P. O. Box 467, Ellicott Station, Buffalo, N. Y. 14205-0467; (800) 423-9140.
Single-waler system. Forming hardware.

Dayton Superior Corp., 721 Richard St., Miamisburg, Ohio 45342; (513) 866-0711.
Jahn single-waler system. Full line of form ties and coil hardware.

Gates and Sons, Inc., 90 South Fox St., P. O. Box 9509, Denver, Colo. 80209-0509; (303) 744-6185.
Single-waler system.

Richmond Screw Anchor, 7214 Burns St., Fort Worth, Texas 76118; (817) 284-4981.
Single-waler hardware, specialty ties geared to heavy construction but of potential interest to the home builder.

RJD Industries, Inc., 26945 Cabot Road, #107, Laguna Hills, Calif. 92653; (714) 582-0191.
Fiberglass form ties.

Williams Form Engineering Corp., P. O. Box 7389, Grand Rapids, Mich. 49510; (616) 452-3107.
Single-waler hardware, specialty ties geared to heavy construction but of potential interest to the home builder.

Alternative form ties

Most residential walls can be cast using snap ties to hold the forms together. But if you spend any time pouring concrete, you're going to run into a situation where snap ties just won't do. The alternatives listed here can solve a variety of forming problems. In addition, concrete-accessory companies make specialized hardware that can be useful to anyone building with concrete (see "Sources of supply" on the facing page).

Pencil-rod ties—You can use steel rods with a special clamp to tie two sides of a form together (top left drawing, below). The rod may be cut to any length and thus used to tie across large distances. I've used pencil rods with good results to tie across the corners of thick walls and to tie forms that vary in thickness, such as those used to cast battered walls. But there are no spacers on the rod to hold the faces of the forms at the proper distance apart. One solution to this problem is to make sleeves out of PVC pipe that fit over the rods inside the forms.

The load capacity of a pencil-rod tie depends on the diameter and the strength of the rod. Typical values are 1,000 lb. for ¼-in. rods to 7,000 lb. for ⅝-in. rods. Check with the supplier for actual values.

The fiberglass tie is a pencil-rod variant that won't rust, so it can be used in walls that will be near corrosive moisture, such as salt water. A fiberglass tie is also nearly invisible when you cut it off flush with the wall, so you don't have to patch holes made by snap-tie cones. RJD Industries makes them.

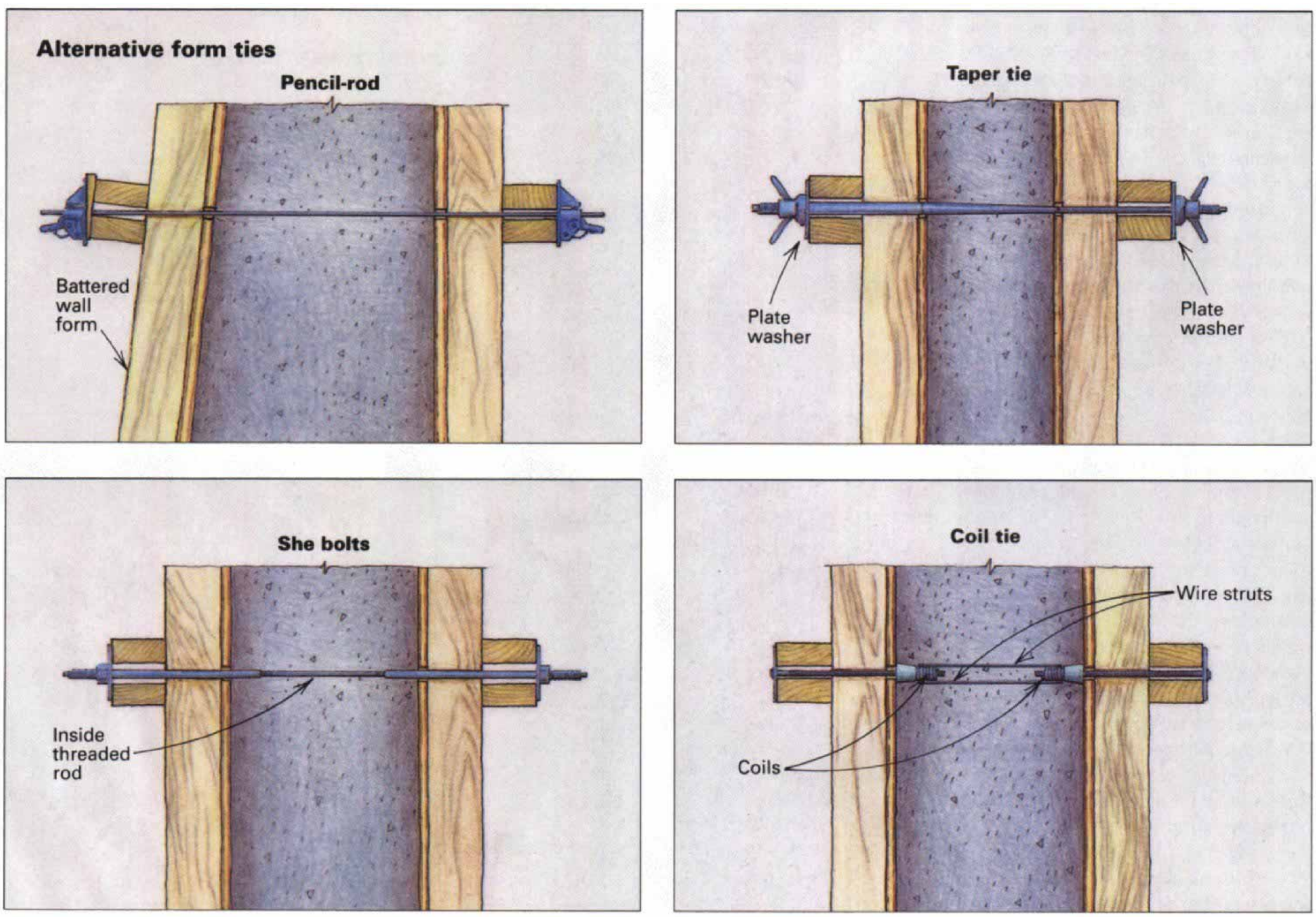
Taper ties—A taper tie consists of a rod, threaded on each end and tapered along the inside faces of the forms (top right drawing, below). Washers and nuts at each end of the ties keep the form from moving outward. Taper ties are used where it is either necessary to remove the tie from the wall or where the tie spacing produces a high loading on the tie. The tapered portion between the form faces allows the tie to be driven out from the small-diameter end and reused. No spacers are provided with this type of tie, and some other means must be used to hold the form faces the correct distance apart. Allowable load values range from a few thousand pounds to over 40,000 lb.

She bolts—She bolts are similar to taper ties except that they are externally threaded on only one end. The other end has internal threads (bottom left drawing, below). The bolt tapers toward the internally threaded end. Usually one she bolt is used on each side of the form and connected to a threaded rod inside the wall. The inner rod remains in the concrete.

To remove a she bolt, remove the nuts and unscrew the she bolt from the inner rod. The tapered portion of the bolt breaks free of the concrete almost immediately so that by the time the bolt is unscrewed from the inner rod, there is no longer any resistance. The threaded ties that connect she bolts can be as long or short as required. When she bolts are coupled with short threaded ties, the steel that remains in the wall ends up several inches from the face of the wall, which can be helpful when moisture and corrosion are a consideration. Allowable load values for she bolts vary, depending on size and range, from a few thousand pounds to over 30,000 lb.

Coil-tie hardware—The principal parts of a coil-thread system are a helically wound coil of wire and a bolt with special threads that grip the coils (bottom right drawing, below). Coil-wire products are quite versatile: If you have to pour a new wall next to an old one, you can grout wire coils into holes drilled in the old wall and use them to anchor the forms in place.

When linked by wire struts, wire coils become form ties. They are placed between the two form faces, and coil bolts are passed through the walers and screwed into the coils. When stripping the forms, the coil bolts are removed, and the tie remains. Some manufacturers make coil ties with plastic cones similar to snap ties so that the coil tie acts as a form spreader too. Different manufacturers use different thread patterns for their coil-wire hardware. They aren't interchangeable. ***—W.D.***



dimple left by the cones is then patched with grout. Snap ties commonly have an allowable load of 3,000 lb., 4,000 lb. or 5,000 lb.

Snap-ties are fast and easy to install, relatively cheap and self-spacing. On the downside, snap ties are labor intensive when it comes time to patch the holes that they make in the wall. And in wet conditions, the metal left by the remaining portion of the tie can be subject to corrosion–even when it's buried under a grout patch.

For most walls, snap ties are the best choice. But there will be cases where snap ties won't work because they aren't the right length or strong enough. The sidebar on p. 51 describes several alternative ties.

Walkways—We insist on putting walkways on any forms over 4 ft. It's just a lot safer and easier on the crew if they don't have to worry about where they're going to put their feet when they are concentrating on filling the forms.

For walkways, I recommend the prefabricated steel scaffold jacks that are designed to be secured to the walers. The jacks are available from the same companies that make the form hardware, and they can be reused many times.

Resist the temptation to stack heavy materials on walkways supported by scaffold jacks. They are designed to take the weight of a couple of workers–not piles of rebar, blocks of concrete and sacks of cement.

Two form systems—Site-built forms must be easy to assemble and strip; they must not unduly deflect; they must be easy to plumb and line; and they must be safe. The first system that fits these criteria is called the stud-and-waler system (bottom drawing, p. 49). It is made up of panels that are held plumb by studs. Horizontal walers hold the form straight. We typically prefabricate 8-ft. by 8-ft. panels. We use two 16d sinkers top and bottom to secure the plates to the studs, and 8d commons on 2-ft. centers to affix the plywood to the studs and the plates. Running the plywood perpendicular to the studs always makes for a stronger form.

When you put the studs close together, the stud-and-waler system can take a lot of weight. The drawing shows an 8-ft. form that can take a pour rate of 4½ ft. per hour at 70 ° F. By shortening the distance between studs to 8 in. and shortening the tie spacing to 16 in., the form can withstand full liquid head (see sidebar above). That means the form will contain 8 ft. of concrete that hasn't yet begun to set up.

Our crew likes to use the stud-and-waler system for long, straight runs of wall. The panels can be made up in advance, and the horizontal walers keep the number of ties necessary to a minimum. Ties on 2-ft. centers in both directions are typical for this system. That means less work patching the snap-tie holes. I also think we get a little more mileage out of our materials with the stud-and-waler system because the plates and studs around the perimeter of the panels tend to protect the edges of the plywood, which is where the panels start to deteriorate.

I don't think hand-set form panels should be any bigger than 8 ft. by 8 ft Anything larger is too

Calculating concrete pressure

Before you can design the forms for a concrete wall, you need to know the maximum pressure that the concrete will exert against the forms. The table below shows in pounds per square foot (psf) how the temperature of the concrete and the depth of the pour affect that pressure.

Fresh concrete approximates the behavior of a true fluid, which means the pressure increases at a constant rate with depth, and the pressure at any point within the fluid is the same in all directions. If the concrete remained fluid throughout the pour, the equation would be simple: the height of the form multiplied by the unit weight of the concrete (150 lb. per cubic ft.). Thus, for a 4-ft. high wall poured in one lift, the pressure at the bottom of the wall would be 4 ft. x 150 lb. or 600 psf. For an 8-ft. high wall poured in one lift, the pressure would be 8 ft. x 150 lb. or 1,200 psf. The pressure exerted on a form filled with fluid concrete is called "full liquid head."

Concrete, however, is not a perfect fluid because, as it passes from the plastic state to a solid state, it starts to support itself. How fast this transition occurs is a function of temperature—the higher the temperature, the sooner the concrete starts to set up.

Other factors that affect the pressure on the forms are the weight of the concrete, how fast it is placed, whether or not the concrete is vibrated in the forms and how far the concrete falls as it enters the forms.

A committee of the American Concrete Institute came up with this pressure formula for walls with a pour rate of 7 ft. per hour or less*:

$$p = 150 + (9{,}000 \times R/T), \text{ where}$$

p = pressure in lb./sq. ft.
R = rate of placement in ft./hour
T = temperature of concrete.

Say you plan to pour an 8-ft. wall in two lifts of 4 ft. per hour with a temperature of 60°. To find the maximum pressure exerted on the forms under those conditions, first divide 4 by 60. Multiply the answer (.067) by 9,000. Add that number (603) to 150. The answer is 753 lb. per sq. ft.

Now look at the table on p. 48 under "Max. concrete pressure." The fifth entry shows 732 psf, which is within the 5% margin I feel comfortable with. I'll choose the form called for in this column. It says to use 4,000-lb. snap ties on 2-ft. centers, ¾-in. plywood oriented perpendicularly, studs on 12-in. centers and waters spaced 2 ft. apart.

The tables also allow you to work backwards in calculating a pour. For example, if your forms are in place, and the weather turns cold, adjust the pour rate according to the table. Check the concrete's temperature as it comes off the truck, and call your batch plant if you are unsure about the correct pour rate. —*W. D.*

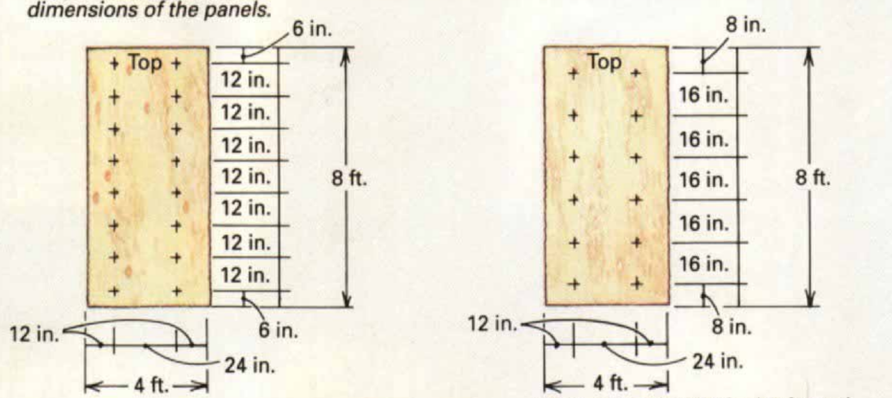
***This formula applies to normal-weight concrete (150 psf) made with type I cement and having a slump of 4 in. Admixtures may increase the pressures.**

Placing rate (ft./hour)	CONCRETE TEMPERATURE (F) 40°	50°	60°	70°	80°	90°
1	375 psf	330 psf	300 psf	279 psf	263 psf	250 psf
2	600 psf	510 psf	450 psf	407 psf	375 psf	350 psf
3	825 psf	690 psf	600 psf	536 psf	488 psf	450 psf
4	1,050 psf	870 psf	750 psf	664 psf	600 psf	550 psf
5	1,200 psf	1,050 psf	900 psf	793 psf	713 psf	650 psf
6	1,200 psf	1,200 psf	1,050 psf	921 psf	825 psf	750 psf
7	1,200 psf	1,200 psf	1,200 psf	1,050 psf	938 psf	850 psf
8	1,200 psf	1,200 psf	1,200 psf	1,090 psf	973 psf	881 psf

The pressure of concrete on wall forms varies depending on the temperature and how fast the concrete is placed in the forms. Numbers are based on an 8-ft. tall form.

Single-waler snap-tie spacing

Snap ties are typically spaced on centers that are compatible with the 4-ft. by 8-ft. dimensions of the panels.



12 in. vertical by 24 in. horizontal snap-tie spacing
Pour rate: 4.5 ft./hour at 70° F.

16 in. vertical by 24 in. horizontal snap-tie spacing
Pour rate: 1.7 ft./hour at 70° F

heavy. The average person can comfortably lift and carry about 70 lb. A ¾-in. thick sheet of plywood weighs about 72 lb., and if you add a stud frame 12 in. o. c., you've got another 70 lb. or so. Thus one person can carry a full sheet of plywood; two people can carry a 4-ft. by 8-ft. panel consisting of ¾-in. plywood and stud frame; and four people can handle an 8-ft. by 8-ft. panel.

The second system is called the single-waler form (top drawing, p. 49). Unlike the stud-and waler system, single-waler forms use no nails. The walers hold the form straight, and every 6 ft. a pair of vertical 2x4s, called a strongback, holds the form plumb and keeps the stacked panels in the same plane. With the single-waler system, the plywood panels are stood up vertically, again to keep the face grain perpendicular to the supports, which in this case are horizontal walers. Although the single-waler system doesn't lend itself as well to fast, tall pours, it is easier to set than the stud-and-waler version because there is less lumber involved. And when disassembled, the plywood panels don't take up much room because the lumber isn't nailed to them.

There are two typical tie spacings for single-waler forms (bottom drawing, facing page). Placing ties 12 in. apart vertically and 24 in. apart horizontally will take a pour rate of 4½ ft. per hour at 70° F. If you open up the spacing to 16 in. vertically by 24 in. horizontally, you can pour at 1.7ft. per hour at 70° F.

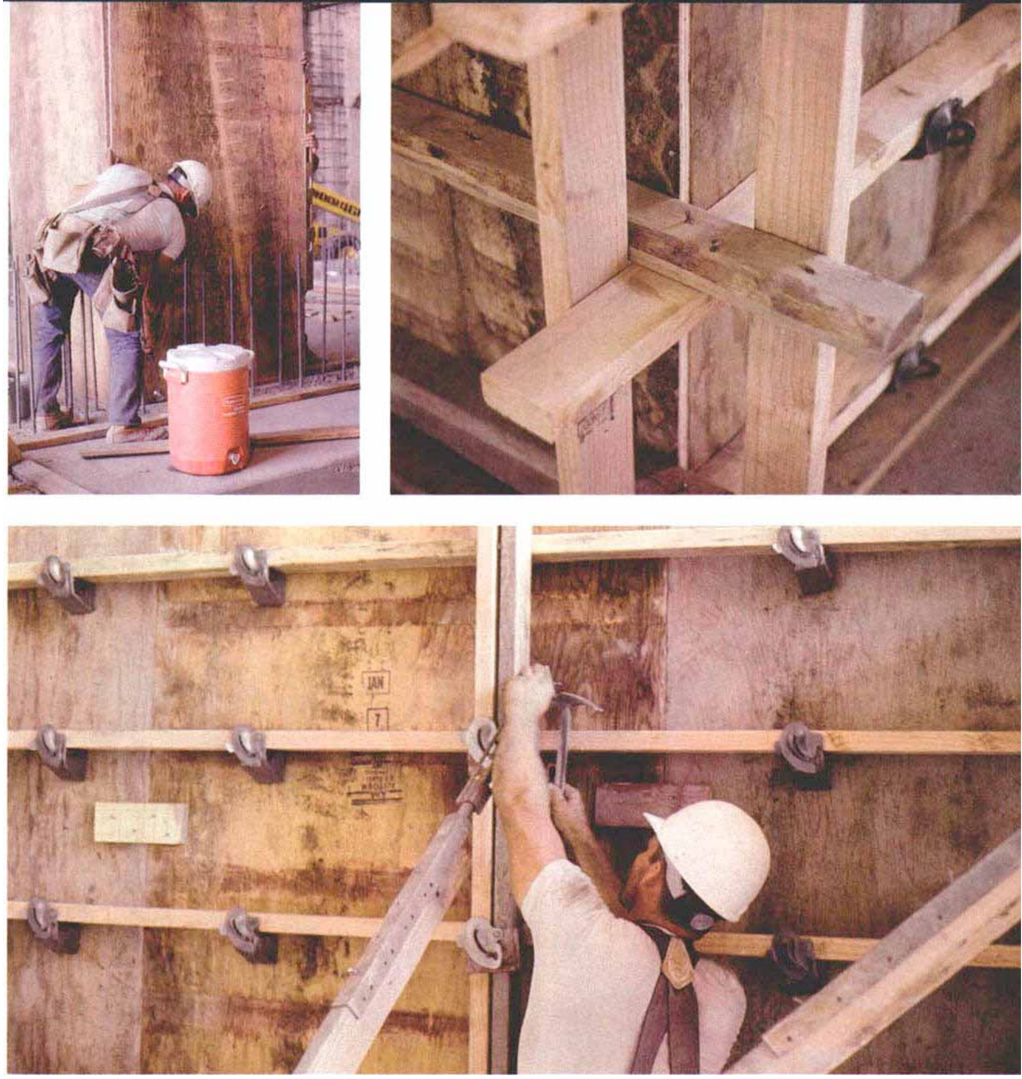
Assembly tips—Before erecting the forms, you should spend a couple of hours planning their placement. The goal always is to use as many full panels as possible, and they need to be. opposite one another for the snap-tie holes to be aligned. Even if the plan isn't perfect, it will be better than no plan at all. Here are some rules to guide you: lay out the forms on paper first; consider how you will get the rebar into place; cut fillers from full panels and drill the tie holes after they are erected; leave no filler section untied for a distance greater than the spacing of the ties. The typical place to start erecting the panels is at an inside comer (top left photo, above).

Form panels bear against 2x4 plates at the bottom. We affix the plates to the footing by drilling ¼-in. dia. holes every 2 ft. through the plates and into the footing with a hammer drill. Then we drop in a pair of 16d nails—one common and one duplex. They wedge each other in place and work as well as a powder-actuated fastener for forming, plus they can be easily removed.

Once the plates are down, we stack up the plywood panels and gang-drill them for the ties with a ⅝-in. spade bit or auger. We drill four sheets at once, using one of the sheets as a template.

When all the inside panels are raised, braced and affixed to one another with cleats across their tops, insert the form ties and assemble the brackets and the lumber. The inside wall should be substantially complete, with the ties sticking out from the wall. Now hang your rebar and raise the outside forms. Where full panels won't fit in the wall, rip plywood form fillers to fit.

Run the walers long at outside comers and lace them one over the other. Then tie them together with vertical 2x4s (top right photo, above).



Building the forms. **Once the plates are affixed to the footing, the formwork panels can be raised. An inside corner is a good place to begin because full panels can be used, and they become self-supporting when tacked together. In the top left photo above, a worker plumbs a panel while the other nails it to the adjacent panel. To brace outside corners, let the walers run wild past the panels (top right photo, above). Then tie them together with duplex nails and vertical 2x4 ties. In the bottom photo above, a worker affixes a turnbuckle form brace to the end of a 2x4. Placing the turnbuckle at the top makes it easy to adjust the form to plumb.**

Bracing—Because they are tied to one another internally, these forming systems don't require external bracing to resist the load of the concrete. But they do need braces to keep them plumb and to keep the wind from moving them. Anyone who has tried to pick up a piece of plywood in a strong wind will appreciate the force that the wind can exert on a broad panel.

For forms that are 8 ft. high or lower, setting a braced 2x4 at 45° every 4 ft. should handle the loads imposed by normal wind conditions and the bumps from construction activity. Our superintendent puts strongbacks on single-waler forms at the same frequency to keep them plumb, so they do double duty. We use the turnbuckle-type braces that are affixed to the end of a 2x4 to plumb the forms (bottom photo, above). In dirt, we nail the other end of the brace to a stake. If we're bracing to a concrete floor, we use powder-actuated fasteners or nails in drilled holes to anchor cleats to the floor for the stakes. The forms only need to be braced on one side. □

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FOR MORE INFORMATION

WCD-3 Design of Wood Formwork for Concrete Structures, National Forest Products Association, Publications Department, 1250 Connecticut Ave., N. W, Suite 200, Washington, D. C. 20036. $4 plus shipping and handling.

Concrete Craftsman Series-2: Cast-in-Place Concrete Walls ($ 11.95), *SP-4 Formwork for Concrete* by M. K. Hurd ($100.95), American Concrete Institute, P. O. Box 19150, Detroit, Mich. 48219.

Formwork to Concrete by C. K. Austin, University Microfilms International, Books on Demand, 300 North Zeeb Road, Ann Arbor, Mich. 48106. $81.40 plus shipping and handling.

Cast-in-Place Walls, Portland Cement Association, Order Processing, 5420 Old Orchard Road, Skokie, 111. 60077-1083. $12.95 plus shipping and handling.

Concrete Masonry Handbook for Architects, Engineers, Builders, Portland Cement Association (address above). $29.50 plus shipping and handling.

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