$28.75

CONCRETE CONSTRUCTION

by Ken Nolan

Craftsman Book Company
6058 Corte del Cedro / P.O. Box 6500 / Carlsbad, CA 92018

Acknowledgments

Alabama Metal Industries Corporation, 3245 Fayette Avenue, Birmingham, AL 35208
APA — The Engineered Wood Association, PO Box 11700, Tacoma, WA 98411
Calculated Industries, 4840 Hytech Drive, Carson City, NV 89706
Cardinal Manufacturing Company, Inc., Form-A-Key Products Division, PO Box 14127, Louisville, KY 40214
CertainTeed Corporation, PO Box 860, Valley Forge, PA 19482
Concrete Reinforcing Products, PO Box 100527, Fort Lauderdale, FL 33310
David White, 255 W. Fleming Street, Watseka, IL 60970
Greenstreak, 3400 Tree Court Industrial Blvd., St. Louis, MO 63122
International Code Council, Inc., Falls Church, VA
Soff-Cut International, Inc., 1112 Olympic Drive, Corona, CA 92881
Steinke Bros. Inc., Chamforcor CFC Products, Milwaukee, WI
Superior Profiles, 1325 Bixby Drive, Industry, CA 91745
SureVoid Products, Inc., 1895 West Dartmouth Avenue, Englewood, CO 80110
Symons, by Dayton Superior, 2400 Arthur Avenue, Elk Grove Village, IL 60007

This book is dedicated to Barbara, for 45 years of encouragement.

Library of Congress Cataloging-in-Publication Data

Nolan, Kenneth J., 1943-

Concrete construction / by Ken Nolan.
p. cm.
Includes index.
ISBN 978-1-57218-237-0
1. Concrete construction. I. Title.

TA681.N65 2010
693'.5—dc22

2010018865

CONTENTS

1

CONCRETE: THE MAN-MADE STONE

Concrete is a remarkable material that can be cast into almost any shape. If properly reinforced, it supports tremendous loads and stresses. Quality concrete work produces long-lasting structures that are pleasing in appearance and require very little maintenance. It's one of the most versatile, economical and commonly-used construction materials.

Concrete is used in buildings, bridges, sewers, culverts, foundations, footings, piers, abutments, retaining walls and pavements. No matter what its final use, concrete's makeup is basically the same worldwide: a mix of portland cement, aggregates, and water. Its strength is determined by the amount of portland cement in the mix, the size of the aggregate used, and the amount of water added.

People sometimes call a concrete floor a cement floor, but the terms aren't really interchangeable. Cement alone is just dust. Add water and it becomes a paste. Add in the aggregates and it becomes concrete. The aggregates, usually sand and gravel or crushed rock, are the inert ingredients of the concrete mix. The portland cement and water are the active ingredients.

The first requirement for good concrete is high-quality cement. (We'll discuss the various types of cement later, along with how to handle them.) Next is a reliable supply of clean sand and coarse aggregate. Finally, you need clean water. Mix the cement and aggregates together. When water is added to the mix, it starts a chemical reaction with the portland cement called *hydration*. It's this chemical reaction that hardens the mixture into concrete. The process of hydration doesn't mean that the concrete is "drying out." On the contrary, you must keep concrete moist during the initial setting period. Concrete will even harden under water, which is one reason it's an ideal foundation material.

The principal factor in controlling the strength of concrete is the water-to-cement ratio — but consistency is also important. To build a uniform concrete structure, you need to create mixes with the same proportions of ingredients each time.

> *"Hardened concrete can be strong, watertight, and resistant to the elements — or weak and unreliable. Everything depends on the quality of workmanship."*

The compressive strength of concrete, measured by the pounds per square inch (psi) of pressure that cured concrete can withstand, is very high. However, its tensile strength — the ability to resist stretching, bending, or twisting — is very low. That's why concrete must be reinforced with steel or some other product. Building codes throughout the country regulate the design of reinforcing in concrete structures. In earthquake zones or tornado-prone areas, they need additional engineered reinforcement. It's a wise contractor who works with the code office and checks out the correct reinforcement requirements before starting construction.

Freezing and thawing are concrete's worst enemies, especially when it's in the curing stage. We'll discuss preventative measures to use in freezing temperatures later. Concrete can withstand a tremendous amount of heat. Because of its resistance to fire, it's the material of choice in fire-hazard areas.

Concrete is fairly predictable. Knowledgeable contractors can usually control the setting time with additives or placing and curing methods. Any contractor using concrete has to understand its variables. After all, once water is added to cement, it will harden. You can speed up or slow down this process, but the bottom line is that the concrete will get hard. Hardened concrete can be strong, watertight, and resistant to the elements — or weak and unreliable. Everything depends on the quality of workmanship.

Storing Portland Cement

An important point to remember is that portland cement is moisture-sensitive. You must be careful how you store it. If kept dry, it will retain its quality indefinitely. But if stored in contact with damp air or moisture, portland cement will set more slowly and have less than optimum strength. Whenever possible, store bagged cement in a warehouse. Cover any cracks and openings in storehouses. If you have to store it outdoors, pick a shaded area, stack the bags on pallets and cover them with a waterproof covering.

Types of Portland Cement

The American Society of Testing Materials (ASTM) Designation C150 discusses types of cement and their characteristics. Portland cement is the most active component of concrete, and usually the most expensive. Type II is a hydraulic cement that forms a water-resistant product as it hardens. Selecting and using the proper cement is important in achieving the best mix at the most economical price. Fortunately, the widespread availability of limestone, shale, and other naturally-occurring materials used in its production helps keep portland cement affordable.

> ***ACCORDING TO*** the U.S. Dept. of Transportation, Federal Highway Administration, more than 92% of the portland cement produced in the United States is Type I and Type II. Type III cement accounts for about 3.5% of cement production, and Type IV cement is only available on special request. Type V cement (less than 0.5% of total production) may also be difficult to obtain.

Different types of portland cement are manufactured to meet different physical and chemical requirements for specific purposes. Type I and II portland cements, which provide adequate levels of strength and durability for most applications, are the cements used most often for concrete. However, specialized applications may require other cements that provide higher levels of certain properties. Using high-early-strength cements for pavement repairs and blended cements with aggregates susceptible to alkali-aggregate reactions are examples of such applications.

Although IA, IIA, and IIIA (air-entrained cements) are available as options, concrete producers prefer to use an air-entraining admixture during concrete manufacture. This gives them better control over the desired air content. But air-entrained cements can be useful under conditions where there's no way to measure the air content of fresh concrete.

The availability of portland cements will be affected for years to come by energy and pollution requirements. In fact, increased attention to pollution abatement and energy conservation has already greatly influenced the cement industry, especially in the production of low-alkali cements. Using high-alkali raw materials in the manufacture of low-alkali cement requires bypass systems to avoid concentrating alkali in the clinkers, which consumes more energy. If the type of cement you need isn't available, you can get comparable results by modifying available types. High-early-strength concrete, for example, can be made by using a higher content of portland cement or by using admixtures such as chemical accelerators or high-range water reducers (HRWR).

Blended Portland Cements

Blended cement, as defined in ASTM C595, is a mixture of portland cement and blast furnace slag (BFS) or a mixture of portland cement and a pozzolan (most commonly fly ash). Blast furnace slag mixtures are classified as IS, I(SM) and S.

There are several benefits to using blended cements in concrete. These include:

- reduced amount of mixing water needed
- reduced bleeding
- improved workability and finishability
- enhanced sulfate resistance
- inhibited alkali-aggregation reaction
- reduced heat generated during hydration, which reduces the chance of thermal cracking on cooling

Concrete mix plants can provide specialty concrete mixes to suit your specifications by adding admixtures at the plant.

Modified Portland Cement (Expansive Cement)

Expansive cement increases in volume significantly more than plain portland cement during the early hydrating period. Concrete placed in an environment where it loses moisture will begin to shrink. The amount of shrinkage depends on the characteristics of the materials, the mixture proportions, and the placing methods. When subgrade friction, reinforcement, or other parts of the structure restrain concrete slabs, drying shrinkage will induce tensile stresses. These stresses usually exceed the concrete's tensile strengths, causing cracking. Using expansive cements can compensate for the drying shrinkage stresses. This will minimize cracking in concrete slabs, pavements and structures. That's why expansive cement is also called shrinkage-compensating concrete.

There are three types of expansive cements defined in ASTM C845, although only Type K is used in any significant amount in the United States:

Type K: Contains anhydrous calcium aluminate

Type M: Contains calcium aluminate and calcium sulfate

Type F: Contains tricalcium aluminate and calcium sulfate

White Portland Cement

White portland cement is a true portland cement. The only significant difference is its color. White portland cement is made to conform to the specifications of ASTM C150, although no specification provides for white portland cement specifically. The controlled manufacturing process yields a finished product that's white because it contains little or no iron and manganese oxide, the substances that give cement its gray color. Use it wherever you need white or colored concrete or mortar.

White portland cement is used primarily for architectural purposes, such as:

- precast curtain walls and facing panels
- terrazzo surfaces
- stucco
- finish coat plaster
- cement paint
- grout
- decorative concrete

Selecting Cement Materials

To select the best cementitious materials for a concrete structure, you'll have to consider the exposure conditions, type of structure, the characteristics of the aggregates, availability of the material, and the method of construction.

The type of structure must be classified as either *mass* or *structural*:

- Mass concrete is any extremely large volume of concrete, such as in a dam, where special measures have to be taken to minimize cracking from the heat generated by hydration and the attendant volume change.
- Structural concrete is concrete that will normally be placed into reinforced structural elements such as beams, columns, walls, and slabs small enough that heat generation isn't a problem.

Of course, all concrete is considered structural, since it's at the core of most construction projects. However, many features of a structure fall into the two extremes — either strictly massive or flexural. The designer needs to determine if measures should be taken to limit the heat generation. Flexural concrete has reinforcing metal or fiber-reinforced polymers (FRP) embedded in the concrete, and is designed by engineers to resist bending forces.

Aggregates

One of the most important factors in the quality and economy of concrete is the quality and quantity of the aggregates.

You need to use quality aggregates to get good concrete. It's cheaper to use good aggregates when you build than to go back and repair a finished project later. Most concrete ready-mix companies buy government-approved aggregates. The aggregates have to pass tests for specific gravity, absorption rates, and organic impurities.

Absorption (ASTM C127; ASTM C128)

Determining the absorption rate of the aggregate helps the laboratory and field workers know how much mixing water to use with that aggregate when making concrete. The aggregate's absorption capability is also a gauge of the durability of the concrete when subjected to critical saturation during freezing and thawing. Modern concrete batch plants use computer-controlled tests of their aggregates when loading ready-mix trucks. The aggregate has to measure up to the demands of the pour where the batch will be placed.

If you need aggregates for concrete with strengths of 6,000 psi or greater, be sure and choose your aggregates wisely. Run tests on concrete strength specimens made from concrete using the aggregates being evaluated, with the required slump and air content. Use various cement factors and water content, and include any required chemical admixtures. If the needed strength can't be reached with a reasonable slump, air content, cement factor, and chemical admixture(s), the aggregate isn't acceptable for high-strength concrete.

In general, it's best to use the largest aggregate compatible with the structure being built. See Figure 1-1. On projects that don't involve large quantities of concrete, make a careful study of the economy of using large aggregates. Using large aggregates reduces the cement content, but increases the labor cost involved in the handling of larger aggregates. Most concrete suppliers will help you determine the correct aggregate size for your needs. But keep in mind that they may charge a considerable amount more for a mixture using larger aggregates, depending on the availability of those aggregates.

Mixing Water

As we already know, concrete is the most dependable, versatile and widely-used of all construction materials. It even beats out lumber. This is true in spite of the fact that it's also the most abused material. The most common mistake — and the most costly — is using too much water.

Maximum Size of Aggregate* Recommended for Various Types of Construction				
	Maximum size of aggregate (in inches) for:			
Minimum dimension of section (inches)	Reinforced walls, beams and columns	Unreinforced walls	Heavily reinforced slabs	Lightly reinforced or unreinforced slabs
2½ - 5	½ - ¾	¾	¾ - 1	¾ - 1½
6 - 11	¾ - 1½	1½	1½	1½ - 3
12 - 29	1½ - 3	3	1½ - 3	3
30 or more	1½ - 3	6	1½ - 3	3 - 6

*Based on square openings

Figure 1-1
Recommended size of aggregates

As soon as water is added to cement, hydration begins. It's an irreversible chemical change that ends with the cement permanently locking the sand and gravel into a stone-like bond. During hydration, the temperature increases, the mix stiffens and loses plasticity, and excess water within the mix is forced to the surface in a process called *bleeding*.

The stiffening and bleeding take place about the same time. This process is called *initial set*, or simply *the set*. When the temperature of the mix with water is about 70 degrees F, initial set takes about one hour. At lower temperatures, it takes a little longer, and higher temperatures speed it up a little. Excess water in the mix will slow the set a little; too little water will cause a false set — the mixture stiffens almost as soon as mixing is stopped. If that happens, quickly add more water and mix until you have the proper lubrication. Hydration will take place whether you're hand mixing or machine mixing, even when the concrete is covered with water. The controlling factors are time and temperature.

In a correctly-proportioned concrete mix, you only need about half of the mixing water to hydrate the cement. The rest acts as a lubricant to produce workability. When you add more water than is actually needed for workability, the concrete is diluted, reducing its density and strength. The effect is the same as diluting paint — the more water you add, the thinner and weaker the paint becomes. Many contractors make the mistake of adding water to allow them to shoot concrete into place rather than shovel it. But the savings in labor is likely to backfire if the job has to be redone.

When concrete dries out too soon, a shell forms over the unhydrated cement in the gel and the hydration stops — even if water is applied later. You need approximately 3.5 gallons of water per sack of cement for hydration. Additional water used for lubrication will leave voids when it evaporates. If enough cement is present, these voids may fill later with cement gel, but only when water is still present in the concrete.

Every extra gallon of water you add to the mix makes it more fluid, but it also dilutes the concrete and makes it more porous. Much of the space occupied by this extra water remains as voids, which makes the concrete weak after it's dry and hard. The result is concrete with poor wear and substantially reduced strength.

Adding too much water also separates the cement and fines out of the concrete. The coarse aggregates settle to the bottom, creating layers of different density and strength. The lower sections of the concrete often have honeycombed areas caused from the cement paste leaking out. This seriously reduces its resistance to weathering.

The cost of finishing concrete also increases when there's excess water. Workmen have to wait for the mix to stiffen. If they also have to wait for extra water to bleed off, evaporate, or be absorbed by the subgrade, the overtime work cost builds up. In cold weather, where this process is slower, these costs can be substantial.

Excessive water in concrete shows up as dusting and crazing, the formation of cracks and leaks, scaling, sand streaks and rough surfaces.

A Rule of Thumb for Concrete Mixes

While rules are useful in making quick changes in mixes, remember that you should only make adjustments in emergency situations. The mix will be slightly altered by these changes, so it'll need to be redesigned as soon as possible.

As a rule, adding 1 gallon of water per cubic yard of 3,000 psi concrete will:

- increase the slump about 1 inch
- cut the compressive strength by 200 psi
- increase the shrinkage potential about 10 percent
- decrease the freeze-thaw resistance by 20 percent

Water-to-Cement Ratio

The water-to-cement ratio is the pounds of water compared to the pounds of cement in the mix. See Figure 1-2. Stronger concrete has a lower water-to-cement ratio. If you divide the weight of water in a cubic yard of concrete mix by the weight of the cement, you'll get the water-to-cement ratio. Since 1 gallon of water weighs 8.33 pounds and a bag of cement weighs 94 pounds, a mixture of 4.5 gallons of water ($4.5 \times 8.33 = 37.49$ pounds) to one bag of cement ($1 \times 94 = 94$ pounds) is equal to a cement ratio of 0.399 ($37.49 \div 94 = 0.399$). So if a cubic yard of concrete has 235 pounds of water and 470 pounds of cement, it would

Amount of Mixing Water for Concrete						
Proportion			Mixing water required per bag		Mixing water required per cubic yard	
Cement	Sand	Stone	Minimum (gallons)	Maximum (gallons)	Minimum (gallons)	Maximum (gallons)
1	1½	3	5½	6	42	46
1	2	3	5¾	6¼	40	43½
1	2	4	6	6½	36	39
1	2½	5	7¼	7¾	36	38½
1	3	6	8¼	8¾	35	37

Figure 1-2
Water-to-cement ratio

Concrete Mix Designs								
Class	**A**	**D**	**DP**	**E**	**F**	**H**	**HP**	**J**
W/C ratio	0.46	0.44	0.4	0.44	0.38	0.44	0.4	0.44
Slump range	2½-3½	2½-3½	2½-4	3-4	2-3	3-4	3-5	½-1½
Water (lbs)	279	319	290	285	272	297	270	269
Cement (lbs)	606	725	535	648	716	675	500	680
Fly ash (lbs)	0	0	145	0	0	0	135	0
Air (%)	6.5	7.5	7.5	6.5	6.5	6.5	6.5	6
Sand (lbs)	970	1136	1146	942	901	1039	1047	1237
#1 stone (lbs)	973	1520	1533	962	972	884	890	1655
#2 stone (lbs)	973	0	0	962	972	884	890	0
Microsilica (lbs)	0	0	44	0	0	0	24	0

Figure 1-3
Concrete mixes

be a 0.50 ratio (235 ÷ 470 = 0.50). One ready-mix producer explained that when a customer doesn't request a specific mix, it's common for a 3,000-pound mix to have a water-to-cement ratio of 0.41 to 0.49.

Typically, concrete mix formulas give the ratios for different classifications. Figure 1-3 has some typical concrete mix designs, based on New York Department of Transportation specifications. They use eight different classes:

1. Class A:
   Normal structural concrete
2. Class D:
   Thin section concrete

3. Class DP:
   Thin section concrete with fly ash and microsilica added
4. Class E:
   Structural bridge deck concrete
5. Class F:
   High-early-strength concrete for pavement or structural slabs
6. Class H:
   Concrete suitable for pumping applications
7. Class HP:
   Concrete suitable for pumping applications with fly ash and microsilica added
8. Class J:
   Concrete suitable for slip forming structural medial barriers, parapet walls and curbs

They also specify requirements for admixtures, including:

ASTM C260 Air-entraining admixture: 6 percent ± 1.5 percent by volume

ASTM C494 Type A Water-reducing admixtures

ASTM C494 Type D Water-reducing and retarding admixtures, for use in hot weather concreting

Other requirements include 1 to 1.5 pounds of polypropylene fibers per cubic yard of concrete for reinforcement as required by the manufacturer, and a slump of 2 inches minimum to 4 inches maximum before the addition of water-reducing admixtures at the site.

Curing Water

Curing water must not contain impurities. Some impurities can attack and damage the surface of the concrete. Others, including iron salts and organic matter, cause stains and discoloration. Generally, the same water that you use for the concrete mix can also be used for the curing process.

Admixtures

Admixtures enhance the durability, workability or strength of concrete. They can also help overcome special problems, such as hot and cold weather concreting and delaying the set during transportation.

Admixtures can be either manufactured or natural chemicals, and are generally added to the concrete mix before or during mixing. Manufactured admixtures include air-entraining agents, superplasticizers, accelerators, retarders, water reducers, corrosion inhibitors, and coloring. Natural chemicals are minerals that make cements more resistant to moisture, increase strength, and generally make concrete more economical. Fly ash and silica fume are two of the most common.

Pozzolans

ASTM C618 defines a pozzolan as "a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely-divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties." There are some natural materials (shells, diatomaceous earth and pumicite) and some artificial materials (fly ash) that are used for pozzolans. Class F and C pozzolans, fly ash and silica fume, are the ones most likely available. If a source of natural pozzolan is accessible to your building site, consider using a Class N.

Class F pozzolan is the most commonly used. It's a fly ash that's usually obtained from burning anthracite or bituminous coal. It increases the concrete's ultimate strength, lowers heat from hydration, reduces bleeding and segregation, and requires less mixing water. It increases sulfate resistance and reduces alkali aggregate reaction. Concrete made with fly ash reaches its maximum strength more slowly than concrete made with portland cement alone. Class F fly ash might need an air-entraining agent in the mix.

Class C pozzolan is a fly ash usually obtained from the burning of lignite or sub-bituminous coal. This type is especially useful in prestressed concrete. Typically Type C fly ash doesn't need an air-entraining agent.

Class N pozzolans are raw or calcimined natural pozzolans. These include some diatomaceous earths, opaline cherts, tuffs, and volcanic ashes like pumicite.

> ***THE SOLID WASTE DISPOSAL ACT*** requires all agencies using federal funds in construction to allow the use of fly ash in the concrete unless it can be shown to be technically improper. The basis of this regulation is both energy savings and waste disposal, since most fly ash in use today is the result of burning coal for electric power.

Use pozzolans with most types of available cements. Portland cement used alone, blended cements, or the combination of portland cement with slag cement, may all benefit from the addition of pozzolans, unless the specifications determine one of these to be technically improper. Classes F and C fly ash are generally accepted on all Corps of Engineers civil works projects. Their use should be allowed in all specifications unless there are technical reasons not to. Any project funded by taxpayer money will have concrete mix designs, including additives, as part of the bidding specifications.

Microsilica (silica fume), a byproduct of the manufacture of silicon or silicon alloys, is much more expensive than other pozzolans. Properties of silica fume vary, but in general, a silica fume is a very finely-divided product that's used in concrete in different proportions and for different applications than the more conventional pozzolans. Silica fume is used in the production of concretes that need high compressive strengths, high abrasion resistance, very low permeability, and increased aggregate bond strength. Silica fume acts as a microscopic filler in concrete, and improves bonding.

Microsilica is used in concrete for structures such as bridges. These projects need extra compressive and tensile strength. One pound of silica fume creates about the same amount of heat as a pound of portland cement, but it yields three times the compressive strength.

You need to take certain precautions when specifying silica fume concrete. Silica fume produces a sticky paste and increases the water demand for equal slump. Using high-range water-reducing admixtures (HRWRA) to achieve the required slump normally counteracts these characteristics. This combination, together with an air-entraining admixture, may cause an air-void system. The higher water demand for silica fume concrete greatly reduces or eliminates bleeding, but tends to increase the likelihood of plastic shrinkage cracking. It's important to take steps to minimize moisture loss. You should also plan for a longer curing period than is required for conventional concrete. The structural engineer's specifications for the project should include both the curing method and the required curing time.

Corrosion Inhibitors

Corrosion inhibitors contain calcium nitrate. It reacts with the embedded steel to form a barrier against chloride penetration, protecting the reinforcing. Corrosion inhibitors may reduce the setting time of the concrete, so the ready-mix supplier might suggest adding a retarder to the mix.

Accelerators

Accelerating admixtures are classified in ASTM C494 as Type C, accelerating, or Type E, water-reducing and accelerating. They speed up the setting time or early strength development, or both. Initial and final setting times must be accelerated by a minimum of one hour, and three-day compressive strengths must be increased by 25 percent in order for an accelerating admixture to comply with the requirements of ASTM C494. Since the rate of cement hydration decreases with lower temperatures, and increased setting times cause delayed finishing, using accelerators

YOU CAN ACHIEVE accelerated setting time and early strength development by other means as well. These include:

- ☑ Using a Type III portland cement
- ☑ Using additional cement
- ☑ Reducing the pozzolan content
- ☑ Warming the water and aggregates

is common practice. If you use an accelerator, be prepared to finish the concrete sooner, and be sure you have sufficient manpower available.

Type C accelerating admixtures have no significant effect on the initial workability or air content of a concrete mixture. But they *do* affect the setting time, heat evolution, and strength development of the mix. Concretes containing an accelerating admixture can have a more rapid slump loss, especially if they have high cement content. An accelerator generally reduces the bleeding of a concrete mixture. Accelerators can also cause the compressive strengths and flexural strengths to be greater at an early age, but they may be lower than those of plain concrete at later ages. There's no indication that nonchloride accelerators attack the passive layer of protection where the concrete and steel are in contact.

Retarders

Retarding admixtures are chemicals that delay the initial and final setting time of concrete. However, retarding admixtures don't reduce the rate of slump loss. You have the option of using a retarder, except in situations where retardation would be detrimental, such as extending the set time when there's a completion date specified in the contract and you can't afford any delays. Consider using a retarder when you're placing uncooled concrete in very hot weather and you anticipate a danger of cold joints or problems in finishing.

ASTM C494 classifies retarding admixtures as Type B, retarding, or Type D, water reducing and retarding. They must retard the initial set of the concrete by a minimum of 1 hour and the final set by 3½ hours. Setting times of concrete made with a cement-pozzolan blend will typically be retarded more than portland cement alone because the pozzolan often has a retarding action.

Retarding admixtures are very useful in hot weather, when hauling long distances, where there'll be a line-up of ready-mix trucks waiting to unload, or any time you need extended working times. They increase the available time between the screeding and troweling operations of concrete slabs. But even if you use retarders during hot-weather pours, you need to take additional precautions to protect the new surface from wind and heat. Spray fresh concrete with a fine mist, and provide tarps, sun screens and wind screens to keep it from drying prematurely and developing a crust. Workers should never leave fresh concrete unattended during hot weather. Concrete can "flash-set" and make proper finishing impossible.

High-Range Water Reducers (Superplasticizers)

High-range water-reducing admixtures (HRWRAs) are chemically different from normal water-reducing agents (WRAs). They can reduce water content by as much as 30 percent without adversely affecting the air content, bleeding, segregation, setting time, and hardened properties of concrete. By definition, HRWRAs are required to provide a water reduction of at least 12 percent. They are classified by ASTM C494 as Type F, high-range water reducing (usually added at the jobsite) or Type G, high-range water reducing and retarding (added either at the jobsite or at the batch plant).

You can use HRWRAs to produce concrete with high workability for easy placement, high strength with normal workability, or combinations of the two. HRWRAs can produce significantly higher strength concrete that flows easily into forms. The increased workability allows you to place the concrete in congested reinforcement, and in areas where access is limited, such as in insulated polystyrene foam forming systems. HRWRAs allow you to produce concrete with a lower water content without the loss of workability that may occur with WRAs. Under some conditions, concrete containing HRWRAs may exhibit a rapid slump loss as soon as 30 minutes after completion of mixing. Superplasticizers are sometimes used when pumping concrete long distances.

Air Entrainment

Air entrainment is the addition of a chemical that produces millions of microscopic air bubbles in the concrete mix. An air-entrained mixture provides more freeze-thaw resistance, better yield control, and makes finishing the concrete easier. The tiny air bubbles act like a lubricant, increasing the plasticity and workability of the concrete. Air-entrained concrete can be made with less mixing water with no loss of slump. Slump and vibration affect the air content of air-entrained concrete. In most slumps, more than 15 seconds of vibration causes a considerable loss in air content. The greater the slump, the larger the percent reduction in air content during vibration. However if vibration is carefully done, only the larger bubbles will be lost. For best results, move the vibrator quickly throughout the form without holding it in any one position or in one spot for longer than 15 seconds.

The temperature of concrete also affects its air content. As the temperature increases, less air is entrained. This effect is especially important during hot weather pours.

Certain admixtures (especially fly ash) and coloring agents may reduce the amount of entrained air. Use air-entrained concrete on structures such as sidewalks, curbs, steps, loading platforms, driveways and any structure where large amounts of deicing agents will be used.

Measuring Air Entrainment

The photographs in Figure 1-4 show the procedure for testing the entrained air in a concrete mix using the pressure method. This test is

A Fill one-third full

B Rod 25 times

C Tap

D Add second batch, rod and tap

E Fill container and rod

F Tap

G Screed

H Clean the rim

I Perform test

Figure 1-4
Testing for entrained air

covered by ASTM C231. Start by using the same scoop you use for the slump tester to shovel fresh concrete into the test cylinder. Now follow the pictures in Figure 1-4.

A) Fill the container one-third full.

B) Rod the concrete 25 times.

C) Tap the container 10 to 15 times with a rubber hammer.

D) Add the second batch of concrete until the cylinder is two-thirds full. Repeat the rodding and tapping.

E) Fill the remaining third of the container and rod as before.

F) Tap the filled container again, 10 to 15 times.

G) Screed the concrete off, level with the top of the container.

H) Clean the rim of the container and place the top on it.

I) Perform the test, using an air meter.

Pressure meters are widely used because they're fast, easy and able to give you a reading when you don't know the mix proportions and specific gravity of the materials. The pressure method of determining air content is based on Boyle's Law, which relates pressure to volume. Many commercial air meters are calibrated to read air content directly when a predetermined pressure is applied. The applied pressure compresses the air in the concrete sample, including the air in the pores of aggregates. For this reason, tests by this method aren't suitable for determining the air content of concrete made with lightweight aggregates or other porous materials. There are small correction factors you should apply for most normal-weight aggregates, as listed in the instructions that come with the air meter. Also make sure the instrument is calibrated for the correct elevation above sea level.

Here's how to conduct the test using a Type B pressure meter:

1. Open both petcocks.
2. Close the air valve between the air chamber and the bowl.
3. Continue injecting water into the petcock while jarring and tapping the meter to ensure air is expelled.
4. Close the air bleeder valve and pump air up to the initial pressure line.
5. Allow a few seconds for compressed air to stabilize.
6. Adjust the gauge to the initial pressure.

7. Close both petcocks.

8. Open the air valve between the chamber and the bowl.

9. Tap the sides of the bowl sharply with a mallet.

10. Read the air pressure after lightly tapping the gauge to stabilize the hand.

11. Close the air valve and then open the petcocks to release pressure before removing the cover.

12. Calculate the air content using this formula:
Air content = (meter reading) – (aggregate correction factor)

Coloring Concrete

Concrete coloring agents are made of pure natural and/or synthetic iron oxides. They're finely milled and blended under strict quality control procedures to produce a uniform and consistently-strong tinting strength for maximum coloring powder.

By adjusting the percentage of color added to the cement, you can create almost any color shade. Some coloring agent suppliers recommend not using more color than 10 percent of the total weight of the cement used. Maximum color tint value is normally reached at 7 to 8 percent (9 percent in gray cement). Using less than 1 percent can lead to inconsistent coloring in the final product.

FOR BEST COLOR RESULTS, use between 1 and 7 pounds of pigment per 100 pounds of cement. Always add ingredients in the same order in each batch. Add the color after the aggregate charge and before the major water and cement addition. The water-cement ratio shouldn't exceed 0.45 for the best mixing results.

The key to successfully adding color in concrete products is consistency. The most important factor is measuring the color accurately. Weigh the dry pigment before you add it, unless you're using preweighed batch-size bags. Adding the same amount of water to each batch is also very important in keeping the color consistent. Increasing the water content will usually lighten the color shade of the batch.

Routinely check and verify for color consistency in the base color of all materials used in the production of colored concrete. A change in the gray color of cement products will create an equal change in the color accuracy of the finished product. For this reason, it's best to avoid the use of fly ash when manufacturing colored concrete.

Before you order colored concrete, contact your ready-mix supplier to see if they'll follow these mixing steps:

Step 1: The truck mixer drum must be completely clean, with no leftover water or aggregates, before mixing a batch of colored concrete.

Step 2: The slump must range from 3½ to 4 inches. If air is entrained, it should range from 5 percent to 7 percent.

Step 3: Put the drum in reverse (discharge) to shift the concrete toward the back of the drum and then stop the drum. Place the bags of pigment directly onto the concrete and put the drum into the forward (mix) position.

Step 4: Let the drum turn slowly (5 rpm) for 2 or 3 minutes.

Step 5: Run the mixer at optimum speed (12 rpm) for 10 to 15 minutes.

To maintain the color consistency, never add extra water to a batch of colored concrete. Any difference in slump in successive batches will result in color variations in the concrete. Never add calcium chlorides or any accelerators.

Finishing Colored Concrete

Follow these steps when finishing colored concrete to maintain its color consistency:

Step 1: Place the concrete, then strike off using any of the recognized methods.

Step 2: Once the concrete has been struck off, use a vibrating screed or magnesium float. Take care to work in one direction.

Step 3: Allow a waiting period, but don't let the concrete get too hard. Allow sufficient time for the concrete to set. Rushing the other steps can alter the final appearance of the concrete.

Step 4: Watch for bleed water on the surface of the concrete during initial floating. If there is any, stop the float — bleed water can result in scaling. Continue floating once the bleed water has evaporated.

Step 5: Use a power trowel or magnesium hand float for a smooth finish, but overworking the surface will cause discoloration.

ONE SUPPLIER IN NEW YORK charges a minimum of $40.00 extra per cubic yard for colored concrete, and up to $489.00 a cubic yard for cobalt blue coloring.

High-Strength Concrete

The use of high-strength concrete has increased over the years because of compressive strength requirements and new developments in application techniques. Today, high-strength concrete is used to build large composite columns, bridges, and structures subject to chemical attack. Its increased use has brought about stricter quality control requirements. You can achieve high strength and low permeability in concrete with admixtures containing silica fume. Superplasticizers produce a low water-to-cement ratio, also giving a high-performance concrete.

High-strength concrete by definition has a 28-day design compressive strength over 6,000 psi. In regions where concrete is regularly poured at strengths around 6,000 psi, concrete with strengths up to 9,000 psi is readily available. Similarly, 12,000 psi concrete would be available in the regions that regularly produce 9,000 psi concrete. In most instances, the required compressive strength is specified to be obtained at 50 to 90 days, rather than the standard 28 days, to take advantage of the use of pozzolans in the concrete.

When high-early strength is specified, all the ingredients should be checked carefully, including the aggregate size, strength and shape. You also have to take into account the effects of chemical admixtures and pozzolans, as well as the type of cement used. High-early-strength concrete proportions usually include a high cement content, low water content, normal-weight aggregates, admixtures, and pozzolans.

Type I portland cement is appropriate for high-strength concrete. If high strength is required with a shorter curing time, then Type III (if available) may be better. One problem with using high-strength cements is that higher temperatures develop in the curing process. If there could be a problem with heat buildup, Type II, with moderate heat of hydration, can be used, provided it meets the strength-producing requirements. But even within the same type of cement, such as Type I, II, or HI, different brands can have different strength development characteristics because of the variations in the physical and chemical compositions.

Cement Content

Cement content for high-strength concrete usually ranges between 660 and 940 pounds per yard. However, higher cement contents don't always mean higher strengths. The concrete strength for any given cement content will vary with the water demand of the mixture and the strength-producing features of the cement being used. The optimum cement content depends on the combination of all the materials being used. Test trial batches to make sure you've got the desired strength.

Aggregates

The choice of aggregates is very important to the ultimate strength developed by high-strength concrete, since they occupy the largest volume of any of the concrete ingredients. Most high-strength concrete is produced using normal-weight aggregates, although some high-strength lightweight aggregates and heavyweight aggregates have been used successfully in high-strength concrete.

In general, crushed coarse aggregates, ¼-inch nominal maximum size or smaller, are preferred for high-strength concrete. Their shape and surface texture enable the cement paste to bond to them better than rounded natural aggregates. Smaller-size aggregates have better bond strengths and less severe concentrations around the particles.

Compressive Strengths

The structural engineer or designer will determine the required compressive strength of concrete. Normally a specified compressive strength of 3,000 psi at 28 days is an attainable value in rural areas and remote locations where many smaller structures are located. Higher compressive strengths may be specified for individual projects. The designer is responsible for the requested psi strength, and must determine what strength is required and at what age the strength is needed. If construction loads or operational loads aren't anticipated for a long period of time, you can save money by proportioning the concrete mixture to reach design strengths at a later age, such as 90 days.

Many ready-mix companies will suggest compressive strengths for the particular project by citing a psi common to projects in the area. The ready-mix companies will also be able to tell you what the local, state or federal agency specifications are. Traditionally, if it's acceptable to the Federal or State Department of Transportation, it will be all right to use. If durability alone is the limiting factor, then the water content shouldn't be more than 0.50. Figure 1-5 shows the typical water-to-cement ratio by weight to produce the needed strength in psi.

Other Specialty Concretes

Lightweight Concrete — Concrete that uses admixtures like vermiculite, pumice, perlite, expanded shale, slate, slag and cinders to reduce the total weight is considered lightweight concrete. Lightweight concrete is usually used for fill inside other structures. The compressive strength

Compressive Strength for Various Water-Cement Ratios	
Compressive strength (psi)	**Water/cement ratio by weight**
2,000	0.80
3,000	0.69
4,000	0.57
5,000	0.47
6,000	0.40

Figure 1-5
Compressive strength for water-cement ratios

of lightweight concrete can vary from 300 to 6,000 psi. Lightweight concrete with a 3,000 to 4,000 psi can be made with a cement ratio of 425 to 800 pounds of cement per cubic yard.

Heavyweight concrete — This type of concrete is usually used in walls that have to shield people from the harmful effects of x-rays or other kinds of radiation. Heavyweight concrete can contain magnetite (iron ore) or steel shot and weigh as much as 8,000 pounds per cubic yard.

Now that you've had an overview of the remarkable material you'll be working with, let's move on to preparing for the jobs you'll be working on. The next chapter covers planning the job, and doing the initial site work.

2

PLANNING AND SITE WORK

Residential and commercial building contractors must comply with all local building codes and zoning laws, including the use of civil or structural engineers when required. You may need a civil or structural engineer to design or supervise the construction of foundations, as well as the design of force-resistant and load-supporting structural members, including walls, beams and trusses. Your first step in building is to contact your local building authorities to find out their requirements.

Building Codes

There are model building codes published by private organizations, but they have no meaning unless and until they're adopted by the local municipality. However, once a building code is enacted as a local law, all builders must comply with it. The published building codes are fairly similar, but when working in different jurisdictions, it's a good idea to consult the local code office to make sure you're in compliance with their particular regulations.

Major contracting companies, engineering companies and estimators generally own a set of code books. However, because there are many different building code books (some trade specific), and they're all complex as well as expensive, smaller companies and individual contractors operating on a smaller scale generally find it preferable to contact local code offices for answers to questions or interpretations of the building code.

Most building code offices are interested in helping contractors and builders. It's to your advantage to be friendly with the code officers. Ask for their direction rather than trying to argue with the inspector. It takes time to find every regulation that applies to your job. So, when there's a question about how to proceed with your project, it's easier (and cheaper) to consult a code official. If you're in doubt, it's usually better to use the code official's interpretation of the regulations rather than your own.

Standards of Construction

A standard reference, commonly just called a *standard*, is a specification, code, guide, or procedure recognized and accepted throughout the industry. Some organizations issuing standards that apply to concrete construction are:

American Society for Testing Materials (ASTM)
777 East Eisenhower Parkway
Ann Arbor, MI 48108
www.astm.org

American National Standards Institute (ANSI)
1819 L Street, NW
Washington, DC 20036
www.ansi.org

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
www.concrete.org

You can contact these agencies by mail (or e-mail) and they'll provide you with their most up-to-date standards.

Building Permits

Building permits are required in almost all municipalities. To start building without a permit is a violation of the law, and the penalties are severe. The building code office can issue a stop work order to force you to discontinue construction and vacate the premises. There have even been cases where the construction was actually torn down. And even if you finish, if a building is built without a permit and the required inspections, it may not be issued a Certificate of Occupancy. Without the certificate, the building is useless. A Certificate of Occupancy is required before people are allowed to live or work in a building.

When the building code office issues a permit, they'll also arrange a schedule of inspections. For the concrete contractor, the first inspection may be after the forms and reinforcing are in place, but before the concrete is poured. If you pour concrete before inspection, the inspector can make you take the structure apart and rebuild. Staying on schedule and keeping up with inspections is very important for every contractor on every project.

After the work is done and the inspections complete, the last step is to obtain a Certificate of Occupancy from the code office. In most instances, the building permit will be issued to the general contractor and covers all the subcontractors. This certificate shows that the construction covered by your building permit is complete and that you've passed the final inspection. Check with your local jurisdiction, as some have stricter regulations than others. In a situation where there are multiple buildings within a project, each building is usually considered a separate project, and requires its own permit and certificate. Again, check with the local building department for its regulations.

Zoning Laws

Zoning laws control the type of building allowed on a site and where the building has to be located. Zoning regulations specify, among many things, minimum setback, width of side yards, and property use. Tract restrictions may put additional restrictions on property use.

"Most municipal building departments will have maps available for public inspection. Use their maps to verify that you're building in the correct zone for your type of project."

Zone maps show areas designated for residential, commercial, industrial and agricultural uses. Most municipal building departments will have maps available for public inspection. Use their maps to verify that you're building in the correct zone for your type of project. There may also be utility plans that would be helpful to you. If you know the locations of sewage pipe and other utility lines, you can plan ahead. It's much more economical to provide openings in concrete walls or floors for utility access than to have to cut holes in finished concrete.

When reading zoning rules for building layout, you may need to become familiar with the following terms (illustrated in Figure 2-1):

Building line: A legally-determined boundary that no part of the building can cross. Be aware that this isn't just the foundation or walls — it includes the roof overhang. Exceptions,

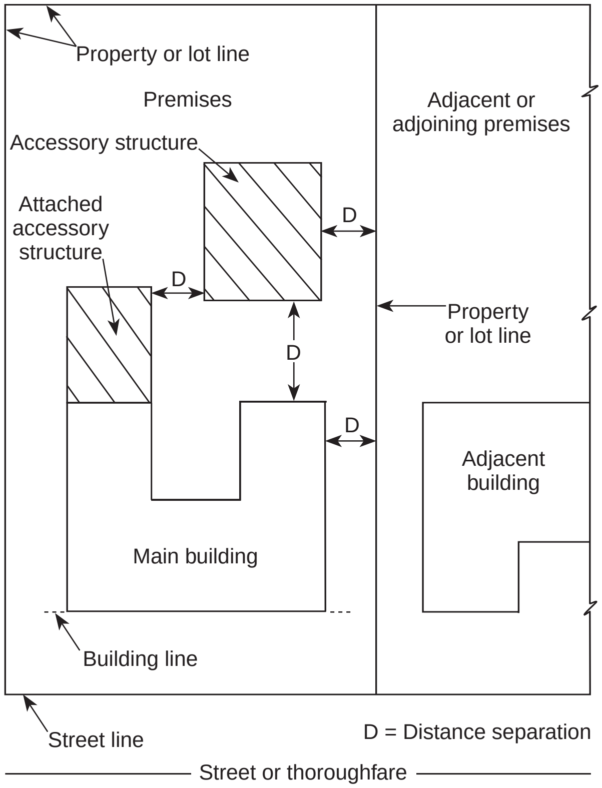


Figure 2-1
Terms used in the building code

usually called variances, are common but their details vary widely. Never assume that what's allowed in one municipality will be allowed in another. Always check the local ordinances first.

Distance separation: This describes the amount of open space required between buildings. Open space helps prevent fire spreading from one structure to another.

Lot line: A surveyed and recorded boundary that separates one piece of property from another. The same phrase also describes the legally-determined boundary that separates a piece of private property from a public street or other public property.

Premises: A term used to collectively describe a piece of property as well as any buildings or structures on it.

Property line: The legal boundary marking a lot or parcel of property.

Setback: The open space required between a building line and the street centerline.

Street line: The boundary separating a lot or parcel of land from the street. The street line and building line are the same if there's no setback required.

Here are two more terms you may need defined:

Basement: A space in a building that meets both of the following requirements: First, it's partly below grade. Second, more than half of its height, measured floor to ceiling, is above the average outside grade. Most codes allow habitable space in a basement if the basement floor isn't more than 4 feet below the average outside grade. Most codes also treat a basement as a story if the floor directly above it is at least 7 feet above the finished grade.

Cellar: A space in a building that's similar to a basement, except for the following differences: First, the floor level is more than 4 feet below the level of the average outside grade.

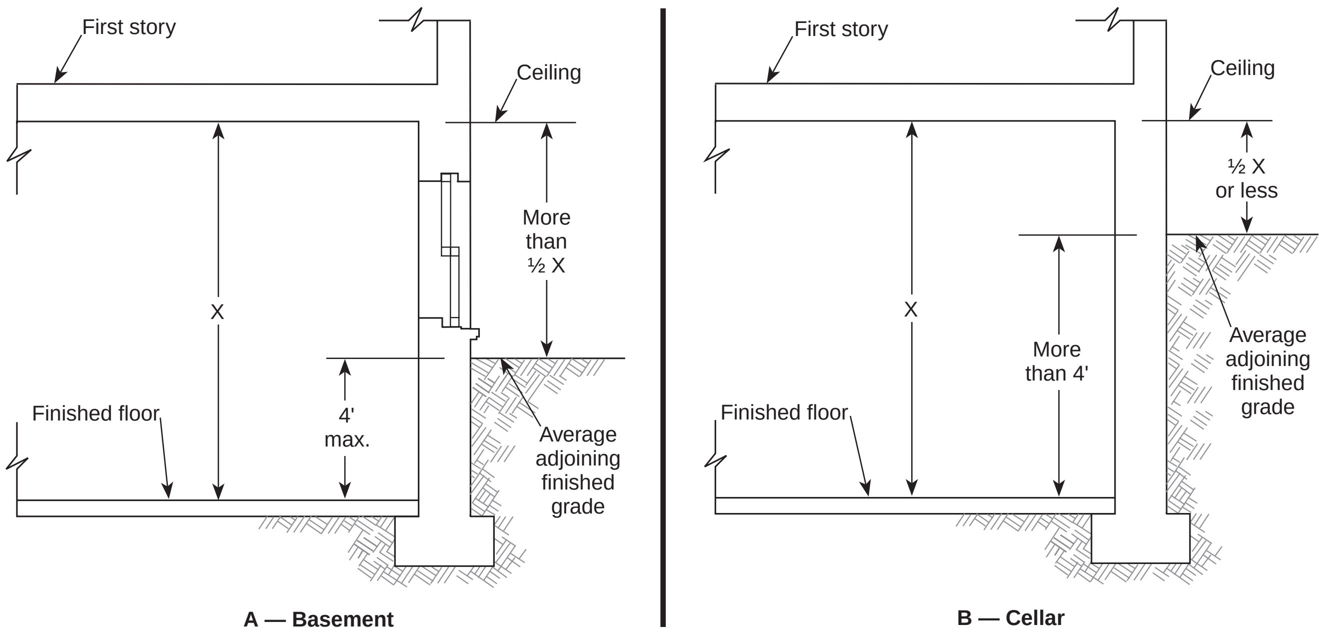


Figure 2-2
Basement and cellar with respect to grade level

Second, less than half of a cellar's floor-to-ceiling height is above the average outside grade. Most codes don't allow habitable space in cellars, although a recreation room is usually allowed. Cellars are rarely counted as a story. Figure 2-2 shows the differences between a basement and a cellar.

Site Survey

The first, and most important, step in construction is to start the building layout so the structure is facing the correct direction and will be built at the correct elevation above the finished grade. That's why it's standard practice to contact a licensed surveyor and have a site survey completed before beginning the excavation work. The surveyor will mark out the property lines and establish a bench mark that the foundation contractor can use as a reference point to determine the height of the foundation. The bench mark may be a street elevation, sewer line or some other elevation mark. The contractor has to reference this mark when digging footings, pouring or laying block foundation walls, or installing sewer systems. After the surveyor has determined the property lines and the location of the building on the property according to local zoning or codes, you can plan your excavation and grading and set up the foundation lines.

Soil Surveys

There's another important step before you begin work on footings or building walls: Make sure the soil will support the building. You'll need to know the loadbearing capacity of the soil at the building site, and that will vary with the type of soil. The best soil for a foundation bed is one that:

- Supports the building's weight
- Doesn't swell when wet
- Doesn't shrink when it dries
- Isn't affected by frost heave

Figure 2-3 shows allowable foundation and lateral bearing pressure for different types of soils. This is useful, but it would be better to get more detailed information for your specific site. Try to get a copy of the U.S. Soil Conservation Service's soil survey for your area. The Soil Conservation Service collects soil, climate, and geographic data worldwide. Their maps plot this data over the top of an aerial photograph. They also publish written reports to match the mapped areas which

Table 1804.2
Allowable Foundation and Lateral Pressure

Class of Materials	Allowable Foundation Pressure (psf)[d]	Lateral Bearing (psf/f below natural grade)[d]	Lateral Sliding	
			Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500[c]	100	—	130

For SI: 1 pound per square foot = 0.0479 kPa, 1 pound per square foot per foot = 0.157 kPa/m.

a. Coefficient to be multiplied by the dead load.

b. Lateral sliding resistance value to be multiplied by the contact area, as limited by Section 1804.3.

c. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

d. An increase of one-third is permitted when using the alternate load combinations in Section 1605.3.2 that include wind or earthquake loads.

From the 2006 *International Building Code*, Courtesy: International Code Council

Figure 2-3
Allowable pressure for different soil types

have more detail. But the maps alone usually have all the information you'll need. They show:

- soil types
- soil pH
- soil grain size
- depth to bedrock
- soil permeability
- boundaries between soil types
- seasonal high water table levels

If there's an Agricultural Extension Bureau in your area, you can contact them. Their staff can often answer questions about local soils. They may also have maps with the information that you need. If not, you can order the maps from:

Superintendent of Documents
United States Government Printing Office
Washington, DC 20402
www.gpo.gov

Types of Soil

It may be hard to find the ideal soil to build on. But if you can't do that, you can try to build correctly on the soil that's available. Here's a brief summary of common soil types.

Rock

This doesn't always mean bedrock, although it's easy to mistake a thin layer of rock for bedrock. If you do, your building could actually sit on an unstable bed of soft clay or sand that's under the layer of rock.

Sand

Sand swells or flows when wet. Then when it dries, it shrinks and settles. All of these (settling, flowing, swelling, shrinking) are bad news. Footings can be ruined by any movement below them. The only time sand is safe to build on is when the moisture level is stable.

Clay

Clay soaks up moisture like a sponge. And, like a sponge, clay soils expand when they take on more and more moisture. Footings and foundations can literally be lifted right up by the swelling action. And clay is slippery and unstable when it's wet. The weight of a footing on a bed of clay can make the soil squeeze right out from under the footing, possibly causing the foundation to crack and fail. You may be able to improve the loadbearing capacity of clay by adding a layer of gravel to the top of the soil and providing adequate drainage.

> ***IF THERE'S ANY QUESTION*** about soil conditions, contact a soils engineer. Your best resource for help in finding one is through the local code office, or the State Environmental Conservation Office.

Peaty or Spongy Soils

These soils need specially-designed foundations. When it comes to planning footings and foundations for this type of soil, you'll need a structural engineer.

Fill

Avoid filled-in areas if possible. The problem here is that the differences of depth of fills and type of fills may make settling uneven. Also, filled areas of different materials have different loadbearing capacities. Often, this is impossible to calculate. If the site has very well-settled fill, there may not be a problem.

Acid or Alkali? What pH Testing Tells You

Soil pH is a measure of its relative acidity or alkalinity. This data is sometimes given on the soil map that we discussed earlier in this chapter. A contractor needs to know the pH of three things on the jobsite: soil, ground water, and water used for mixing.

If the pH of the water or the soil is less than 7, it's acidic. The lower the pH, the more acidic the soil or water is. For example, a soil with a pH of 6.5 isn't very acidic, but a pH of 4.5 is very acidic, and may require special handling, such as the application of polyethylene sheeting on the surface before the concrete is poured.

> *"If the pH of the water or the soil is less than 7, it's acidic. The lower the pH, the more acidic the soil or water is."*

At the other end of the scale are pH values greater than 7. Soil or water in this range is alkaline. The higher the pH, the higher the alkalinity of the soil or water. Why is this so important? Because ground water with a pH of 9 will quickly break down concrete made with Type I normal cement. You should use Type II, or better yet, Type V portland cement in concrete exposed to high amounts of alkaline. If this isn't available, use any sulfate-resistant portland cement.

Minimum Excavation Depths	
Temperature zone (°F)	**Minimum depth below existing grade (feet)**
+20°	2
0	3
−20°	4

Figure 2-4
Minimum footing depths

Frost Heave

Frost heave describes the way soil is lifted up and disturbed when the water in it freezes. Water expands by about 9 percent of its volume when it freezes. This reaction can cause footings to move, cracking the foundation or wall above it. The soil in a given area usually freezes to a certain depth, but rarely below that. This depth is called the *frost line*. The point below the frost line isn't affected by the frost and that's where you should construct the bottom of your footings. Figure 2-4 shows the current minimum excavation depths needed for footings in the different temperature zones.

Drainage

Most health departments require safe sanitation practices for drinking and wastewater. If you're building in an area without sewers, make sure you know the regulations for that area. If it's at all possible, look over the jobsite after wet weather or when the water table is at or near its peak. This is when you'll be able to spot drainage problems, such as areas where water collects or places where seepage might be a problem later on.

Percolation Test

To test drainage, you should conduct a percolation test to see how well wastewater disperses into the soil. This test is required in many areas. Always check with the local code office before starting your excavation to make sure you know what's required. The following is a common method for performing the perc test:

1. At the jobsite, dig a hole 2 feet deep and 18 inches wide.
2. Fill the hole with water.
3. Time how long it takes the water to drop 1 inch, 2 inches, and then 3 inches. You can use a yardstick or folding rule to measure.
4. Fill the hole with water again, repeat number 3 above, and average the results.

Look for a time factor of 5 to 7 minutes per inch. If the water level drops too quickly, it may mean that wastewater could flow into drinking water at some distant location. If it drops slowly, you may have poor

Excavation Factors		
Depth in inches	Depth in feet	Cubic yards per square foot
2	0.167	0.006
4	0.333	0.012
6	0.500	0.019
8	0.667	0.025
10	0.833	0.031
12	1.000	0.037
18	1.500	0.056
24	2.000	0.074
30	2.500	0.093
36	3.000	0.111
42	3.500	0.130
48	4.000	0.148
54	4.500	0.167
60	5.000	0.185
66	5.500	0.204
72	6.000	0.222
78	6.500	0.241
84	7.000	0.259
90	7.600	0.278
96	8.000	0.296
102	8.500	0.315
108	9.000	0.333
114	9.500	0.352
120	10.000	0.370

Example of how to use the table: Assume an excavation is 4 feet × 32 feet × 5 feet deep.

1. Calculate the square feet:

   4 × 32 = 128 square feet

2. In the table, locate the factor for a 5-foot depth (the number of cubic yards in a 1-foot square by 5-foot deep excavation), which is 0.185
3. Multiply the square feet by the factor to find the number of cubic yards:

   128 × 0.185 = 24 cubic yards

Figure 2-5
Factors for estimating earthmoving quantities

drainage. If you're going to have a drainage problem, it's best to know it before you begin construction. If the percolation test shows there's a problem, you'll need to hire an engineer to design the system. Contact your local building code office for help in finding an engineer.

Setting Grade Stakes for Footings and Foundations

After the survey and the soil testing are completed, the next step is excavation and grading. A good excavator will use a transit, a builder's level or some other sophisticated device to position and locate the bottom of the excavation. Never let an excavator "eyeball" the job. If the excavation contractor doesn't come equipped with a leveling instrument of some kind, tell him to pack up and leave. You can use the information in Figures 2-5 and 2-6 to help you check the excavation contractor's earthmoving estimates. The charts in the figures show the volume of dirt that will have to be removed per square foot of depth and per 100 linear feet of trench.

It's important for both you and the excavation contractor to establish the correct grades so that the building and the site work is constructed to allow proper drainage away from the site. After the excavation contractor finishes his work, set up your transit and take a reading off the surveyor's bench mark. Use this as your reference to ensure that the building is constructed level and at the correct elevation. Without a leveling instrument it would be almost impossible to plan and level the forms for the footings. This is your first construction operation — and by far the most important one of the job. This first reading is critical to the construction of the structure. If the foundation is correct, the rest of the building will be right. At this time you should also double-check the setback and the separation distance against what the local law requires. Don't rely on others to get it right. If there's a mistake, the building inspector is sure to issue a stop work order against you. And if you have to stop work and move the building, you'll find yourself in a serious economic bind.

Cubic Yards per 100 Linear Feet of Trench							
Depth in inches	Trench width in inches						
	12	18	24	30	36	42	48
6	1.85	2.78	3.70	4.63	5.56	6.48	7.41
12	3.70	5.56	7.41	9.26	11.11	12.96	14.81
18	5.56	8.33	11.11	13.89	16.67	19.44	22.22
24	7.41	11.11	14.81	18.52	22.22	25.93	29.63
30	9.26	13.89	18.52	23.15	27.78	32.41	37.04
36	11.11	16.67	22.22	27.78	33.33	38.89	44.44
42	12.96	19.44	25.93	32.41	38.89	45.37	51.85
48	14.81	22.22	29.63	37.04	44.44	51.85	59.26
54	16.67	25.00	33.33	41.67	50.00	58.33	66.67
60	18.52	27.78	37.04	46.30	55.56	64.81	74.07

Figure 2-6
Trench excavation factors

Using Levels and Transits

Once again, it's almost impossible to build without a leveling instrument. Small contractors will occasionally use the least expensive level available. This type of instrument is called a *builder's* level or *dumpy* level. It's very accurate if you take the time to set it up properly. The image in the telescope is magnified 20 times — meaning the object sighted appears 20 times closer than it would with the naked eye. In most cases this level is used with a leveling rod graduated in eighths of an inch. Figure 2-7 shows a builder's level.

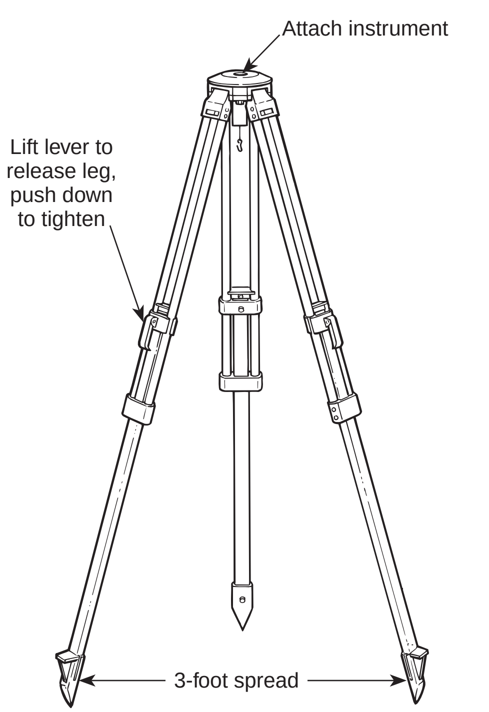
Courtesy: David White®

Figure 2-7
Builder's level

For building concrete footing and wall forms, the level of choice is the transit. A level-transit is shown in Figure 2-8. A builder's level moves only horizontally, but a transit moves both horizontally and vertically. Its telescope moves up and down 45 degrees, and rotates 360 degrees, to measure vertical and horizontal angles as well as set elevations. The level-transit has horizontal and vertical circles divided into degrees and 30-minute (½-degree) increments. You can read a 1-minute transit to 1 minute of an angle in either the vertical or horizontal circle. We'll explain what this means later on in the chapter.

Courtesy: David White®

Figure 2-8
Level-transit



Courtesy: David White®

Figure 2-9
Setting up the tripod

Levels and level-transits, like all sighting instruments, operate on the principle that any point along a level line of sight is exactly level with any other point along that same line. Use them in the level position (with closed lock lever) for:

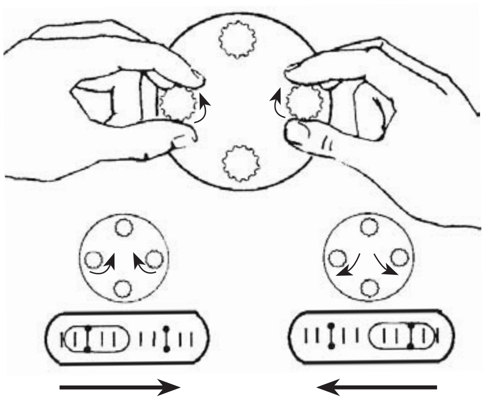
- grading
- plotting contour lines
- laying out drainage ditches
- setting fence lines
- estimating cut and fill requirements
- setting forms and footings
- leveling walls and foundations
- building terraces and stone walls

Setting Up Your Instrument

Attach the instrument (either builder's level or transit) to the tripod securely, hand-tightening the tripod mounting stud to the instrument base. To position the instrument, set the tripod firmly on the ground with the telescope approximately at eye level. It's important that the tripod is set up firmly, with the tripod points well into the ground. If you're setting up in dirt, apply your full weight to each leg to prevent settling. When setting up on a smooth floor or paved surface, secure the points of the legs by chipping the concrete, attaching chains between the legs to limit their spread, or putting a brick in front of each leg. The tripod legs should have about a 3-foot spread and be positioned so the top of the tripod head appears level. Be sure the leg levers are securely tightened. Figure 2-9 shows a tripod that's set up correctly.

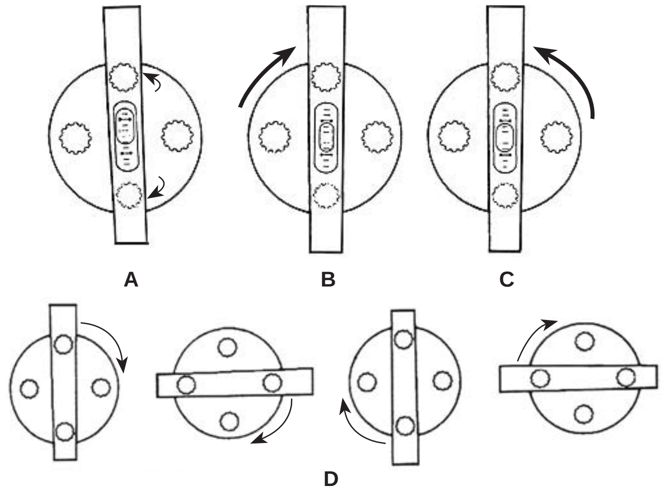
Use a plumb bob to center your level on an exact point. To hang the plumb bob, attach the cord on the bottom of the instrument, then move the tripod and the instrument until the plumb bob is over the exact point. This may take time, but it's the only way to be accurate. Again, make sure the tripod legs are set firmly.

The level should be set up away from heavy vehicle traffic because the vibration could disturb the setting. Adjust the leveling screws so the level is horizontal and the plate stays level no matter what



Courtesy: David White®

Figure 2-10
Leveling with the thumb screws



Courtesy: David White®

Figure 2-11
Checking the level

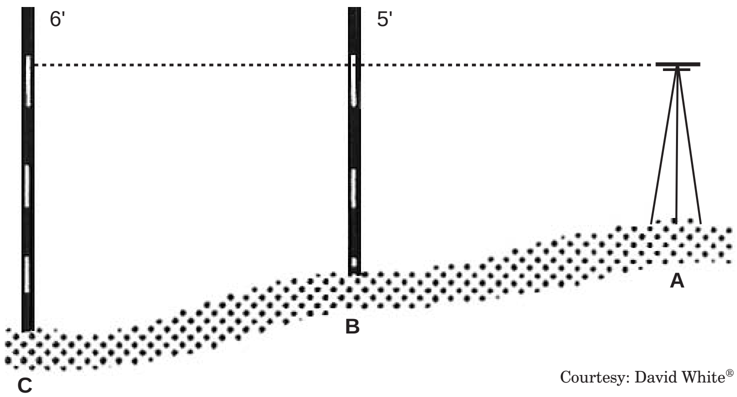
direction you point the telescope. Turn down the instrument leveling screws until it makes firm contact with the tripod head. If the instrument shifts on the tripod, turn the screws more firmly by hand. A word of caution here: it's possible to overtighten the leveling screws. You want only a firm contact between the screws and the tripod head.

Leveling the instrument so the vial bubble remains centered through a 360-degree rotation of the telescope is the most important operation in preparing to use your instrument. When leveling your instrument, be sure not to touch the tripod. The Golden Rule for quick and simple leveling is *thumbs in, thumbs out*. Turn *both* screws equally and simultaneously. Practice will help you get the feel of the screws and the movement of the bubble. It also helps to remember that the direction your left thumb moves is the direction the bubble will move. See Figure 2-10.

Line up the telescope so that it's directly over one pair of leveling screws (Figure 2-11A). Grasp these two leveling screws with the thumb and forefinger of each hand. Turn both screws at the same time by moving your thumbs toward each other or away from each other, until the bubble is centered.

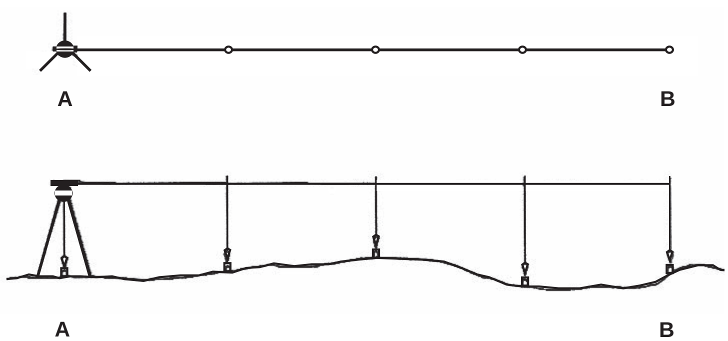
When you have the bubble centered, rotate the telescope 90 degrees over the second pair of leveling screws and repeat the thumbs in, thumbs out leveling procedure until the bubble is again centered (Figure 2-11B).

Shift back to the original position and check the level (Figure 2-11C). Make minor adjustments with the leveling screws if necessary. For a final check, rotate the telescope over each of the four leveling points to be sure the bubble remains centered (Figure 2-11D).



Courtesy: David White®

Figure 2-12
Finding the difference in height



Courtesy: David White®

Figure 2-13
Running a straight line

Determining Differences in Elevation

One of the main uses of levels is for measuring differences in elevation for grading. With the instrument leveled, we know that since the line of sight is perfectly straight, any point on that line of sight will be exactly level with any other point.

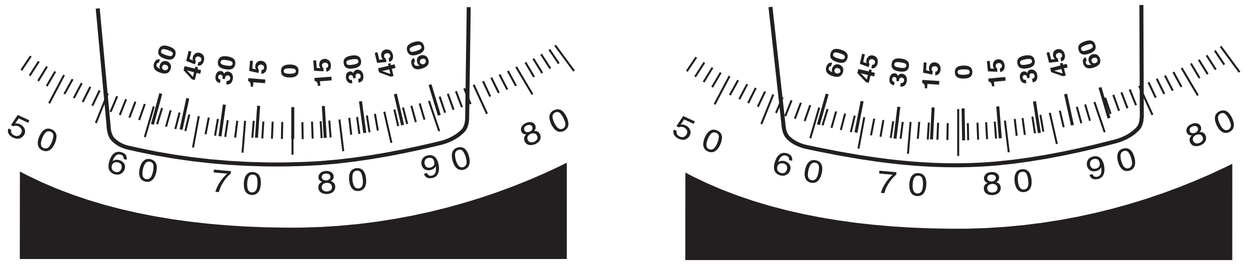
Figure 2-12 shows how you can check the difference in height (elevation) between two points. If the rod reading at *B* is 5 feet and the reading at *C* is 6 feet, we know that point *B* is 1 foot higher than point *C*. Using the same principle, you can easily check if a row of windows is straight, or a wall is level, or how much a driveway slopes.

Running Straight Lines with a Level

Look at Figure 2-13. To run a straight line, set up the instrument over point *A*, and direct your helper to hold a plumb bob over point *B*. Sight approximately on the plumb bob cord and turn the telescope so that the vertical crosshair coincides with it. To align the intermediate points, direct the person with the leveling rod to the right or left until the rod also coincides with the vertical crosshair. It's important not to move the instrument during operation. After you've set all the points, check point *B* again to be sure that the instrument didn't move.

Determining Contour Lines

Contour lines are lines connecting points of equal level. To determine contour lines, first level the instrument carefully. Hold a sighting rod at the beginning contour line about 100 feet from the instrument. Sight the rod and set a target on the rod at the point where the horizontal crosshair intersects the rod. Then move the rod to the next position



A — 75 degrees

B — 75 degrees, 45 minutes

Courtesy: David White®

Figure 2-14
Reading the circle and vernier

where a contour line stake is to be set and move the rod up or down the slope until the line of sight through the telescope again intersects the target. This determines a second point on the contour line. Repeat this step as many times as necessary.

If the person holding the rod is moving too far away from the instrument, simply hold the rod in one of the positions determined from the original instrument position and move the instrument to another convenient location along the contour. Sight on the rod in this position and move the target up or down until it lines up with the crosshair. Then you can continue the line from the new position.

Reading the Circle and Vernier

The 360-degree horizontal circle is divided into quadrants (0-90 degrees). The circle is marked by degrees and numbered every 10 degrees. To obtain degree readings, just read the exact degree at the intersection of the zero index mark on the vernier and the degree mark on the circle (or on the vertical arc of the level-transit). Figure 2-14A shows a reading of 75 degrees.

For more precise readings, use the vernier scale. The vernier lets you subdivide each whole degree on the circle into fractions, or minutes. There are 60 minutes in a degree. If the vernier zero doesn't coincide exactly with a degree mark on the circle, note the last degree mark passed and, reading up the vernier scale, locate a vernier mark that coincides exactly with a circle mark. This will indicate your reading in degrees and minutes. Figure 2-14B shows a reading of 75 degrees, 45 minutes. The zero on the vernier scale is just above the 75 degree mark, indicating 75 degrees, and the first vernier mark that coincides with a mark on the circle is at 45, indicating 45 minutes.

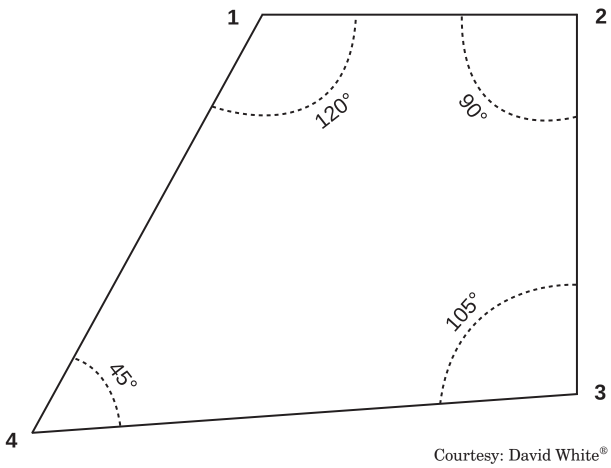


Figure 2-15
Measuring and laying out angles

Sighting and Focusing the Telescope

Aim the telescope at the object and sight first along the top of the telescope tube. Then look through the telescope and adjust the focus. When the crosshairs are positioned on or near the target, tighten the horizontal clamp and make final settings with the tangent to bring the crosshair exactly on point.

Measuring and Laying Out Angles

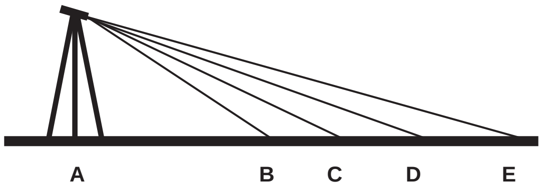
For measuring angles, attach a plumb bob cord to the hook on the screwdriver-style handle of the tripod. The point of the plumb bob will indicate the point on the ground directly below the center of the instrument, and therefore, the center of all angles to be measured. This point should be marked by a stake about 2 inches square with a tack indicating its center. Horizontal angles are always read at the vernier zero mark.

Look at Figure 2-15 to see an example of how to measure angles. First, set up your instrument so the plumb bob is directly over station 1, and level it as explained previously. Turn the telescope so that the vertical crosshair is directly in the center of the rod at station 2. Set the horizontal circle at zero to coincide with the vernier zero. Then turn the telescope to sight on station 4 and read the angle. (In this case, it would be 120 degrees.)

Move the instrument and tripod to station 2 and level exactly as before. When the instrument has been leveled, sight back to read on station 1. Set the horizontal circle to zero, then sight the telescope to locate station 3 and read the angle (90 degrees). Move the instrument and tripod to station 3 and level again. Again, sight back to station 2 and set the circle at zero. Then turn the telescope to sight on station 4. Your angle should be 105 degrees. Follow the same procedure to measure the angle at station 4, and you'll get 45 degrees. You can prove the accuracy of your reading by adding the four inside angles together. The total of the inside angles of a quadrangle is always 360 degrees:

120 degrees (station 1)
90 degrees (station 2)
105 degrees (station 3)
\+ 45 degrees (station 4)
360 degrees

Laying out an angle works just like measuring an angle. Set the instrument at station 1, level it, and set the circle at zero. Swing the



Courtesy: David White®

Figure 2-16
Running straight lines with a level-transit

telescope to the desired angle and move the rod to intersect the vertical crosshairs. This establishes your angle.

Running Straight Lines with a Level-Transit

Although you can run straight lines with a builder's level, it's faster and more accurate to use a level-transit. Figure 2-16 shows the procedure. To run a straight line between stakes *A* and *E*, position the instrument directly over *A*. After you level the instrument, release the lock that holds the telescope in the level position and swing the instrument until point *E* is aligned with the vertical crosshair. Tighten the horizontal clamp so the telescope can move only in a vertical plane. By pointing the telescope up or down, you can locate points *B*, *C* and *D*.

You always need a level-transit for taking vertical sights, such as lining up a building wall or plumbing windows or doorways. To establish vertical lines and planes, first level the instrument, then release the locking levers that hold the telescope in the level position. Swing the telescope vertically and horizontally until the line to be established is directly on the vertical crosshair. If the telescope is rotated up or down, each point cut by the vertical crosshair should be on a vertical plane with the starting point.

Care and Handling of Levels and Transits

Keep your instrument clean and free of dust and dirt. All precision instruments should be cleaned, lubricated, checked and adjusted at least once a year, and *only* at a qualified instrument repair station or by the manufacturer. During use, follow these rules to keep your instrument in good condition:

- Clean the objective and eyepiece lenses using a soft brush or lens tissue. Rubbing with a cloth may scratch the lens coating and impair the view.
- Clean the instrument with a soft, nonabrasive cloth and mild detergent. Never use solvents or submerge the instrument in water. Don't try to take the instrument apart.
- If the instrument is wet, dry it before you return it to its case.
- When the instrument isn't being used, keep it in its carrying case.

- When moving the instrument over a long distance, by foot or by vehicle, remove it from the tripod and place it in its protective case.
- When moving a tripod-mounted instrument, handle with care. Carry only in an upright position. Don't carry it over your shoulder or in a horizontal position. Improper handling may result in damage to the instrument.
- Handle the instrument by its base when removing from the case or attaching to a tripod.
- Never use force on any parts of the instrument. All moving parts will turn freely and easily by hand.

Staking Out a Building

This process involves more than just pounding four stakes into the ground. It's also an important part of your early on-site survey work. We'll go through the stages, step by step. Look carefully at Figure 2-17. We'll refer to it often, so let's begin by identifying its main features:

- Points *A*, *B*, *C* and *D* mark the corners where you place the stakes.
- The shaded area shows the future location of the foundation.
- Lines *AB*, *BD*, *DC* and *CA* are the building lines.
- The diagonal dashed lines, *AD* and *BC*, mark measurements you use to check for square.
- The right-angle shapes, shown outside the building lines at the corners, are the batterboards.
- Each *N* marks the location of a nail driven into the top of the batterboard.
- The lines that extend the building lines out to each nail location show part of the path followed by the string lines. The rest of a string line path matches that of the building line.

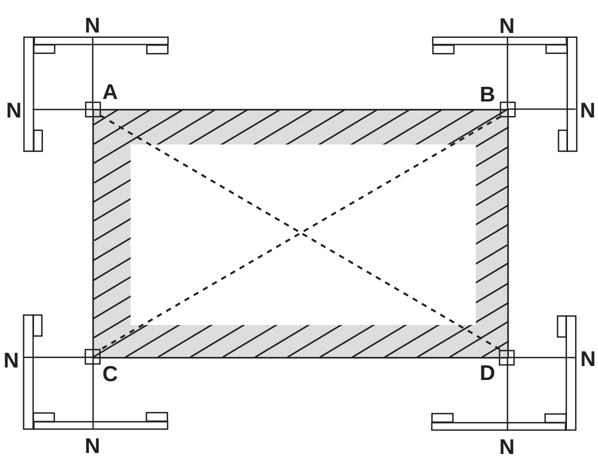


Figure 2-17
Building layout and batterboard setup

TO STAKE OUT THE BUILDING:

1. Level and center your transit on point *A*.
2. From *A*, sight on point *B*. Do that by turning the transit 90 degrees to the left.
3. Set point *B* at the known distance from *A*. Mark point *B* with a corner stake.
4. Leaving the transit at point *A*, sight on point *C*. That means you turn the transit 90 degrees to the right.
5. Set point *C* at the known distance from *A*. Mark point *C* with a corner stake.
6. Move the transit to point *B*. Center and level the transit on point *B*.
7. From *B*, sight on point *D* by turning the transit 90 degrees to the left.
8. Set point *D* at the known distance from *B*. Mark point *D* with a corner stake.

Let's also assume we know:

- Line *AB* is the building's frontage.
- The location of point *A*.
- Point *B*'s direction, relative to point *A*.
- All angles are 90 degrees.
- The length of all four building lines.

Before you move on to setting up the batterboards, stop and check the work you've done so far. There are two ways to check this part of your work. The first way is to compare the lengths of a set of parallel sides. Measure the lengths, for example, of line *CD* and line *AB*. If they're equal, then your work's accurate.

The second way to check the layout is to compare the lengths of the diagonals. In Figure 2-17, these are the dashed lines *AD* and *BC*. I recommend using the diagonals method because it also checks the layout for square. Equal diagonals mean you've set the corners accurately and square. If any of the four angles isn't 90 degrees, the diagonals won't be equal. If your diagonals aren't equal, go back and check the angles with your transit. What does it mean if all four still read exactly 90 degrees? The problem is probably an out-of-level transit setup. Start over with step 1 in the sidebar above, and this time work more carefully!

Placing Batterboards

Now that you've set and staked your four corners, let's move on to setting up batterboards to define the building lines. Your carefully marked corner points *A*, *B*, *C* and *D* will all disappear when the foundation is excavated. But the string lines that you run from the batterboards extend the building lines and cross each other exactly over the corner points. They make the job of re-establishing the corner points a piece of cake. The whole reason batterboards and string lines work is that they're set up *outside* the building lines. Excavation or other site work won't be done close to them, so their positions won't be disturbed. A comfortable separation distance between the batterboards and building lines is usually about 4 feet.

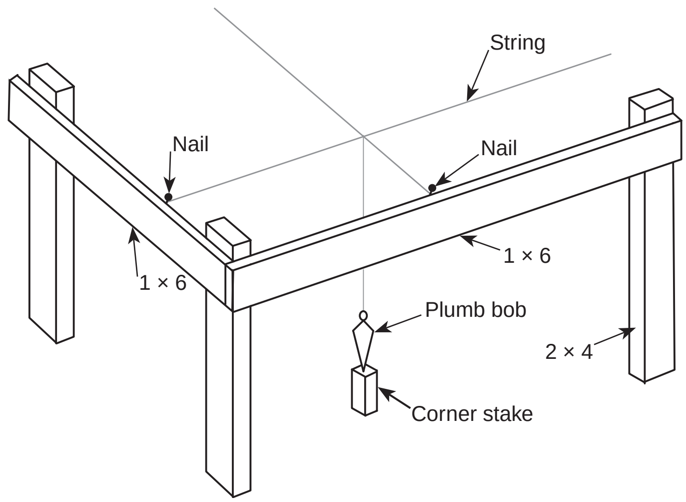


Figure 2-18
Checking batterboard and string line placement

Here's how to set up the batterboards shown in Figure 2-17:

1. Level and center the transit in a convenient spot near the building's center.
2. Set three posts, the batterboard uprights, about 4 feet out from the building lines at each corner.
3. Take sightings at each corner on the foundation's top.
4. From this reading subtract the clearance — the distance between the foundation top and the string lines.
5. If the result isn't a whole number of feet, add as needed to make a whole-foot number and set the rod target for this elevation. Adjusting this elevation to read as a whole number of feet makes it much easier to sight with the transit for the following steps.
6. Holding the preset rod at each of the batterboard uprights (posts), raise or lower the rod and center the target reading in the transit's crosshairs.
7. Mark each post with the location of the rod's foot. This marks the correct position for the top edges of the batterboard crosspieces.
8. Attach the crosspieces to the uprights following the markings.

The next step is setting the nails in the batterboard to attach the string lines:

- First, level and center the transit over each corner position.
- Then take sightings in turn on the two adjacent corner points.
- Mark the points on the top edge of the batterboard, and drive a nail into the batterboard at each mark.

Now, for the final step, simply run the string for the string lines from nail to nail. The string lines extend the building lines out to the batterboards and crisscross exactly above the corner points. It's easy to check the positions of the string lines. Take a look at Figure 2-18, then just follow these steps:

- Tie a plumb bob to a short length of line.
- Attach the line to one of the string line crossing points.
- Lower the plumb bob until its tip touches the top of the corner stake.

Your string line and batterboard setup is correct if the plumb bob tip touches the corner stake at its center.

Electronic Automatic Levels

Many public work projects are done with electronic equipment. These instruments are extremely accurate — but they're also very expensive. Figure 2-19 shows an automatic laser level mounted on a tripod. It has a battery with a charger. The technology of this type of level goes way beyond the capability of a transit. Electronic automatic levels are also called laser levels.

Laser levels should be set up on a surface as close to level as possible, or on a leveled tripod. Automatic laser levels have no leveling bubbles, and — as the name says — automatically level themselves.

Laser levels can be used to plumb walls and other vertical alignments, run straight and level lines, and set the height of concrete forms and floor slabs. They're accurate to within $^{1}/_{16}$ inch at 100 feet. And there's another advantage: using a rotating laser and receiver, you do leveling work by yourself. Lasers work by extending the level reference point through the use of a laser beam. As the laser beacon rotates, it generates a 360-degree level plane over a large-diameter area. Some laser levels also have a hinged top so that they can generate a vertical reference plane. You use a bull's eye bubble to initially level the instrument. It automatically keeps itself level after that. If you accidentally knock the instrument out of level, it stops rotating and a light flashes.

Courtesy: David White®

Figure 2-19
Automatic laser level

The laser level is used with a receiver attached to a staff or a leveling rod like the one shown in Figure 2-19. When the receiver intercepts the beam, you'll hear a constant tone and see the center line display in the window of the receiver. If the laser beam isn't intercepted by the receiver, you won't hear anything and you must slide the receiver up or down until you pick up the signal. When centered, the index line (center line) in the window of the receiver indicates it's level with the laser beam and on grade if it's pointing to the desired rod reading.

Conversion Table — Inches to Decimals (in feet)								
Whole inches	**Fractional parts of an inch**							
	0	**1/8**	**1/4**	**3/8**	**1/2**	**5/8**	**3/4**	**7/8**
0	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07
1	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16
2	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24
3	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32
4	0.33	0.34	0.35	0.36	0.38	0.39	0.40	0.41
5	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49
6	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57
7	0.58	0.59	0.60	0.61	0.62	0.64	0.65	0.66
8	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74
9	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.82
10	0.83	0.84	0.85	0.86	0.88	0.89	0.90	0.91
11	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99

Figure 2-20
Converting inches and fractions of inches to decimal equivalents in feet

The measurements on the rod in Figure 2-19 are graduated in eighths. They're $^1/_8$ inch apart and marked in feet, inches, and eighths of an inch. The measurements you'll find on building plans and blueprints are usually in feet and inches. However, the measurements on site plans for heights and linear distances are usually in units of whole or decimal parts of a foot. For instance, $^1/_8$ inch is about one hundredth of a foot (0.01). You can use Figure 2-20 for easy conversions from inches to decimal equivalents of a foot. Occasionally, a metric rod may be used. The metric rod is graduated in meters, decimeters, centimeters and half centimeters.

Helpful Hints for Accuracy

Set up the laser as high as practical to avoid *scintillation*. Scintillation, or a disturbance in the line of the laser beam, can be caused by variations in the air temperature. For instance, warm air rising above pavement or asphalt can affect the beam. Scintillation is more likely to occur when the laser is set up close to the ground where it can be affected by heat or vibration.

Once the laser is set up:

- Establish reference bench marks to periodically check laser setup.
- Be careful not to pick up signals with the receiver from reflective surfaces such as polished metal or glass. This could cause erroneous readings.

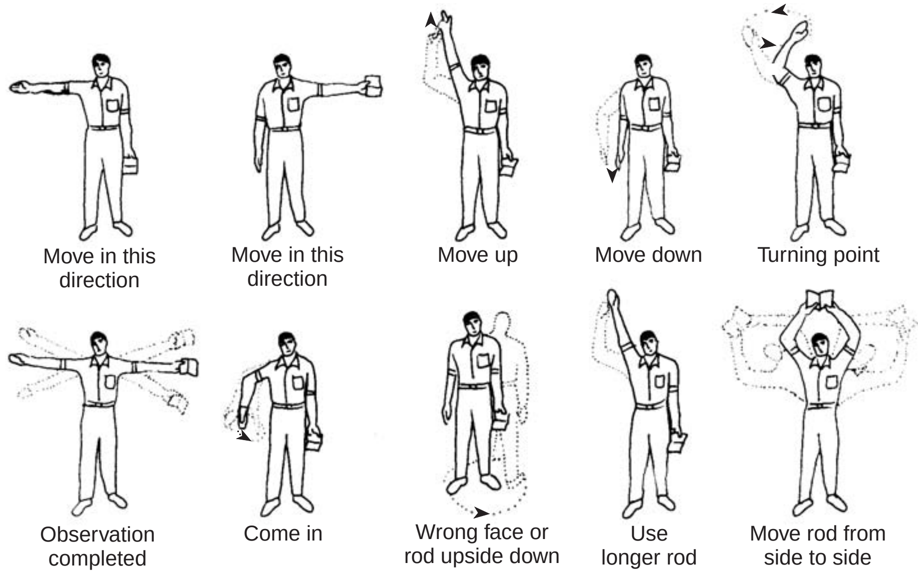


Figure 2-21
Standard surveyors' hand signals

- Hold the rod as plumb as possible when taking readings.
- Check often to make sure the receiver is at the correct elevation.
- Make sure you're using the correct accuracy setting on the receiver.
- Keep the capture window on the receiver and the window around the rotating head of the laser as clean as possible.
- Turn the receiver and the laser off when not in use.
- Replace batteries in the receiver and laser as soon as possible after the low battery indicator comes on.
- Always store receiver and laser in the case when not in use.
- Check for other laser setups on the jobsite that could interfere with signal reception.

Several people can use the same automatic level at the same time. When using a regular transit, two people are needed. One operates the transit and the other holds the architect's rod or engineer's rod. Accurate communication between the two operators is extremely important; and on a noisy, congested building site, it's often difficult to hear. Figure 2-21 shows standard hand signals that are used for communicating directions.

Once the planning and site work, including excavation, are complete, it's time to get on to the actual work of building footing forms for the foundation. That's the subject of the next chapter.

3

FOOTING FORMS

The first structural work done on a building is forming and pouring the footings. Footings are the base that the foundation is built on. They're designed to distribute the structure's weight over a larger area, providing a more stable foundation. Footing size depends on the structural load and the bearing capacities of the soil. Since footings aren't usually seen, their appearance isn't that important. However, they *do* need to be located accurately and built to the specifications of the engineer or architect.

Building Footing Forms

For residential footing forms, the general rule is to make the footing twice as wide as the foundation wall and as thick (deep) as the wall is wide. This means residential foundation footings are typically 8 inches thick (deep) and 16 inches wide for an 8-inch-thick (wide) wall. A 10-inch-thick (wide) wall would need a footing 10 inches thick and 20 inches wide. Of course, there are many variables that affect footing design, such as the weight of the structure, the soil-bearing characteristics on the site, and the climate. Don't assume all footings will follow the general rule. Always check the local building codes before building footing forms. They'll tell you the minimum required footing size and depth in your area. For example, in locations where there's frost, the footings should always be built below the frost line to prevent heaving.

Figure 3-1
Using a laser level to level footing forms

It's important to check with the code office to find out reinforcing requirements as well. If you pour a footing without the required reinforcing, the code officials can make you tear it up. This could cost you any profit you may have made on the job. Many contractors overbuild the footing to make sure that the structure won't move and crack. Using an extra inch of concrete or a higher psi-rated concrete is cheap insurance against a lawsuit.

Form Materials

Concrete footing forms are commonly built using 2 x 8, 2 x 10 or 2 x 12 structural lumber. They're usually as wide as the footing is thick. So to build a 10-inch-thick wall, you'd use a 2 x 10 board. Sometimes contractors will have concrete left over — even though they've accurately figured the cubic yardage to fill the forms. This is because they forget that "nominal lumber" isn't the actual size. A 2 x 10 structural board is about 1½ by 9¼ inches. If accuracy is important, you can add a ¾-inch strip of wood to the top of the 2-by material to make the footing the exact 10-inch size. This is another reason contractors sometimes pour footings thicker than required.

Rough-cut lumber is very close to the actual 2 x 10 size. But because of its extra weight, it's not as useful for other applications when it's removed as form lumber. Smart contractors will strip and clean form lumber as soon as possible so they can reuse it for other projects. Form lumber can be used for some part of the framing or reused for forming on your next project. Cleaned form lumber is easier to stack and store. Since wood form material will eventually bond to the concrete, you must remove the forms within one to two days of the pour.

Setting Up the Forms

Construct the footing forms for walls before you build the footing forms for piers. If the foundation forms are built first, it's easier to locate the correct position for the pier forms. Piers are built into the wall to support a beam or Lally columns and jack posts.

When setting up footing forms for vertical concrete formed walls, build them so that the prebuilt forms used for the walls will sit on a flat level surface. Figure 3-1 shows carpenters using a laser level to make sure their forms are perfectly level. The laser level is in the left background. As we discussed in the last chapter, this type of level allows the men to work together on the formwork. With the receiver attached

Figure 3-2
Footing excavation
with rebar and electrical conduit installed

Figure 3-3
Reinforced footing with rod covers on rebar

to the leveling rod, they can check the correct height of the forms at different locations while they're building them.

After the forms are built, use dirt or gravel to fill in low spots around the bottom exterior of the forms. Placing soil against the outside of the forms adds support and helps prevent any movement when the concrete is poured. The interior bottom of the concrete footing must be poured on undisturbed soil or well-compacted gravel. Never fill in depressions with loose earth or pour concrete on top of vegetation. In time the earth will settle and vegetation will rot, forming voids under the concrete — weak spots that could crack.

Many commercial buildings and schools have interior block walls. For one-story block interior walls that will be laid on the concrete slab, thicken the slab under the location of the interior block walls. Residential homes with masonry fireplaces that require a masonry fire separation may also need this type of footing. Support these walls with a thicker slab that's also part of the wall footing. Reinforce the footings and build them thicker than the slab at the required positions to conform to the local building codes. Using this method, you can pour the wall footings and the concrete slab at the same time.

The footing excavation in Figure 3-2 shows both reinforcing rods and electrical conduit installed prior to the concrete pour. There's also a boxed-out form for a column. After the slab is poured, the form will be removed and the concrete for the column poured, creating an isolation joint.

If you plan to erect Symons Steel-Ply® forms (which we'll cover in the next chapter) or any other factory-manufactured wall forms, you can save yourself time and effort by removing the footing forms when the concrete reaches its initial set. In Figure 3-3, a carpenter removes the spreaders and smooths out the concrete where the manufactured forms will be set. These forms have flat edges, and it's easier to set them on a flat footing. You can also see the OSHA-approved reinforcing rod covers in the picture. Many of the accidents in building construction involve reinforcing rods, so OSHA requires that the ends of the reinforcing rods be covered.

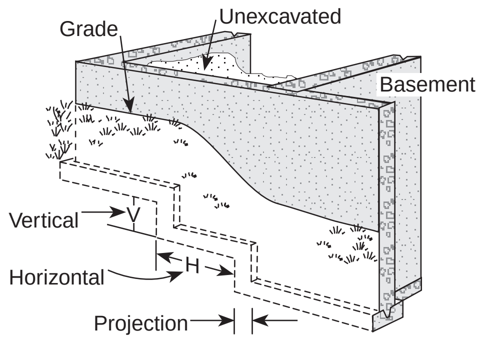


Figure 3-4
Stepped foundation on sloping ground

Figure 3-5
Stepped footing with bulkhead

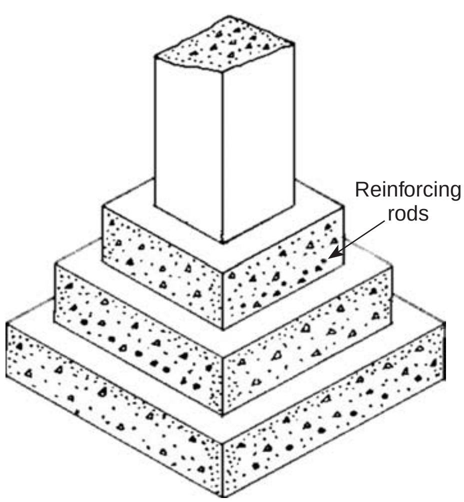


Figure 3-6
Stepped pier

Stepped and Tapered Footings

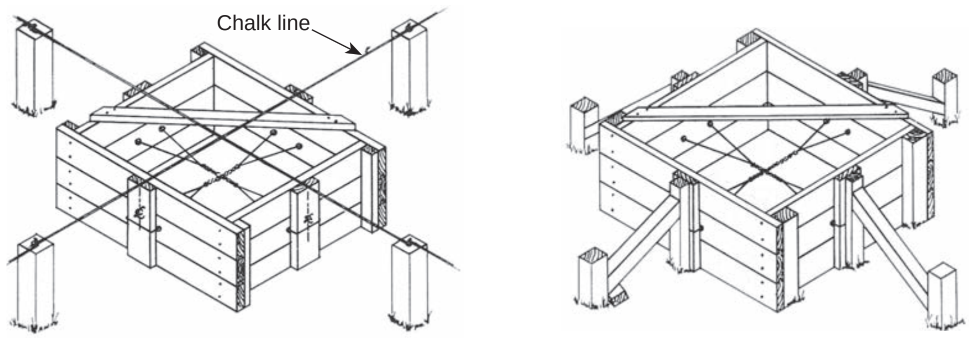
Use stepped footings when building on sloping ground. Figure 3-4 shows a typical stepped foundation. If the excavation is dug parallel to the slope and poured accordingly, the building will have a tendency to "creep" or slide toward the lowest point. You can prevent this by building a stepped footing. Each step must be level and positioned in increments of 8 inches for a concrete block foundation. Why 8 inches? It's the height of a course of concrete blocks. Figure 3-5 shows an example of a bulkhead. A bulkhead is designed to accommodate the height of the finished block work. It should always be built to fit modular construction. If concrete blocks are to be laid on the footing, then the bulkhead and form height should be in increments of 8 inches. This allows the correct coursing of block work. This spacing also works well with preformed concrete forms. The steps should be no more than 24 inches high and no less than 24 inches long. Overlap the step forms by at least 24 inches, and place reinforcing rods that continue from the flat footing through and into the bottom of the stepped footing to tie the layers together.

Pier Footings

Pier footings may have stepped or tapered sides. Figure 3-6 shows a stepped pier. This type of pier is used for ordinary residential construction projects when the load on the pier per square foot is greater than the bearing strength of the soil per square foot. The pier sits on top of the ground, and is sometimes used in post and beam construction.

Build each stepped pier footing individually to meet the blueprints or specifications. Since you build them after the exterior wall forms are set, you can stretch layout lines across the foundation. This allows you to accurately align the pier form. Once it's aligned, you can set braces to reinforce it for the pour. See Figure 3-7A and B.

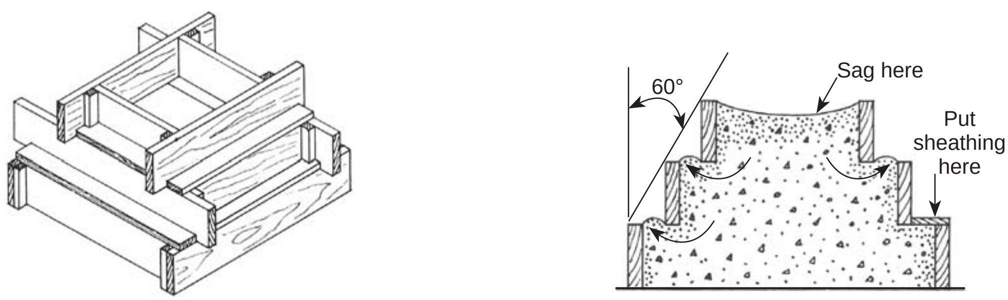
Stepped footing forms are constructed in layers. Each layer is 4 to 8 inches smaller (or whatever the code permits) than the previous layer. Put pieces of



A — Setting pier form by center lines

B — Bracing the form

Figure 3-7
Aligning and bracing a pier form



A — Stepped footing form

B — Section of stepped form

Figure 3-8
Stepped footing form

formwork or sheathing on the top outside of each level of the stepped form (see Figure 3-8A). This will prevent sags in the top of the form or overflows in the top level of each step (Figure 3-8B).

There may be times when soil conditions are poor, and you'll want to use a *tapered* footing to spread the structure's load over a larger area. Figure 3-9 shows a tapered footing. The sides are tapered to conserve material. The angle of slope for tapered pier footings should be 60 degrees from the horizontal. This is based on the fact that the angle of shear (the point at which the concrete will crack) caused by a load on the footing is 45 degrees. This angle is within the 60 degrees of slope. Pier footings are typically set on solid ground to support a building. You might use this type of footing for a trailer or modular structure.

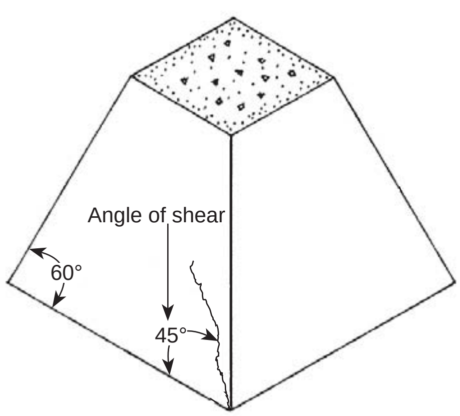
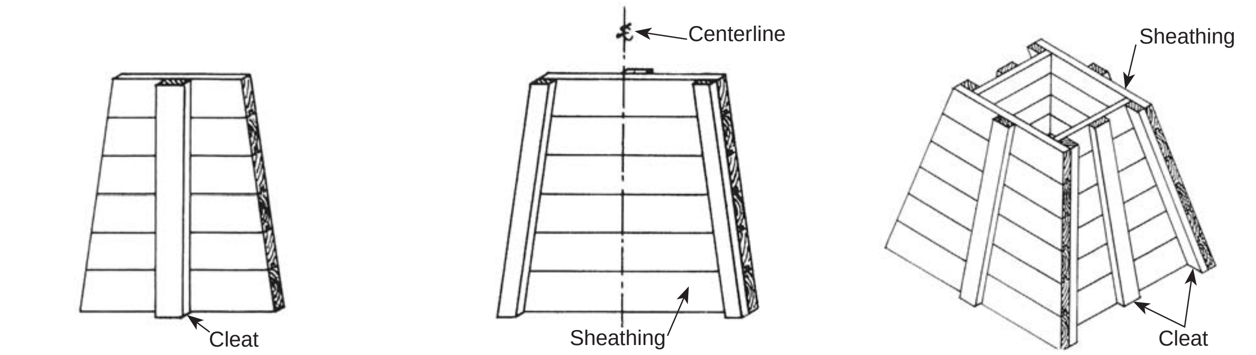


Figure 3-9
Tapered footing

Figure 3-10 shows how to construct a tapered form using 2 x 4s. You can substitute ¾-inch plywood for the sheathing (sides), if you want.



A — Side panel of tapered pier form **B —** Another side panel of tapered pier form **C —** Tapered pier form

Figure 3-10
Building a tapered pier form

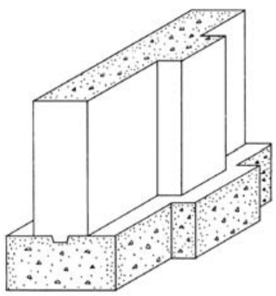


Figure 3-11
Pilaster wall footing

Combination Wall and Column Footings

Combination wall and column footings are used when a wall and a column are combined to form a pilaster. A pilaster is a projection, typically rectangular in design, that's incorporated into a concrete wall to support a beam, or to strengthen the wall against horizontal pressure. See Figure 3-11. This type of footing is used where piers are set at intermediate points in a continuous wall, such as the projection shown in the illustration.

Footings **Cubic Measure per 100 Linear Feet**		
Size	**Cubic feet concrete per 100 linear feet**	**Cubic yards concrete per 100 linear feet**
6 x 12	50.00	1.9
6 x 16	65.05	2.4
8 x 12	66.67	2.5
8 x 16	88.89	3.3
8 x 18	100.00	3.7
8 x 20	108.00	4.1
10 x 12	83.33	3.1
10 x 16	111.11	4.1
10 x 18	125.00	4.6
10 x 20	135.00	5.1
12 x 12	100.00	3.7
12 x 16	133.33	4.9
12 x 20	166.67	6.1
12 x 24	200.00	7.4

Figure 3-12
Cubic feet of concrete per linear feet of footings

If you're planning a small concrete project, use Figure 3-12 to help estimate the amount of concrete you need. Make sure the base for the footing is perfectly flat, with no voids. Remember, filling up hollow areas in the base will require more concrete, and you don't want to run out of material. If you come up short on concrete, it's very expensive to order a short load, or try to mix up the small amount needed. You'll also run the risk of having a "dry crack," which means that the newly-added concrete doesn't completely bond with the previous pour. Inspectors look for this.

Some concrete suppliers provide, or sell, hand-held concrete calculators, which can help you estimate the volume of material you need. Figure 3-13 shows the ConcreteCalc™ Pro manufactured by Calculated Industries (www.calculated.com). It can be used for very fast concrete-related math solutions. It shows feet-inch fractions, solves for area and volume, and has length, width and height keys, as well as the regular calculation keys.

Courtesy: Calculated Industries

Figure 3-13
Concrete calculator

Form-A-Drain Footing Forms

CertainTeed Corporation has a forming system called Form-A-Drain. It's a permanently-installed system that's a nice improvement in forming practices. The system includes footing forms and foundation drains, as well as a complete line of assembly accessories. In addition to the time and manhours saved by not having to disassemble and remove the forms, one of its major benefits is that it comes with a means for evacuating radon gas from the foundation.

The forms come in 12-foot-long sections that are easily cut with a hand saw, circular saw or orbital saw. When cutting the sections to the length you need, make sure your cuts are as square as possible for tight connections. Assemble the outside of the formwork first. Make sure that the holes (slots) in the forms face the outside. The accessories are easy to put together. Figure 3-14 shows the factory-supplied spacer strips. They're available in 16-, 20- and 24-inch widths. They both hold the forms apart and support the reinforcing rod that's suspended in the concrete, and they remain a permanent part of the concrete reinforcement system.

You can either level the sections separately as you put them together, or when all the sections are assembled. Use grade stakes, steel forming pins or wood stakes to brace the sections. Place the stakes on the outer side (slotted side) of the form, as in Figure 3-15. One good method of attachment is to use long deck screws through the stakes and into the forms. Once the forms are leveled, add additional stakes to hold back the pressure of the concrete when it's poured into the forms. Place the stakes about every 4 feet along the forms. When forming for a pilaster, porch or fireplace base footings, cut each form section to the correct length and simply use the corner accessories to connect them, as shown in Figure 3-16.

Form-A-Drain incorporates the foundation drainage system into the forms. Use the drainage outlet accessory to provide a transition to a 4-inch drain. The adapter should be installed at the bottom of the form

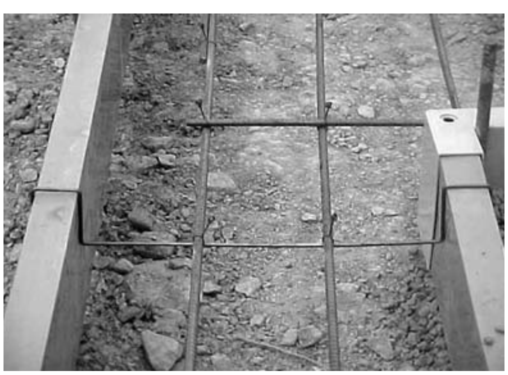


Figure 3-14
Spacer strip also supports rebar

Figure 3-15
Place stakes on the outer side of form lineals

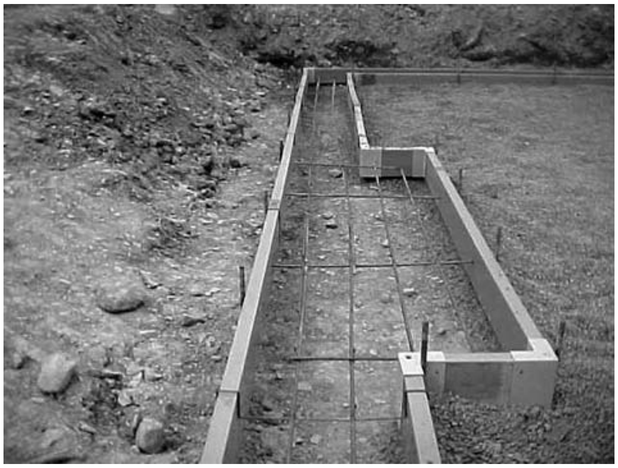


Figure 3-16
Use corner accessories to widen form base footing for a fireplace, porch or pilaster

Figure 3-17
Completed footing formwork using the Form-A-Drain system

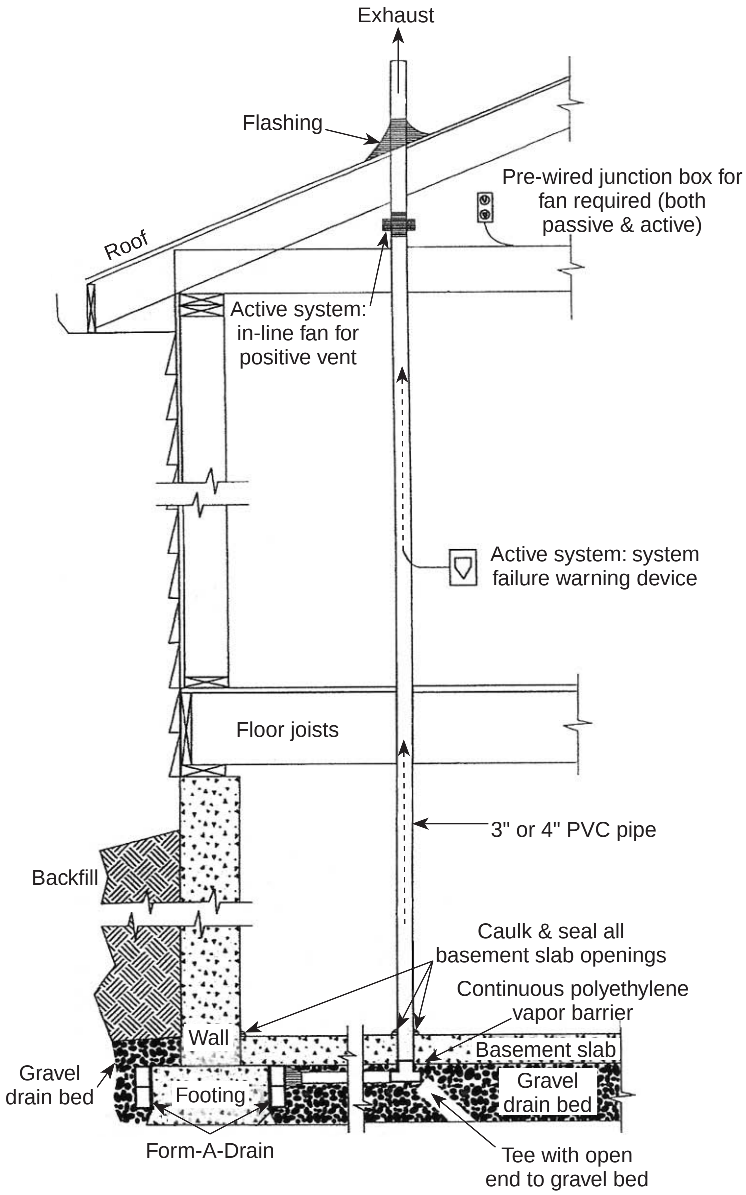
on the outside. Make sure the drainage complies with local codes and practices. Connect the inner and outer drainage channels by building crossovers. You can make a crossover from one lineal section to another by aligning two drainage outlets and connecting them using the correct diameter pipe. Another option is to cut crossover outlet holes into the lineal sections, then install two outlet adapters in the cut-out holes so they line up with each other. Or use 2- or 3-inch PVC pipe, cutting the ends at 45 degrees to keep the lineal sections from being blocked. Figure 3-17 shows a completed footing system. The cost savings in using this system comes from incorporating the drainage system into the forms, the ease of assembly, and the fact that the whole system is left in place after the pour. In addition, Form-A-Drain also includes a radon reduction system, which we'll look at next.

Radon and the Form-A-Drain System

In recent years, passive radon systems have become standard features of new home construction in many areas of the country. This trend is supported by home buyers as a result of the widespread concerns of the scientific community regarding the potential cancer-causing properties of radon gas. The scientific studies and resulting consumer demand have encouraged local agencies to include requirements for these systems in their building codes and practices.

Home builders have been able to use or adapt conventional radon construction techniques developed for below-grade foundations when installing radon systems during construction. But, with radon systems being installed in more and more areas and in many different building styles, construction professionals are often faced with situations calling for alternative installation techniques.

These alternatives, like other proven radon-resistant construction techniques, are based on soil suction or depressurization. Passive radon systems prevent soil gas, including radon, from entering a building. They form a pressure barrier and then redirect the gas outside. For a home with a basic slab foundation (see Figure 3-18), this would require:



Courtesy: CertainTeed Corporation

Figure 3-18
Proper installation of Form-A-Drain in radon-resistant new construction (passive and active system)

- A uniform layer of clean aggregate at least 4 inches thick in the subslab space. This is put down before the slab or any floor system that directly contacts the ground.
- 6-mil polyethylene sheeting or equivalent, placed on top of the gravel layer.
- PVC or other gas-tight venting pipe, at least 3 inches in diameter, installed vertically from the aggregate layer in the subslab space through the building's floors and extending to at least 1 foot above the roof. The vent pipe must be securely embedded in the aggregate with a "T" fitting or similar for support. Its exit from the roof must be at least 10 feet from any window or similar opening.
- All openings in and around the foundation must be sealed and/or caulked.

- An electrical junction box installed in the attic in case a fan-drawn or active venting system is needed in the future. This electrical box would also be used for a system failure warning device. If, at any time after construction is completed, the indoor radon levels measure 4.0 pCi/L (pico curies per liter) or higher, a fan can be installed and operated continuously — actively drawing the gases into the vent pipe to reduce the radon levels.

Accommodations for Active Systems

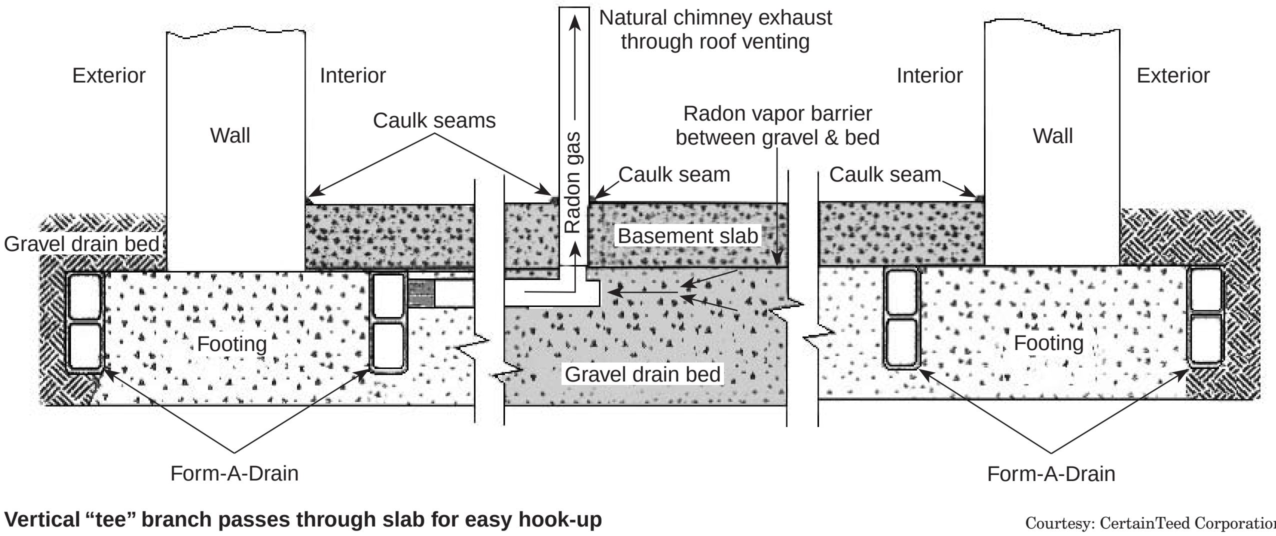
1. Follow the steps above for installing a passive system for a home with a slab foundation. For an active system, you're permitted to install the vertical pipe within the exterior wall.
2. Install a ventilation fan in the attic to convert the system from passive to active.
3. Install a system failure warning device in an easily-accessible location in the living area of the home.

Alternative Passive Systems

Currently, the demand for alternative techniques is centered in regions where crawl space foundations (rather than slab basements) are the norm, and also in areas where moisture-control measures (usually drain loops or sump pits) are commonly used with slab-basement foundations.

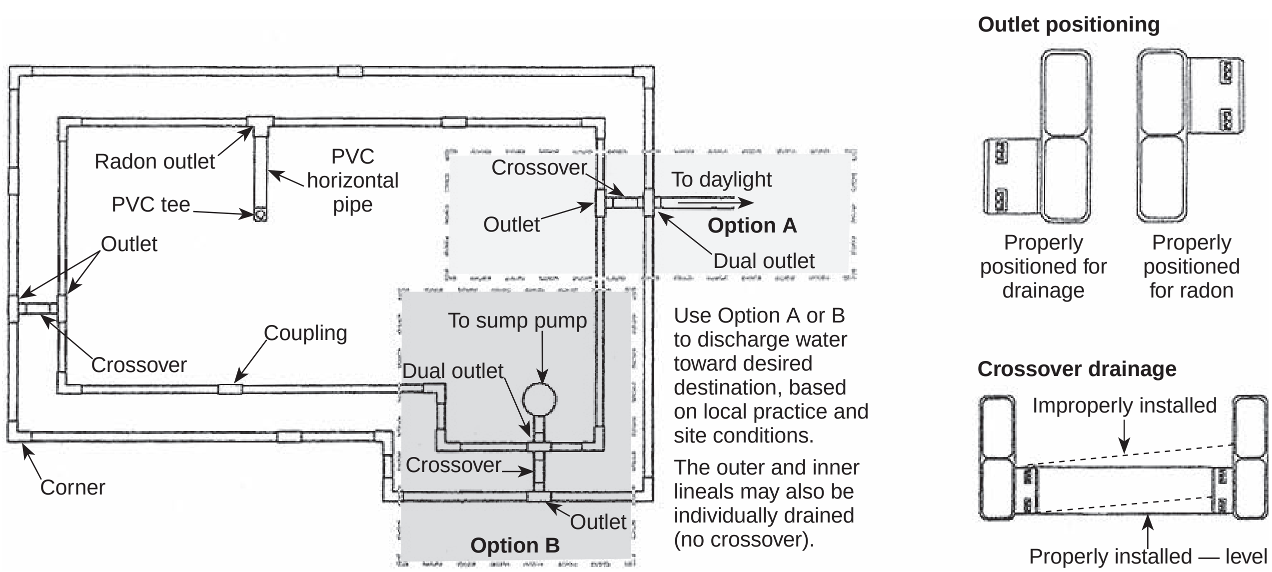
Most alternative passive systems only need minor modifications to the techniques we've already discussed in order to provide effective radon control. The changes that we'll cover are recommended for a crawl space foundation, drain tile loop, or drain tile loop with sump pit. They're based on field experience and input from builders, architects and engineers across the country.

What's the major difference in the installation of a radon venting system for a crawl space foundation and one for a typical slab-basement foundation? The polyethylene radon vapor barrier is placed on top of the soil in a crawl space, instead of under the slab as shown in Figure 3-19, but the venting for radon is essentially the same. Don't use aggregate or gravel in a crawl space. Instead, place perforated drain tiles (usually in lengths of 5 feet or more) under the sheeting and connect them to a "T" fitting to extend the width of the suction. Maximize the soil suction in the crawl space by overlaying and sealing all the joints in the polyethylene. Be sure to seal around all pipes and piers.



Courtesy: CertainTeed Corporation

Figure 3-19
Using Form-A-Drain for radon reductions



Courtesy: CertainTeed Corporation

Figure 3-20
Drain tile loops — with and without a sump pump

Builders across the country use drain tile loops for moisture control. Usually with this type of installation, a 4-inch diameter perforated pipe or tile is placed around the foundation perimeter, under the slab and just inside the foundation footing. See Figure 3-20. An easy way to create an effective radon control system in this situation is to install the radon vent pipe and a "T" fitting in a convenient section of the loop, and then run the pipe vertically through the floors to the roof. Just as you would with a slab basement, place polyethylene sheeting under the slab on top of the gravel layer and drain tile loop. If the loop is designed to discharge its water outside, install a one-way flapper to allow the flow of water out, but prevent outlet air from being drawn back into the system.

When you're installing drain tile with a sump pit, where drain tile loops and sumps are used in conjunction for moisture control, you can use one of the following two methods to install a radon system:

1. Place a solid cover on the sump pit and insert the venting pipe directly into the drain tile loop as discussed above.
2. Use a sump pit cover designed to accommodate vent penetration. Then you can run the venting pipe directly from the sump up through the roof. (See Option B in Figure 3-20.)

Contact the United States Environmental Protection Agency (EPA) and your state's radon control organizations for more information. The address for the EPA is:

U.S. Environmental Protection Agency
Ariel Rios Building, 1200 Pennsylvania Ave., NW
Washington, DC 20460
www.epa.gov

Waterstops

Concrete joints, including footing, wall and foundation intersections, are only as watertight as the waterstops that join them. Waterstops stop the flow or migration of water through open joints. They're made of a preformed metallic or nonmetallic material and embedded in the concrete to span the joint and form a continuous watertight barrier. In large concrete structures, waterstops must accommodate expansion, contraction, and lateral or other movements of the concrete. You can use waterstops in many different concrete structures, but they're most common in the monolith joints of hydraulic structures such as dams and tanks.

Nonmetallic waterstops, such as butyl rubber, neoprene, polyvinyl chloride, butadiene rubber and natural rubber are specially shaped to permit a mechanical interlock between the concrete and the waterstop. Rubber waterstops are stretchable and flexible, and highly resistant to water and most chemicals. They can be formulated for fast recovery and fatigue resistance. Polyvinyl chloride waterstops aren't as elastic as rubber and they're slower in recovery and more susceptible to oils and chemicals, but they're used more than any other type of nonmetallic waterstops. Because they're thermoplastic and can be spliced on the job, they offer a big advantage over rubber. They can be configured on site for special applications such as intersections or directional changes.

Figure 3-21
Waterstop placed in keyway

Figure 3-22
Waterstop installed in split formwork

Figure 3-21 shows a footing that has been poured with a keyway. The waterstop is set in the center of the keyway and has been formed to turn a corner. Notice the ribbing in the material. That helps to lock it into the concrete when the wall is poured. Be sure to secure the exposed flange of the waterstop in place before the next concrete pour to prevent the waterstop from folding over. You can do this using *hog rings*, which we'll discuss in more detail shortly.

Installing PVC Waterstops

Install PVC waterstops before the initial concrete pour to ensure proper positioning. You're generally required to use split formwork for slab-to-slab, slab-to-wall, and wall-to-wall joints using ribbed or dumbbell style waterstops. Figure 3-22 shows a waterstop properly secured in the split form. Split forms allow you to place half the waterstop inside the first pour, with the other half projecting into the second pour. Once you align the centerline of the waterstop with the center of the joint, the split form will hold the waterstop in position and prevent it from becoming misaligned during the second pour of concrete. The keyway form material must fit tight to the waterstop to prevent concrete paste from leaking past the form material, which could lead to honeycombing of the concrete.

As mentioned earlier, you must properly secure the exposed flange of the waterstop prior to placing the next concrete pour. You can do this with hog rings or factory-installed grommets (which are cheaper and faster) attached to the waterstop at the outermost rib, on 12-inch centers. Purchase waterseal material with hog rings or grommets from the factory. Loop tie wire through the hog ring or grommet and tie it off to an adjacent reinforcement. This secures the waterstop and prevents it from being displaced or folding over during the concrete pour. Never place nails or screws through the body of the waterstop. It's important to note that the thicker the waterstop is, the less likely it is to fold over. Also, thicker waterstops reduce the chance of the hog rings or grommets tearing out (as nails or screws might) from the stress of the concrete pour.

The continuity of the waterstop is critical for optimum performance. Poorly constructed fabrications and splices are prime locations for leaks. And the continuity of waterstop features, such as ribs, center bulbs, etc. is also critical and should be maintained through changes in direction and transitions. One way to ensure this is by using mitered joints. A mitered joint has a longer weld line, resulting in a stronger weld. Waterstops should never be lapped.

PVC waterstops are easily butt-spliced with a Teflon-coated thermostatically-controlled splicing iron. I feel that splices made using a splicing iron are more reliable than solvent-welded rubber splices. Cut the ends of the waterstop square to form matching edges. Uniformly melt the ends at about 380 degrees F, using a thermostatically-controlled splicing iron. It's important to use an indirect heat source for this procedure. When heating the material, take care to heat the splicing iron just to melt temperature to avoid burning or charring the material. Too much heat or direct exposure to a flame will change the chemical composition of the PVC, resulting in a weak weld. When a 1/8-inch diameter melt bead develops on each waterstop end, remove the splicing iron. Then carefully align the two ends, and firmly press them together until the material has fused and cooled. Allow the splice to cool naturally; never quench it in water.

We know from field experience that it's cheaper to use factory-made mitered fittings, such as ells, tees, and crosses, whenever possible. These kinds of fittings require special tooling and custom equipment that's expensive and difficult to use in the field. Most contractors can easily fabricate straight butt-splices in the field, but if you need mitered fittings, you need to contact a Greenstreak supplier. Greenstreak fittings can be factory ordered. Contact the manufacturer directly at www.greenstreak.com. Check the blueprints in the early estimating stage of the project to see if mitered joints are required. You'll need to know in case there are any special costs or lead time.

> ***NOTE:*** Heating irons have resistance-type heating elements. They won't perform as well using a reduced voltage. Never use long runs of small gauge extension cords to do this type of work.

Make sure that you thoroughly consolidate the concrete around waterstops. This is especially important on the underside of horizontally-placed waterstops. Make sure the surfaces of the waterstops are clean prior to the concrete pour. Store PVC waterstop in areas where it's protected from dirt, oils, chemicals, debris, and physical damage. You must also shield it from direct exposure to sunlight, since PVC degrades when exposed to the sun's UV rays.

In the next chapter we'll look at prefabricated forming systems.

4

PREFABRICATED FORMS

For years, contractors spent considerable time measuring and cutting lumber and plywood to construct forms for their concrete pours. After the concrete set, the forms were removed and workers tried to salvage as much material as possible. This was a time-consuming and costly process. And there were always problems reusing lumber that may have warped, wasn't cleaned properly, or was splintered or damaged.

Today, with the exception of very small projects, contractors use prefabricated forms. Prefabricated forms are constructed using various-sized components and assembled with factory-made accessories. Eliminating most job-built construction forms saves you time and money. Prefabricated forms can last through many projects, with little maintenance and loss of supplies. The faces of these forms are smooth and have few seams, making them easy to strip and clean after the concrete has set. Prefabricated forms are made of many different materials, including plywood, steel, aluminum or a combination of materials, such as metal with a plywood facing.

Most contractors in residential and light commercial construction use forms with steel or aluminum frames and plywood facings. The metal frames aren't as easily damaged as wood frames, and using plywood panels makes the frames lighter. If you follow good maintenance and cleaning procedures, you can get 25 or more uses from manufactured forms. You can replace the plywood faces as needed, but the metal hardware accessories that connect the forms can be reused over and over until they are either worn out or lost.

If your work is strictly small projects, you may not need manufactured panels. The first section of this chapter explains how to select the plywood form panels you'll need for your type of work. Many contractors use prefabricated forms in conjunction with job-constructed forms. Later in the chapter, we'll cover the prefabricated forms most commonly used in residential and light commercial construction. Because of the variety of sizes and their ease of assembly, you can form almost any size or shape of concrete wall using these forms. In addition to the relatively simple, straight forming methods, we'll also look at some of the more complicated assembly methods used with the Steel-Ply® system.

Plywood Form Panels

You can use any exterior-type APA panel for concrete formwork because all panels with that identification are manufactured with waterproof glue. But for the purpose of concrete forming, the plywood industry produces a special product called Plyform®. All Plyform panels bear the trademark of the APA (The Engineered Wood Association). These are all exterior-type panels, made with C or better veneer and waterproof glue.

MDO (Medium Density Overlay) and HDO (High Density Overlay) are plywood products with overlaid surfaces. During plywood production, these overlays are bonded to the plywood under high heat and pressure in a press. Thermoset resins, which are hard, and resist water, chemicals and abrasion, are used in overlay production. The overlay process produces a stable surface that's smooth, durable and repels foreign substances. Use HDO when you need the smoothest possible concrete finish with the maximum number of form reuses.

Plywood Grades

Plyform is exterior-type plywood, limited to certain wood species and veneer grades, to assure high performance. Plyform products are available in three basic grades:

1. Plyform Class I
2. Plyform Class II
3. Structural I Plyform

All can be ordered with an HDO surface on one or both sides. Plyform Class I is also available as Structural I Plyform when additional strength is needed.

Plyform Class I

Class I Plyform has Group 1 faces for high strength and stiffness. Group 1 panels are made of the strongest wood species.

Plyform Class II

Class II Plyform provides adequate strength for most forming applications, but may have Group 2 faces.

Structural I Plyform

This concrete forming panel is made with Group 1 wood species throughout — the strongest wood. All other factors being equal, it will support the highest loads both along and across the panel. It's specifically designed for engineered applications and is recommended where the face grain is parallel to the supports.

B-B Plyform

Non-overlaid Plyform is usually made with B-grade veneer, face and back, and so is referred to as B-B Plyform. It's available as Structural I, Class I or Class II. The panels are sanded on both sides and *mill-oiled* (treated with a release agent at the mill), unless otherwise specified.

If the mill treatment isn't reasonably fresh when the panels are first used, the plywood may require another treatment of release agent. It's also important to apply a top-quality edge sealer before the first pour. You can order edge-sealed Plyform panels from the mill. It's common to get five to 10 reuses of B-B Plyform.

HDO Plyform

This Plyform panel meets the same general specifications as Plyform Structural I or Class I or Class II. All classes of HDO Plyform have a hard, semi-opaque surface of thermoset resin-impregnated material that forms a durable, continuous bond with the plywood. Treat the abrasion-resistant surface with a release agent prior to its first use, and between each pour, to preserve the surface and to make stripping easier.

Because the panel has a hard, smooth surface, HDO Plyform is most often specified where you need the smoothest possible concrete finish. It can leave a nearly polished concrete surface. Both sides of HDO are moisture resistant, but they can't always be used to form concrete with equal effectiveness, unless specifically made for that purpose. Scratches and dents in the backs, caused by fastening the panels to the supports, may make using the back sides impractical for a perfect finish. Various grades of HDO Plyform may be available; check

Figure 4-1
Board-and-batten texture

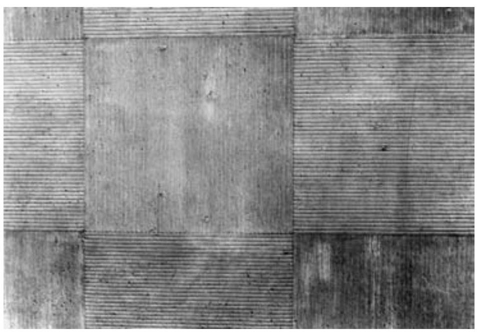


Figure 4-2
Basketweave texture

with your supplier. With reasonable care, you can normally reuse HDO Plyform 20 to 50 times or more. With careful maintenance, some concrete-forming specialists can get as many as 200 reuses or more, with good results.

Medium Density Overlay

There are special grades of MDO manufactured specifically for concrete forming. Regular MDO is intended for use as a paint surface and should *never* be used for concrete forming. Forming panels are typically overlaid on one side only, although they can be produced with MDO on both sides. MDO concrete form plywood is normally factory-treated with a release agent and edge-sealed to protect the edges from water absorption. Treat the abrasion-resistant surface with a release agent prior to its first use and between each pour to preserve the surface and to make stripping easier. MDO form panels create a matte or flat finish on the concrete surface.

Related Grades

Additional plywood grades specifically designed for concrete forming include special overlay panels and proprietary panels. These panels produce a smooth, consistent concrete surface. Some proprietary panels are made only of Group 1 wood species and have thicker face and back veneers than those normally used. These provide greater parallel-to-face grain strength and stiffness for the panel. Faces may be specially treated or coated with a release agent. Check with the panel manufacturer for design specifications and surface treatment recommendations.

Special Textures

Plywood is manufactured in many surface textures, ranging from highly polished HDO plywood to patterned board-and-batten siding panels. Working with either special panels or field-applied patterns, you can create virtually any surface texture. Figure 4-1 and Figure 4-2 show two typical surface patterns.

There are two ways to apply a textured design to exterior-type plywood formwork:

1. Use it as a liner on plywood backing. The liner delivers texture, but adds little to the structure of the formwork.
2. Use it as part of the basic forming panel.

When the design is part of the forming panel, use a minimum number of pours for the best result. The textured surface makes stripping the panels more difficult, and can cause more panel damage during removal than you'd have with a smooth surface. Using film coatings with a release agent, such as lacquer, polyurethane, or epoxy, makes stripping easier and can help reduce form damage.

Concrete Surface Characteristics

Once the forms are removed, surface problems, such as dusting (which could be attributed to the formwork) and staining, may appear on the concrete.

Surface Dusting

Surface dusting occasionally occurs on concrete that's been poured against forming materials. There seems to be no single cause, but the soft, chalky appearance on the surface has been traced to a variety of possibilities, including:

- excess oil
- dirt
- dew
- smog
- unusually hot, dry climactic conditions
- a chemical reaction between the form surface and the concrete

Other factors could also be involved in dusting. The problem appears more frequently at certain seasons of the year, in specific localities, and with certain concrete mixes. Dusting during cold weather pouring can result from additives mixed into the concrete to protect against freezing. Too much water in the mix can cause laitance, which is also dusting. Dusting can be caused by excess vibration of the mixture, too.

You can prevent many instances of dusting by simply keeping forms clean, cool and dry. Avoid exposing forms to dust, oil and weathering and always store them in a cool, dry location. If dusting does occur, one state's Department of Transportation recommends a fine water spray on the surface material to help speed surface hardening. Their report states *"…rather than attempt to employ inconvenient methods of preventing dusting, final results will be satisfactory if affected areas are subsequently cured for a few days with water in a spray fine enough not to erode the soft surface."* Other concrete specialists have recommended surface treatment applications of magnesium fluorosilicate or sodium silicate.

Staining

HDO plywood forms sometimes cause *staining* on the concrete surface. A reddish or pinkish stain may appear as the result of a fugitive dye, but usually disappears with exposure to sunlight and air.

When sunlight can't reach the stain, natural bleaching will take longer. You can apply household bleaching agents, such as Clorox or Purex (5 percent solutions of sodium hypochlorite), followed by clear-water flushing to speed up stain removal.

On rare occasions, other discolorations have shown up on new concrete surfaces. Iron salts, resulting from iron sulfides and ferrous oxides in slag cement, may stain concrete a greenish-blue color, particularly when large, continuous, smooth and airtight form surfaces have been used.

Both the occurrence and intensity of the color seem to be related to the length of time between the application of form release agents and pouring of concrete, as well as to the length of time before the forms are stripped. Loosening or opening the forms as soon as possible after placing the concrete may be helpful in preventing slag concrete from discoloring. If staining does occur, it will usually fade and disappear over time. However, applying a hydrogen peroxide solution to the concrete immediately after the forms are removed has been effective in removing the stain.

Ferrous sulfides, such as pyrite and marcasite in coarse aggregate, can cause rust-colored stains on the concrete.

Plywood Tolerances

Plywood, as an engineered product, is manufactured to exacting tolerances. A tolerance of plus 0.0 inch and minus 1⁄16 inch is allowed on the specified width and/or length under U.S. Product Standard PS 195. The Product Standard also requires panels 4 feet in length and greater to be square, within 1⁄64 inch per nominal foot, when measured corner to corner along the diagonal. Panels must also be manufactured so that a straight line drawn from one corner to an adjacent corner falls within 1⁄16 inch of the panel edge. This ensures a straight edge.

Sanded Plyform panels are manufactured with a thickness tolerance of plus or minus 1⁄64 inch of the specified panel thickness for ¾ inch and less, and plus or minus 3 percent of the specified thickness for panels thicker than 3⁄4 inch. Overlaid Plyform panels have a plus or minus tolerance of 1⁄32 inch for all thicknesses through 13⁄16 inch. Thicker panels have a tolerance of 5 percent over or under the specified thickness.

These tolerances, and the consistent levels of quality required by the APA, help minimize the time and labor required in building forms. But

Grade-Use Guide for Concrete Forms*					
			Veneer Grade		
Use These Terms When You Specify Plywood	Description	Typical Trademarks	Faces	Inner Plies	Backs
APA B-B PLYFORM Class I & II**	Specifically manufactured for concrete forms. Many reuses. Smooth, solid surfaces. Mill-treated unless otherwise specified.	APA THE ENGINEERED WOOD ASSOCIATION PLYFORM B-B CLASS I EXTERIOR 000 PS 1-95	B	C	B
APA High Density Overlaid PLYFORM Class I & II**	Hard, semi-opaque resin-fiber overlay, heat-fused to panel faces. Smooth surface resists abrasion. Up to 200 reuses. Light application of releasing agent recommended between pours.	HDO • B-B • PLYFORM I • 60/60 • EXT-APA • 000 • PS 1-95	B	C-Plugged	B
APA STRUCTURAL I PLYFORM**	Especially designed for engineered applications. All Group 1 species. Stronger and stiffer than Plyform Class I and II. Recommended for high pressures where face grain is parallel to supports. Also available with High Density Overlay faces.	APA THE ENGINEERED WOOD ASSOCIATION STRUCTURAL I PLYFORM B-B CLASS I EXTERIOR 000 PS 1-95	B	C or C-Plugged	B
Special Overlays, proprietary panels and Medium Density Overlaid plywood specifically designed for concrete forming**	Produces a smooth uniform concrete surface. Generally mill treated with form release agent. Check with manufacturer for specifications, proper use, and surface treatment recommendations for greatest number of reuses.		B	C	C
APA B-C EXT	Sanded panel often used for concrete forming where only one smooth, solid side is required.	APA THE ENGINEERED WOOD ASSOCIATION B-C GROUP 1 EXTERIOR 000 PS 1-95	B	C	C

*Commonly available in 19/32", 5/8", 23/32", 3/4" panel thicknesses (4' x 8' size)
**Check dealer for availability in your area

Courtesy: APA — The Engineered Wood Association

Figure 4-3
APA guide for concrete forms

you've got to be aware of these tolerances on the jobsite. In an extreme case, you could use two ¾-inch sanded panels, both within manufacturing tolerances, to form a joint with just a 1/32-inch variation in surface level from panel to panel. Then, realigning and shimming the panels is quick and easy. In a pinch, you need to know what works and what doesn't.

The table in Figure 4-3 gives a description of the types of materials you'll need for various surfaces, the grades, and the APA trademark that should be marked on your panels when you receive your order.

Panel Nominal Dimensions (Width × Length)		
ft.	mm	m (approx.)
4 x 8	1,220 x 2,440	1.22 x 2.44
4 x 9	1,220 x 2,740	1.22 x 2.74
4 x 10	1,220 x 3,050	1.22 x 3.05

Panel Nominal Thickness	
in.	mm
1/4	6.4
5/16	7.9
11/32	8.7
3/8	9.5
7/16	11.1
15/32	11.9
1/2	12.7
19/32	15.1
5/8	15.9
23/32	18.3
3/4	19.1
7/8	22.2
1	25.4
1-3/32	27.8
1-1/8	28.6

Courtesy: APA — The Engineered Wood Association

Figure 4-4
Metric conversions

Metric Conversions

Metric equivalents of nominal thicknesses and common sizes of wood structural panels are provided in Figure 4-4 (1 inch = 25.4 millimeters).

Form Maintenance

As mentioned earlier in this chapter, the better your maintenance practices, the more uses you'll get from your forms. And, even more important, clean, well-maintained forms produce better concrete surfaces with fewer problems. The following are maintenance suggestions that will help you extend the usefulness and quality of your forms.

Stripping

Never use metal bars or pry bars on plywood when stripping forms. They'll damage the panel surface and edges. Instead, use wood wedges, tapping gradually when necessary. Plywood's cross-laminated construction resists edge splitting, and its strength, light weight and large panel size help reduce stripping time.

Cleaning and Release Agent Application

Clean your forms immediately after stripping. Use a hardwood wedge and a stiff fiber brush for cleaning (a metal brush may cause wood fibers to *wool*). Light tapping on the back side with a hammer will generally remove any hard scale concrete.

Soon after removal, inspect forms for wear. Repair, spot prime, refinish and lightly treat with them a form-release agent before you reuse them. Remove nails and fill the holes with patching plaster, plastic wood, or other suitable materials.

With prefabricated forms, you can reverse the plywood panel face if it's damaged (when the grade is suitable). Patch the tie holes with metal plates, plugs or plastic materials.

Handling and Storage

There are specially-coated panels with long-lasting finishes available that make stripping easier and reduce maintenance costs. Handle these panels carefully to assure the maximum number of reuses.

Take care to prevent chipping, denting and corner damage to panels when you're handling them. Never drop panels. Stack the forms carefully for hauling, laying them flat, face to face and back to back. After cleaning, you can solid-stack or stack the forms in small packages, with their faces together. This slows the drying rate and minimizes *face-checking*, the small hairline cracks or splits that occur in the face-ply of a panel. These checks may be more pronounced after you've used the form several times. Checking doesn't mean the plywood is delaminating; you can still use it. However, a thorough program of form maintenance, including careful storage to assure slow drying, will minimize face-checking.

Using plywood stack handling equipment, and small trailers for hauling and storing panels between jobs, will reduce your handling time and panel damage. Keep the stacks of plywood panels out of the sun and rain, or loosely covered, during storage. Allow air to circulate around the stacks, without heat build-up. When panels are no longer suitable for formwork, if they're still in reasonably good condition, you can use them in subflooring or for wall and roof sheathing.

Coatings and Agents

Protective sealant coatings and release agents for plywood forms increase their life and aid in stripping. Mill-oiled Plyform panels sometimes require a light coating of release agent between uses. Check the specifications before using any release agent on the forms.

Apply a form-release agent a few days before using your plywood forms, and wipe them so just a thin film remains. This will prolong the life of the plywood forms, increase their release characteristics, and minimize staining.

A *chemically-reactive* release agent will give overlaid panels the longest life span. It should be applied prior to the first pour. Some concrete additives may degrade overlays. Always check with your manufacturer.

When you select a release agent, make sure you know how the product will affect the finished surface of the concrete. For example, some release agents include waxes or silicones that shouldn't be used on concrete that'll be painted. Consider the finished architectural appearance specified in the plans when you choose any surface treatment.

Plywood form coatings, such as lacquers, resin or plastic base compounds, or similar field coatings, are sometimes used to form a hard, dry, water-resistant film on plywood forms. The performance of these coatings is generally rated somewhere between B-B Plyform and High Density Overlaid plywood. In most cases, a field-applied coating reduces the need to apply a release agent between pours. Many contractors claim that these agents significantly increase the reuse of the forms when using B-B Plyform, but generally not so much with HDO plywood.

In addition to mill-oiled Plyform, there are other mill-coated forming products available. Some plywood manufacturers suggest that no release agents are necessary with their particular concrete forming products, and claim their products will produce exceptional concrete finishes with a large number of reuses.

Time-Saving Forming Products

There are several forming products on the market that can save you time and improve the quality of your pours. It's always a good idea to look into innovative ideas that are available for use with concrete or concrete forming. Here are two that I've found particularly helpful.

Chamfer Strips and Corners

Chamforcor CFC (www.chamforcor.com) has developed a specifically-sized modular plastic form for creating perfect chamfer corners. This has made the time-consuming job of forming exposed column and beam-ends considerably easier.

These reusable plastic chamfer forms come in ¾- and 1-inch sizes and measure 6 inches in each direction. Just nail them to your plywood forms. They also have ¾-inch strips that you can use in conjunction with the corner forms. The strips are ideal for radius work. Chamforcor CFC is manufactured by Steinke Bros. Inc.

Prefabricated Corrugated-Paper Forms

SureVoid® Products Inc. (www.surevoid.com) has developed forms made of corrugated paper. They are commonly known as void forms or carton forms, because they create a void or space between the concrete structure and the soil. The forms provide temporary support when placing concrete structural slabs over expansive soils, isolating the concrete from the swelling ground. The forms allow the soil to expand and contract without damage to the slab. The material gradually absorbs ground moisture and loses its strength, creating a space that is eventually filled in by the soil.

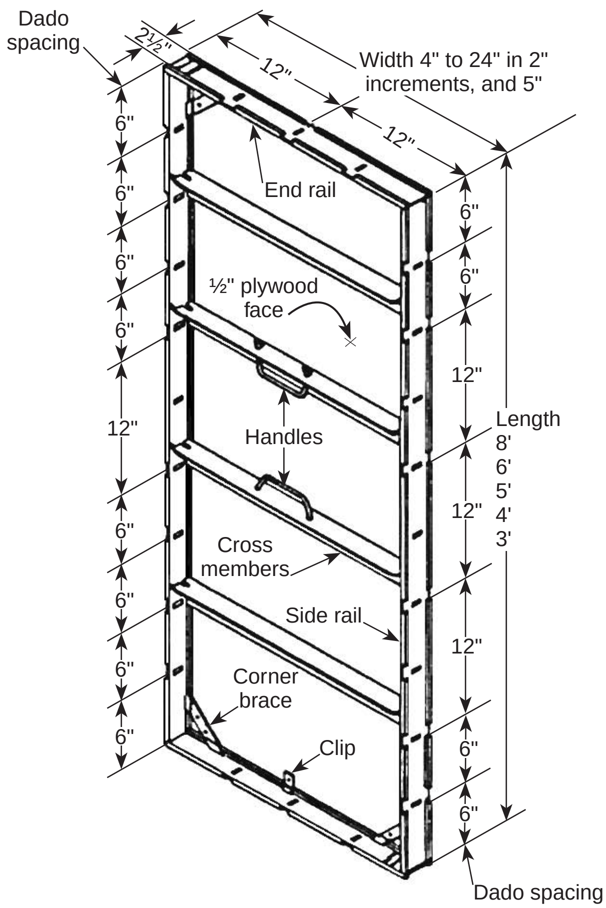


Figure 4-5
Vertical form assembly

The company makes the forms to order. They also provide forms to displace concrete volume in applications where a reduction in the weight of the structure is a consideration, such as for concrete steps and elevated platforms above other supporting structures. They work as a short-term support platform until the grade beam or structural slab sets and can support itself across the piers, pads or footings on which it permanently rests.

Steel-Ply® Forms

If your work calls for a more complicated form assembly, I suggest using the Steel-Ply® system. The Symons Corporation, manufacturer of Steel-Ply, has provided us with the following information on assembling and using their products. Their components and accessories are designed with safety, as well as performance, in mind. Symons recommends that all construction personnel thoroughly familiarize themselves and comply with industry standards for safe practices during the panel assembly and stripping processes. This includes wearing gloves, safety shoes, and safety glasses.

Steel-Ply System Design

Steel-Ply is a pre-engineered, reusable, factory-built forming system. It can be used to form many concrete structures, from culverts to high-rise buildings. You can form practically any size or shape by combining panel or filler sizes and using them vertically or horizontally. The system uses heavy-duty steel rails and crossmembers with special HDO plywood that produces a high load rating, while also getting high scores for safety. With over 80 panel and filler sizes, erecting and removing formwork is quick and easy. You can connect panels, fillers and ties with wedge bolts in one simple operation.

Figure 4-5 shows a vertical form assembly. You don't need to measure or drill for ties. Dado slots, 12 inches on center, in the panel side rails allow you to quickly and accurately insert ties in the joints between panels. On 3-foot-high forms, the slots are located 6 inches on center.

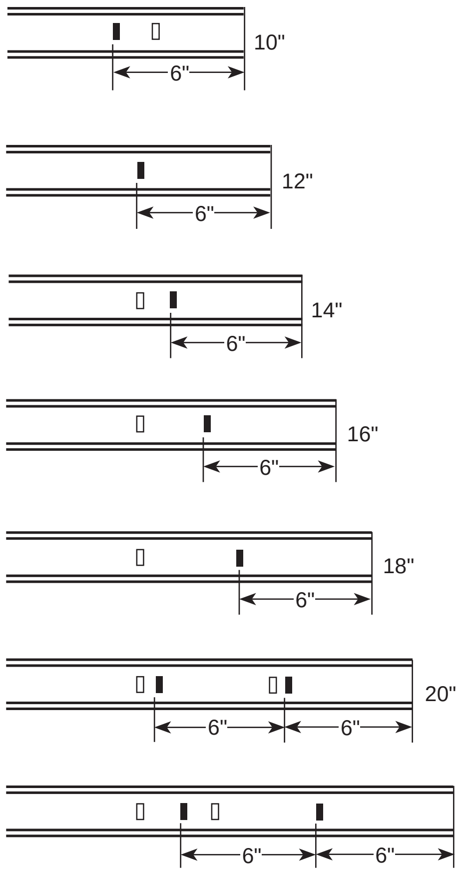


Figure 4-6
Filler rail sizes

Standard Steel-Ply frames (in 20-inch, 22-inch and 24-inch widths) have handles to help in moving or positioning the modular panels by hand. The 5-foot, 6-foot and 8-foot frame lengths have two handles, and the 3-foot and 4-foot lengths have one handle. These handles aren't meant to be used for attachment or for any other purpose. *Never* use the handles for safety belt hook-ups or as connecting points for bracing, scaffolding, or moving multiple panels.

However, if your job requires hook-ups or connections for a high vertical assembly, you can order Steel-Ply forms with Quick-Hook™ handles. These integral handles have a 5,000 pound capacity and give workers convenient handholds and attachment points for safety belts. These handles meet Occupational Safety and Health Administration (OSHA) requirements for personal fall protection.

Assembling the Forms

Calculate your wall length and assemble the panels and fillers you'll need to make up that length. Determine the filler width required by looking carefully at the end rails. Slots are located in 6-inch increments from each end of the end rail for fillers from 10 inches to 22 inches. There are no wedge bolt slots or dadoes on 4-inch to 8-inch filler end rails. Figure 4-6 shows filler rail sizes.

Two identical wedge bolts function as a lock-bolt set, one as the connecting bolt, and the other as a clamping wedge. For a typical side-rail to side-rail form connection, position the loop end of a tie in the dado slot and secure it with the same wedge bolts used to lock the panels together, as shown in Figure 4-7.

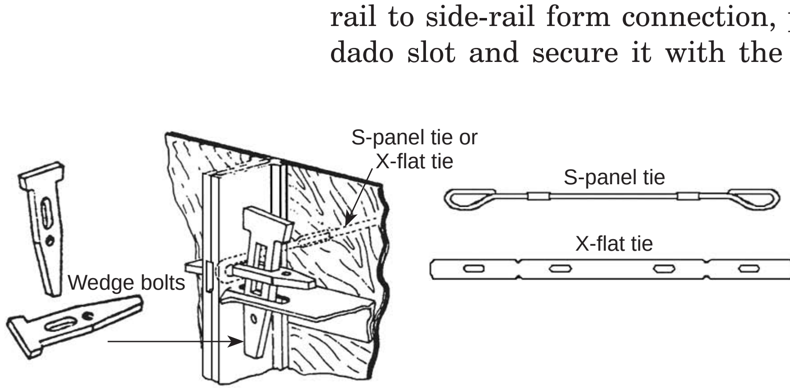


Figure 4-7
Wedge bolts functioning as lock bolts also hold the tie in place

For most walls, you only need form-connecting wedge bolts at standard tie connection positions. You can use additional wedge bolts at other positions to attach walers, scaffold brackets or accessory components.

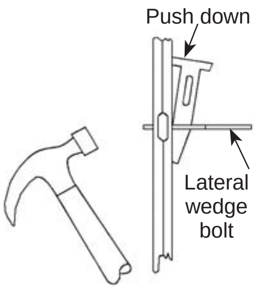


Figure 4-8
Securing the wedge bolts

To tighten the wedge bolt connection, push down on the head of the vertical wedge bolt with one hand while lightly striking the head of the lateral wedge bolt with a hammer. See Figure 4-8. The vertical wedge bolt will move downward to a tight, secure position. Be careful not to overtighten the wedge bolts or you'll have trouble removing them during stripping. Also, be careful not to damage the wedge bolts when using the hammer, both during assembly and removal.

Setting the Forms in Place

You can set the panels directly on the concrete footing if you're working to a chalk line, or set them on lumber plates. Plates are recommended because they provide a positive on-line wall pattern and level out rough areas on the footing.

Use lumber plates to extend a level on-line surface for setting grade beam walls that bear only on intermittently-spaced footing pads. They function to pre-form the position and size of pilasters, as well as changes in wall thickness, and to identify the location of corners, etc. Figure 4-9 shows plates positioned on a concrete footing, and Figure 4-10 shows plates bearing on footing pads. Depending on the distance between footing pads, you may need to use stakes to align and level the plates.

Nail the panels down to the plates so that they'll stay on line. (The panel face should be flush with the inside edge of the plate.) All panel and end rails contain two widely-spaced nail holes. Nail the first panel at both nail holes. Subsequent panels only need one nail, as shown in Figure 4-11.

The wedge-bolt side-rail tie connection is designed with easy-fit tolerances for quick assembly. The tolerances permit up to ¼ inch of slack in the tie spread control between wall thicknesses. This slack will be removed by the lateral pressure of the concrete during placement.

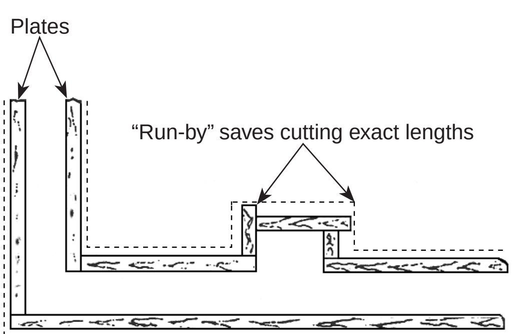


Figure 4-9
Lumber plates on concrete footing

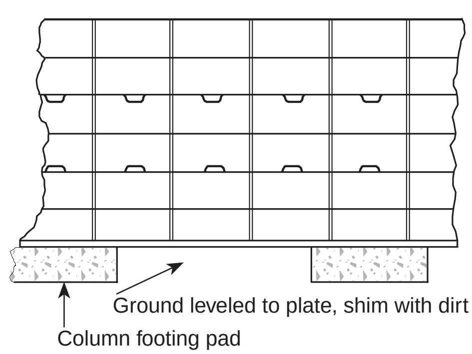


Figure 4-10
Lumber plates on footing pads

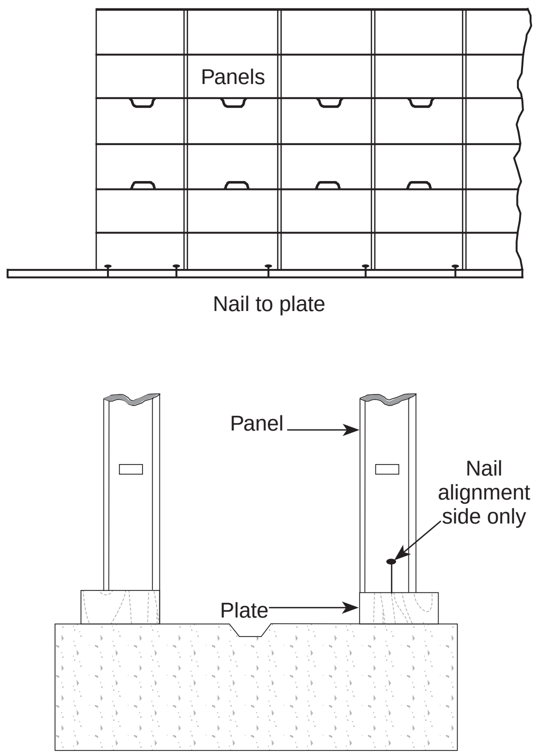


Figure 4-11
Nail panels to the plate

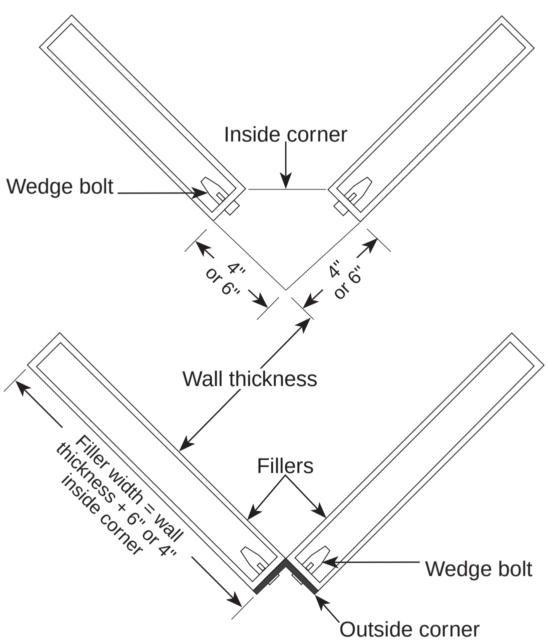


Figure 4-12
Setting outside and inside corners in place

That's the reason panels should be nailed down, aligned, and braced on only one side of the wall. The opposing forms can then pull out any tie slack without affecting the form alignment (look again at Figure 4-11).

Use a double-thick plate to get a small amount of extra form height. For example, an 8-foot panel set on a double plate will form an 8-foot, 3-inch wall. This is much easier than trying to nail wood on top of the form to build it up.

Assembly Procedures

There are several methods of assembling panels, with the best method usually dictated by the job itself. To ensure that you won't need more than one filler for any straight wall run, start your assembly at a dimensionally-positioned detail, such as a wall corner or pilaster.

For light construction foundations where you don't need reinforced steel, you can install both form sides along with ties in a single sequence. If a wall corner is the starting point, use the following procedure:

- Connect an outside corner angle to the two proper-width adjacent fillers. The width of the outside corner fillers depends on the wall thickness, including the face dimensions, of the inside corner. For example, the outside corner fillers for a 10-inch wall with a 6- x 6-inch inside corner would be 16 inches wide. Using the proper filler width will align the opposing form panel joints and help when it's time to install ties.
- Set the inside corner in place, as shown in Figure 4-12.
- After you've installed two or three inside and outside panels along with ties in each direction, plumb and brace the whole assembly. Use a leveling shim, if necessary.

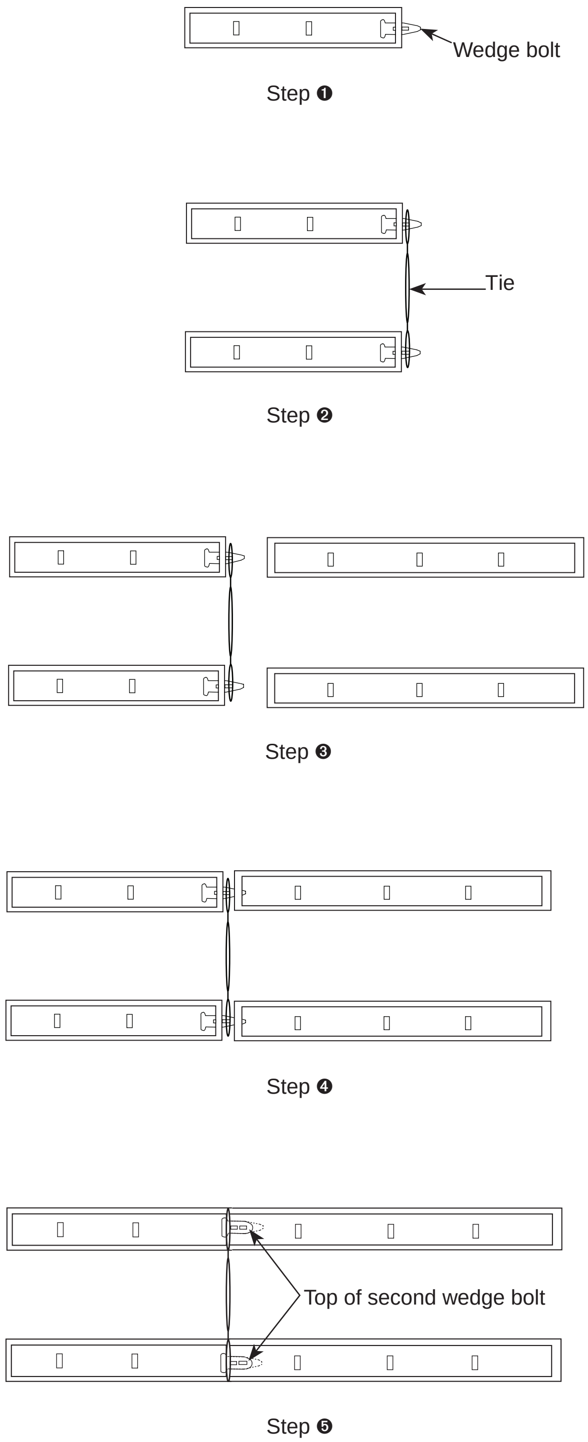


Figure 4-13
Installing panel pairs and ties

- Continue the procedure for installing each pair of opposite panels, along with accompanying ties, as described in the following five steps and illustrated in Figure 4-13:

  Step 1. Position the connecting wedge bolt for each opposing panel with half its shaft length projecting through the side rail slot at the prescribed tie positions.

  Step 2. Place a tie over the end of each projecting wedge bolt.

  Step 3. One at a time, align the next pair of opposing panels with the tips of the protruding wedge bolts, and follow with Steps 4 and 5.

  Step 4. Push the remaining length of connecting wedge bolt into the adjoining side rail slot.

  Step 5. Close the gap (left at Step 4) between side rails. Insert the second wedge bolt and tighten to a closed joint position. Don't hammer down excessively.

- Install walers when enough panels are up to cover the waler lengths you're using. Place alignment bracing immediately after installing each length of waler. Nail the bottom panel rail on the alignment form side, after finishing Step 5.

Carpentry crews easily pick up these panel assembly procedures, and often find new methods that work even better for them.

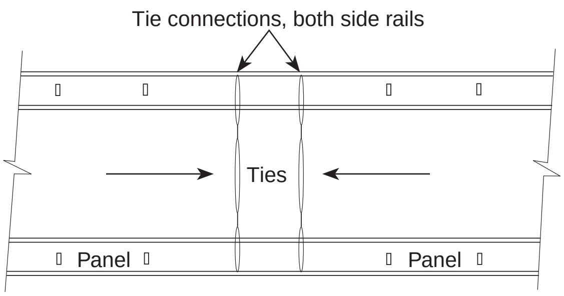


Figure 4-14
Steel-Ply filler

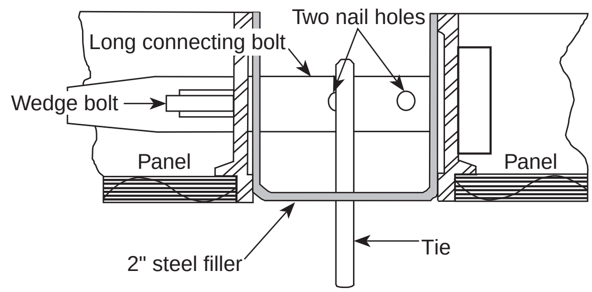


Figure 4-15
U-shaped steel filler

Foundation walls for heavier commercial and industrial construction usually require that you install one form side of the wall first. That's because the rebar and its tie-off must be aligned to the form face, as well as brick ledges and other boxouts that need to be framed into the wall. Normally, the first wall side will incorporate all the necessary aligning walers, strongbacks, and form aligners for the final wall alignment. You can install ties either during the first set or when setting the opposing panels. Be aware, however, that if you install the ties with the first form side, their protruding portion is vulnerable to damage. You must replace any ties that are bent through their breakback flat or breakback notches.

Steel-Ply Fillers

There are three types of fillers that you can use with Steel-Ply in wall form construction:

1. Steel-Ply fillers, manufactured from the same steel and plywood as panels, come in even widths from 4 to 22 inches, and also in 5-inch widths. They connect to both side rails, so either the same size filler must be used for the opposite form or you must provide a specific form detail that accepts the wall tie connections. Figure 4-14 shows a Steel-Ply filler.

2. U-shaped steel fillers made of cold-formed steel are available in 1-inch, 1½-inch and 2-inch widths. There are tie slots in the center of the U for attaching wall ties. A long bolt passes through the filler (and the loop end of the tie) and grips both adjoining side rails, as shown in Figure 4-15. The long bolt has two ¼-inch holes to accommodate a 16d or 20d nail, or a broken off panel tie end to shorten the bolt for 1-inch, and 1½-inch steel fillers. (We'll cover the long bolt installation shortly.)

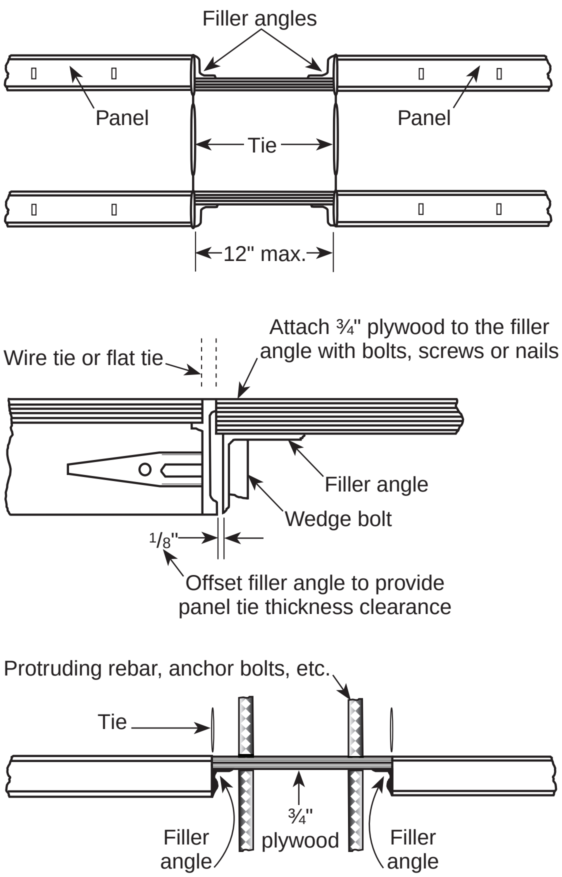


Figure 4-16
Job-built fillers

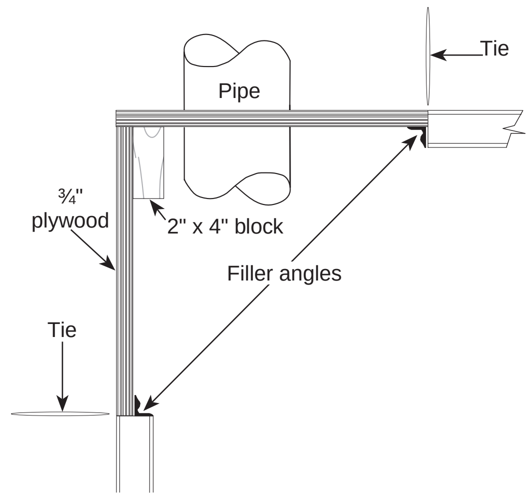


Figure 4-17
Job-built inside corner

Adjustment Range		
Short stop hole no.	**Width of filler wedge bolt at square end**	**Width of filler wedge bolt at tapered end**
1	0"	2" to 2¼"
2	¼" to ½"	1½" to 1¾"
3	¾" to 1"	1" to 1¼"
4	1¼" to 1½"	½" to ¾"
5	1¾" to 2"	0" to ¼"

Note:
1. Form ties must be used at all filler connections.
2. Do not short stop with nail where there will be a high shear load on nail.

Figure 4-18
Long bolt adjustment range table

3. Job-built fillers, using filler angles, can be custom made to fit between panels where necessary. The filler angles make it possible to construct a filler of ¾-inch plywood that can be connected to side rails of adjoining forms. Job-built fillers are recommended where reinforcing steel, pipes, or other materials must project from the form face (see Figure 4-16). Custom inside corners can also be job-built using two filler angles, as shown in Figure 4-17. *Caution:* If tension exists in a job-built filler, install tension rods through the panel side rails. If compression exists, lumber blocking is required.

Adjustable Long Bolt Installation

Make sure the tapered ends of all adjustable long bolts at each fill-in joint are pointed in the same direction (left or right). The width of the filler determines whether the wedge bolt will be located in the slotted hole at the square end or in the slotted hole at the tapered end. Check the Adjustment Range table in Figure 4-18 for more information on positioning the wedge bolt.

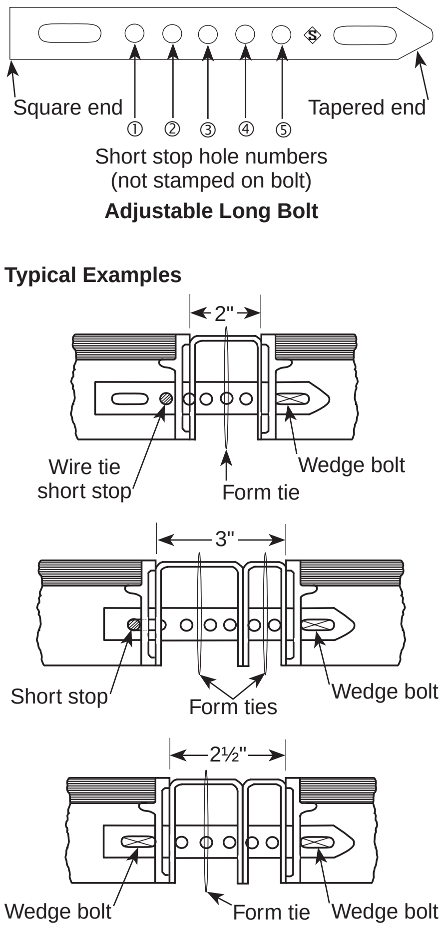


Figure 4-19
Adjustable long bolt installation

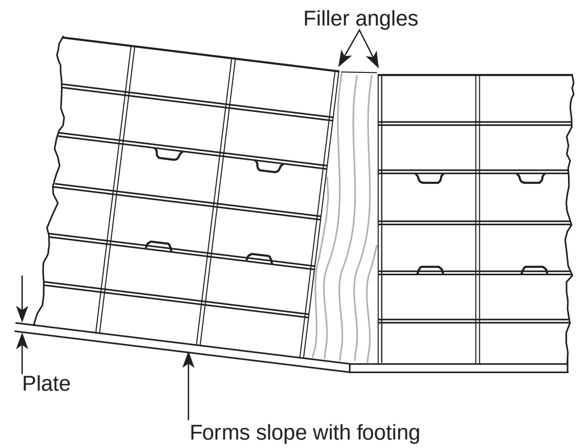


Figure 4-20
Filler angle between panels

1. For fillers that are ½ inch to 2 inches in width, in ½-inch increments, insert the wedge bolt in the hole at the tapered end. See the illustration of the adjustable long bolt and typical installations in Figure 4-19.
2. For fillers that are ¼ inch to 1¾ inches, in ½-inch increments, insert the wedge bolts in the hole at the square end.

Sloping Footings

When footings are slightly sloped, particularly where the top of the wall elevation is also sloped, erect the panels perpendicular to the angle of slope. Where the sloped form must connect to plumb forms, make the transition by building a wedge-shaped filler. Use filler angles and ¾-inch plywood cut to the appropriate shape to construct the filler, as shown in Figure 4-20.

Generally, panels are erected level to the direction of slope. Use a wedge-shaped, job-built filler under the forms to keep the form joints vertical and the side rail slots and dadoes lined up. If the wedge taper exceeds a 12-inch build-up, step the panels down at 12-inch side rail increments. See Figure 4-21.

You'll need to provide proper bracing for the job-built wedge, at 12-inch side rail increments, to enable the form to withstand the concrete pressure with the added height size of the filler. Depending on conditions and the anticipated pressure, you may need to also add waling with additional ties through the form.

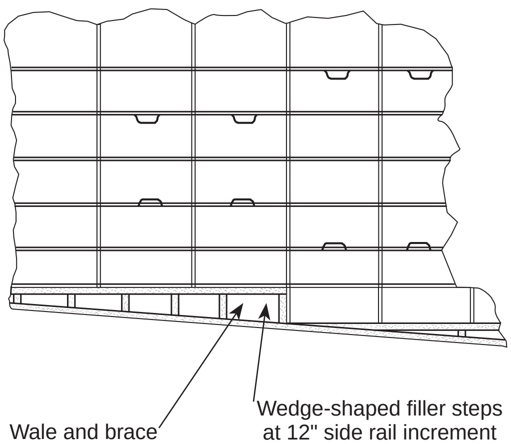


Figure 4-21
Wedge-shaped fillers beneath panels

Stepping Forms for Footings

Most step footings are stepped up or down in 6- or 12-inch increments. The form wedge bolt connections easily match these common steps. At 12-inch increments, panel ties install properly to adjoining tie dadoes. When you have 6-inch step increments, the side rail dadoes don't join. So, if you need a tight form joint, install flat ties in the half tie slot clearance of one side rail dado. When tight form joints aren't required, you can use panel ties at a single dado slot.

2-inch steel fillers and 4-inch step fillers have connecting bolt slots every 2 inches. Use these to step forms in any 2-inch increment. For other than 6- or 12-inch increments, you'll need to use separate wedge bolts to connect either form side of the filler. You can step forms in any odd increment using filler angles. Figure 4-22 shows stepped footing forms.

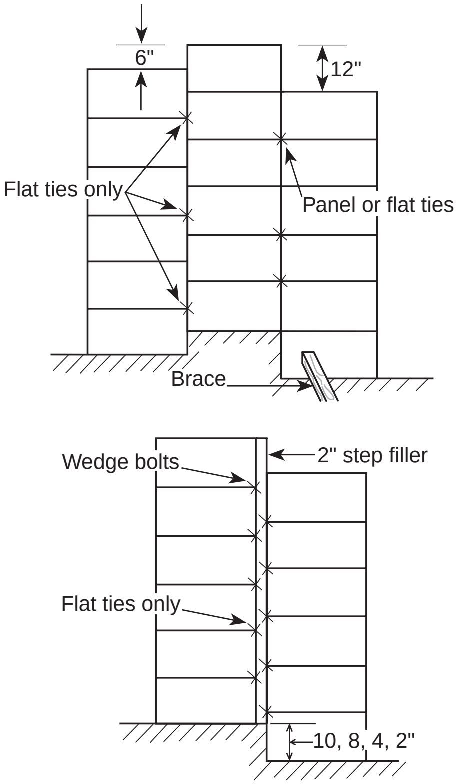


Figure 4-22
Stepped footing forms

Connectors

Symons offers a variety of connecting hardware to help make setting and stripping forms easy. Each of these serves a function in aligning and stabilizing the form design. In the following sections, we'll cover how these connectors are normally used in common construction situations. Then we'll look at special purpose ties and some special alignment situations.

Tie Alignment

Occasionally, to simplify the form erection, it's helpful to connect ties between opposing form joints that aren't quite aligned opposite each other. Both wire panel ties and flat ties can safely swing laterally up to 1 inch on 8-inch walls, or up to 2 inches on 16-inch walls. Exceeding the 1 to 8 angle proportion diminishes the tie strength or can cause the tie to fail by bending through the tie breakback crimp. Exceeding that angle can also reduce the wall thickness, which will weaken the wall.

Wire panel ties can also swing up or down (vertically) 1 inch on 8-inch walls, or up to 2 inches on 16-inch walls. An example would be where there's a plate under only one form side. Using a ¾-inch-thick 1 x 4 plate under

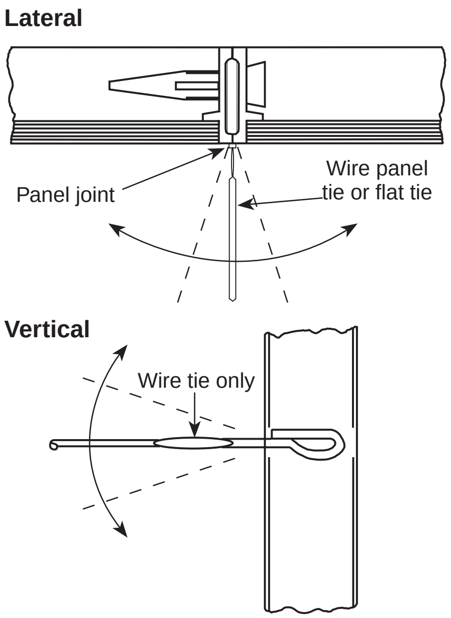


Figure 4-23
Lateral and vertical swing of the wire tie

Safe Load Ratings of Symons Wire and Flat Ties		
	Ultimate load (lb.)	**Rating according to factor of safety 2.0 (lb.)**
Standard duty wire tie	4,500	2,250
Standard duty threaded tie[1]	4,200	2,100
Standard duty S-base tie	3,000	1,500
Heavy duty wire tie	5,600	2,800
Standard duty flat tie	5,600	2,800
Heavy duty flat tie	6,500	3,250
Heavy duty adjustable flat tie	6,500	3,250
Toggle tie[1]	4,200	2,100

[1] *Tie capacity is dependent on adequate anchorage*

Figure 4-24
Load ratings for wire and flat ties

one side for any wall thickness of 6 inches or more, or a 1½-inch-thick 2 x 4 plate under one side for any wall 12 inches or thicker would still be within the 1 to 8 angle proportion. The lateral and vertical swing of the wire tie is shown in Figure 4-23.

Flat ties swing laterally, but can't flex up and down because of their dado slots. Figure 4-24 gives the safe load ratings of both wire and flat ties.

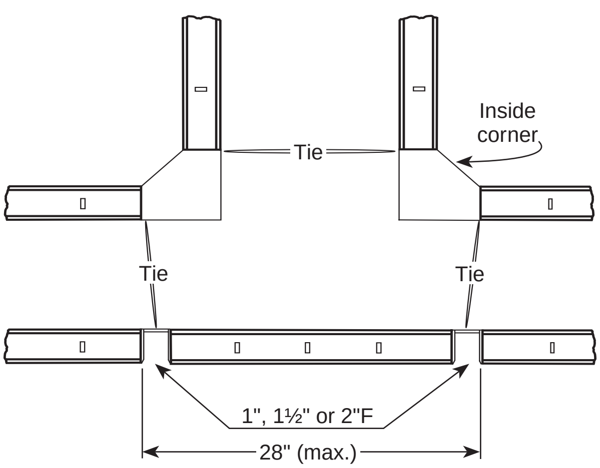


Figure 4-25
Ties are angled slightly at wall intersection

Intersecting Wall Ties

When the thickness of an intersecting wall is 12 inches or less, a single panel or filler will usually be adequate to span the length opposite the wall intersection, so wall ties can be placed at both inside corner form joints.

If the intersecting wall is 13 to 16 inches thick, you many need one or two steel fillers at either or both sides of a 2-foot panel to make up the necessary fill-in form dimension. In this case, the ties will be angled slightly, since they connect through tie slots in the center of the steel filler face (see Figure 4-25). You can form an intersecting wall thicker

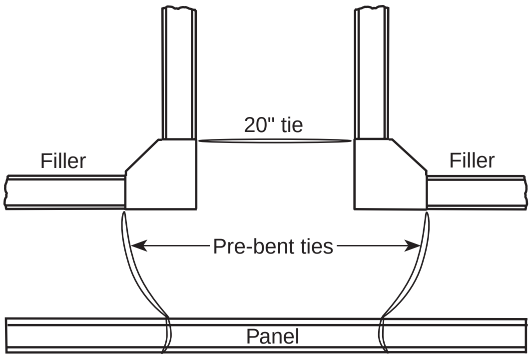


Figure 4-26
Pre-bent ties at wall intersection

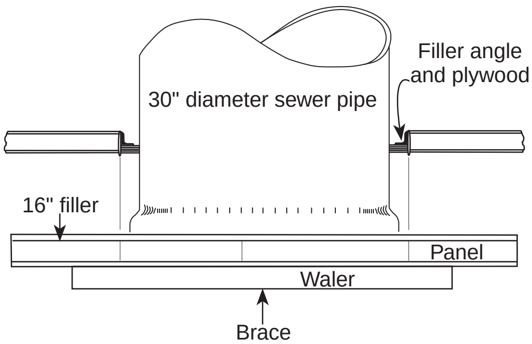


Figure 4-27
Waler and outside bracing at wall intersection

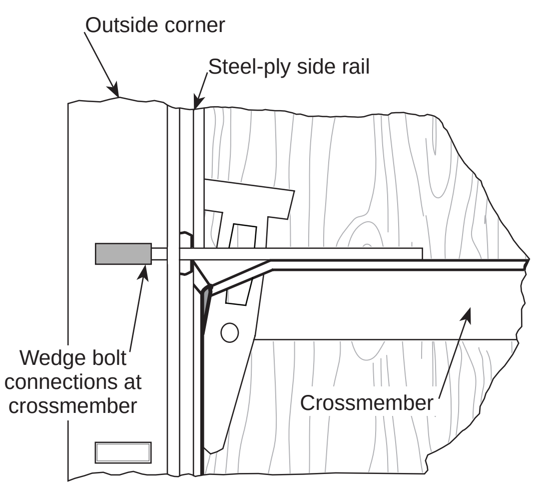


Figure 4-28
Wedge bolt connection at wall corner

than 16 inches using either special pre-bent panel ties (Figure 4-26) or by using walers plus bracing to support the form joint where you can't install ties.

The pre-bent tie method is best, because holding form loads with internal ties is more dependable than using external bracing. Also, the load gathered by the waler can overload the adjacent ties.

However, there are conditions where external bracing is the only solution. An obstruction passing through the forms on one side of a wall, such as a large diameter sewer pipe that must be poured flush to the opposite form face, requires a waler and an outside brace. If forms have no opposing tie joints, the floating panel joints must be waled and properly braced, as shown in Figure 4-27.

Wedge Bolts at Wall Corners

Wall corners need locking wedge bolts only at the same elevations as the wall ties. Make the connections through the side rail slots adjacent to the panel crossmember. Insert the lateral wedge bolts through the outside corner angle first, so that when you place the tightening wedge bolts they'll bear on the side rail side of each connection. Insert the wedge bolts from the corner side into the panel, as shown in Figure 4-28.

Walers

Walers are normally used only for form-alignment when panels are set with either panel ties or flat ties. This is in contrast to methods where the walers are the main load-gathering members to which wall ties are secured, or where the walers take the place of ties, as mentioned earlier. With the Steel-Ply forming system, the panel or flat ties connect directly to the panel side rails, and their length terminates at that point. So in effect, the adjoining side rails act as vertical steel walers at each vertical row, reducing the function of the horizontal add-on walers in form alignment.

For walls 8 feet high or less, using one panel lift and a setting plate secured to the footing, you only need one waler for alignment. It should be placed either 6 or 18 inches from the top on the alignment side of the wall. Align the opposite form side using the appropriate length wall ties.

Waler Connectors

Steel-Ply waler connections are designed to save time and increase productivity. Figure 4-29 shows different attachment options you can use to secure walers.

***Waler Tie and Z-Tie Holder Combination* —** Use a waler tie and Z-tie holder to secure either double 2 x 4 or double 2 x 6 lumber walers. These ties are available in two lengths and offer placement flexibility. The waler tie can be inserted in the side rail dado slots for connection with the wedge bolts, or it can be positioned at a tie/wedge bolt connecting point between the outside of a side rail and the wedge bolt.

***J-Waler Hook* —** A J-waler hook has the flexible advantage of three pieces interlocked to handle as one. It can be used with double 2 x 4 or double 2 x 6 lumber and hooks through any adjoining side rail connecting slots that aren't reserved for panel tie connections.

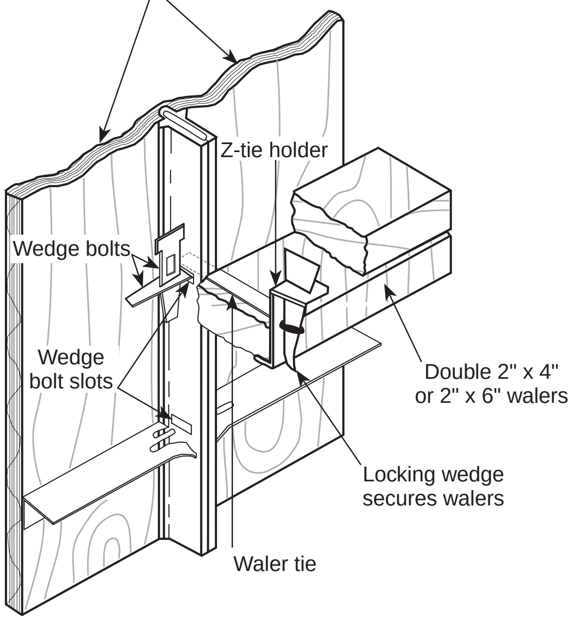
***One-Piece Waler Bracket* —** The one-piece waler bracket is fast and simple to install. Insert the waler bracket into any side rail hole not being used for ties, place a single or double 2 x 4 piece of lumber on top of the bracket, and drop the attached wedge into position. No additional hardware is needed.

Pipe Walers

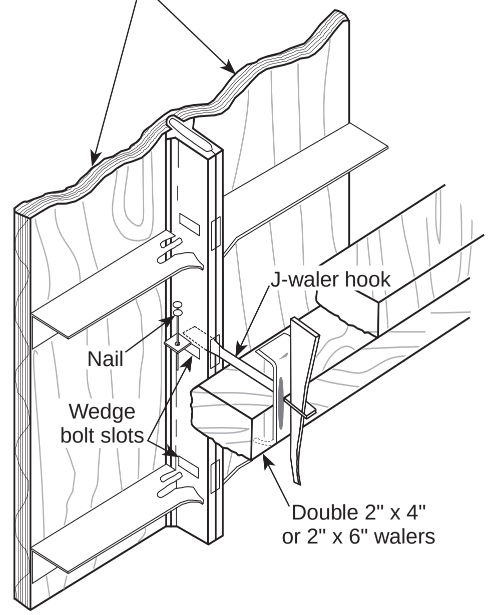
A pipe aligner hook can secure 1½-inch (Schedule 40) pipe or 1.90-inch outside diameter tubing for use as walers. The aligner hooks into position in the dado slots between side rails at either 6 or 18 inches from the top and/or bottom end rails. Two wedge bolts secure the connection. (See Figure 4-30.)

To attach the pipe waler, the pipe length must be held in position before inserting the aligner hook into the dado slots. Tap the first (lateral) wedge bolt through the connection slot with a hammer. Insert the second wedge bolt to lock in the connection.

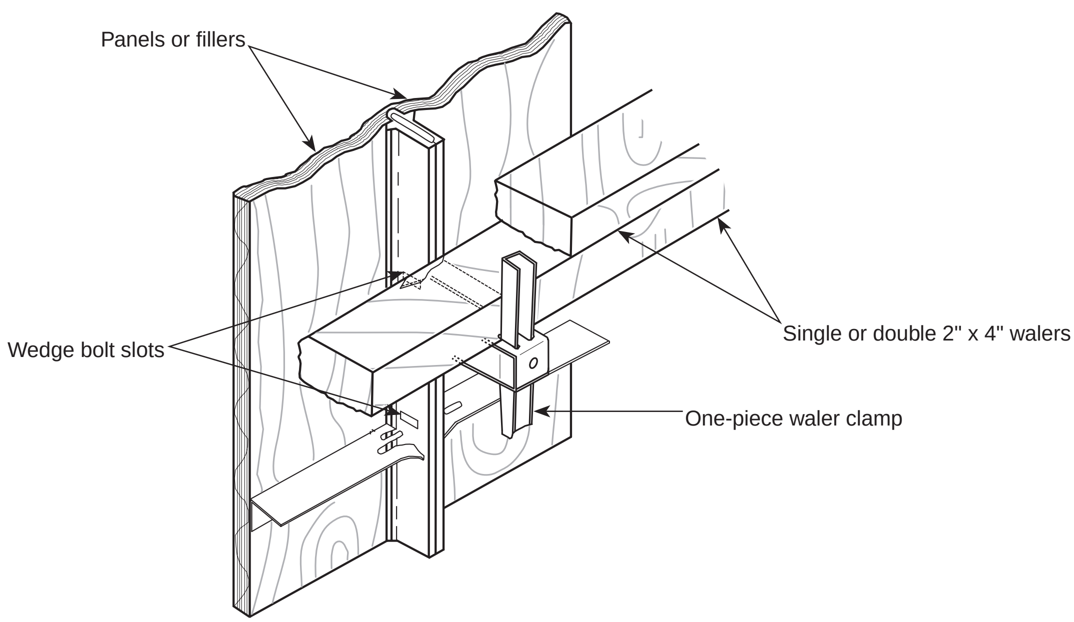
Two pipes can overlap and clamp at the same wedge bolt connection using two pipe aligner hooks. Attach the first hook with two wedge bolts in the normal fashion. Attach the second hook (which holds the second pipe) to the protruding end of the lateral-connecting wedge bolt, as illustrated in Figure 4-30. For security, insert a double-head nail in the wedge bolt's nail hole. *Note:* Pipe walers should only be used for alignment, never as load-gathering walers. The pipe aligner hook isn't designed to support concrete pressure loads, and the pipe could crush or bend.



Waler tie and Z-tie holder

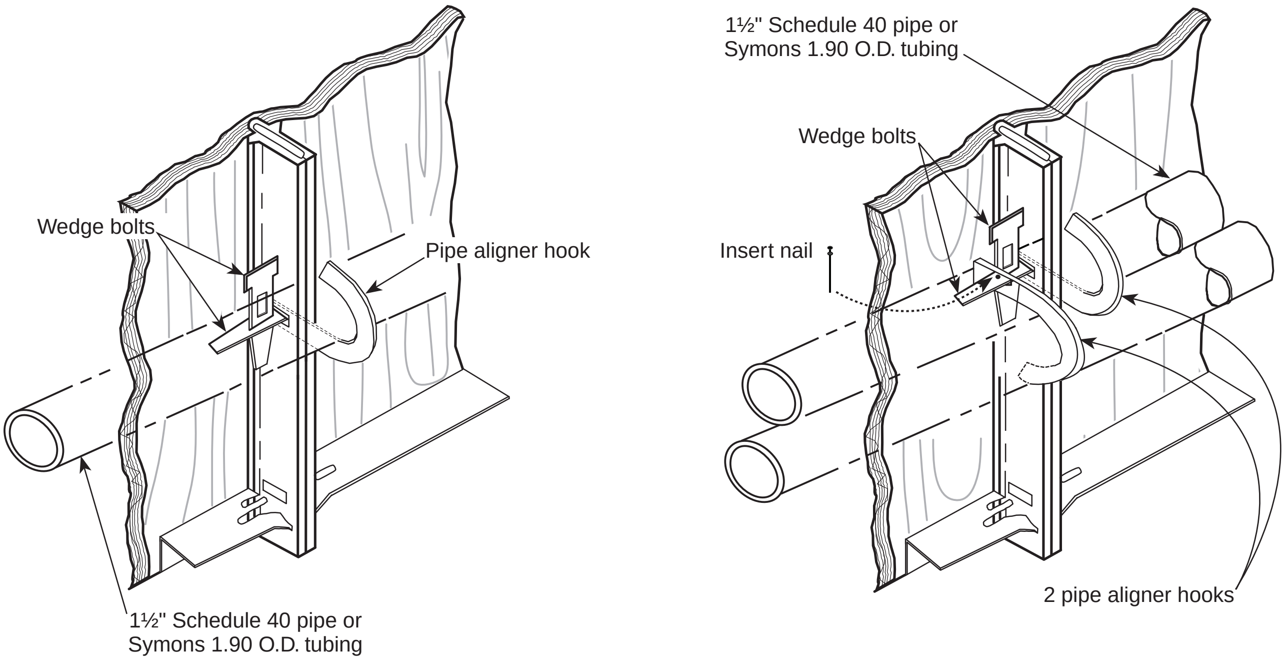


J-waler hook



One-piece waler bracket

Figure 4-29
Waler connectors



Single pipe aligner hook **Overlapping pipes and aligner hooks**

Figure 4-30
Pipe walers

Lap pipes over two or more panel joints, using two or more double hook positions, to provide optimal alignment.

Aligner Channel and Brackets

Attach 3-inch aligner channels using 3-inch channel aligner brackets and 8-inch gang waler rods, to provide straight wall alignment. Use 3-inch aligner channels, custom-rolled to the required curvature, to easily align curved walls. Figure 4-31 shows a channel aligner bracket.

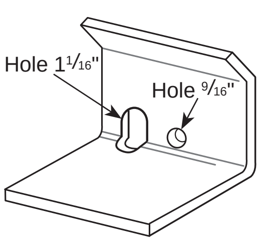


Figure 4-31
3" channel
aligner bracket

Lap and clamp two channels at the same wedge bolt connection simply by using a gang waler plate. Install two 3-inch aligner channel brackets, with one channel bracket above the gang waler rods and the other channel below the waler rods, allowing the channels to lap past each other, as shown in Figure 4-32.

Lapping channels and clamping with gang waler plates at two or more panel joints provides continuous alignment of one length to the other. Lapping channels also saves you from cutting long channel lengths to fit short dimensions.

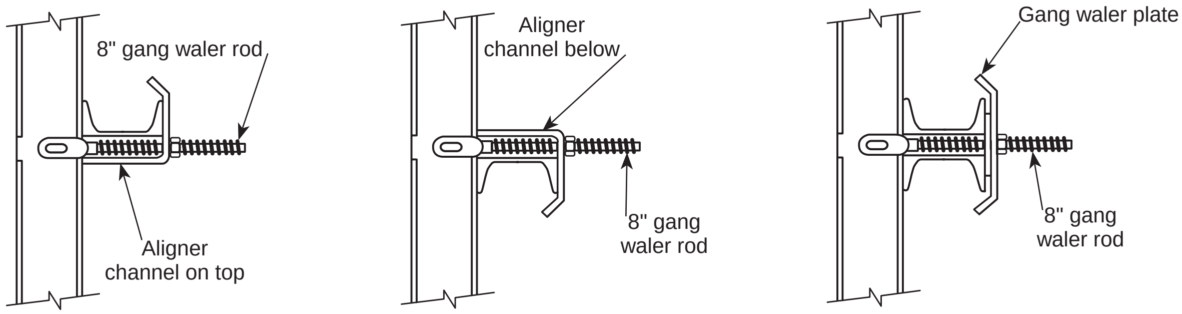


Figure 4-32
Lapping channels

Strongbacks

Strongbacks, shown in Figure 4-33, are vertical alignment members. Place them at 90-degree angles to walers to align the walers. Space the strongbacks about 8 to 12 feet on center, adjusting that spacing as determined by the specific job conditions. Strongbacks are made up of doubled 2 x 4s, 2 x 6s, or 2 x 8s, depending on the stiffness needed by the application.

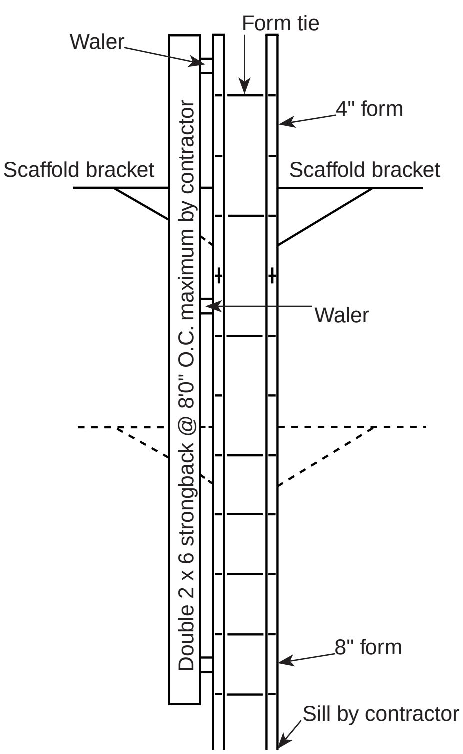


Figure 4-33
Strongback

Attach strongbacks, using either strongback ties with Z-tie holders or J-strongback hooks. Strongback ties secure at the side rail wedge-bolt connection, while the J-strongback hook simply hooks over one member of the lumber waler. When using strongback ties in conjunction with lumber walers and strongbacks, the strongback tie eliminates the need for a waler tie at that connection point. Strongback ties have loops in the same surface plane, as opposed to waler ties with loops that are perpendicular to each other.

Attach strongbacks for pipe-walered forms using a strongback U-bolt. Use either double 2 x 4 or double 2 x 6 lumber for the strongbacks. Figure 4-34 shows different strongback attachments.

Special Purpose Ties

Symons has the largest selection of standard and special ties in the industry. For the safe load ratings of Symons wire and flat ties, refer again to the chart in Figure 4-24. The following ties are used in special applications.

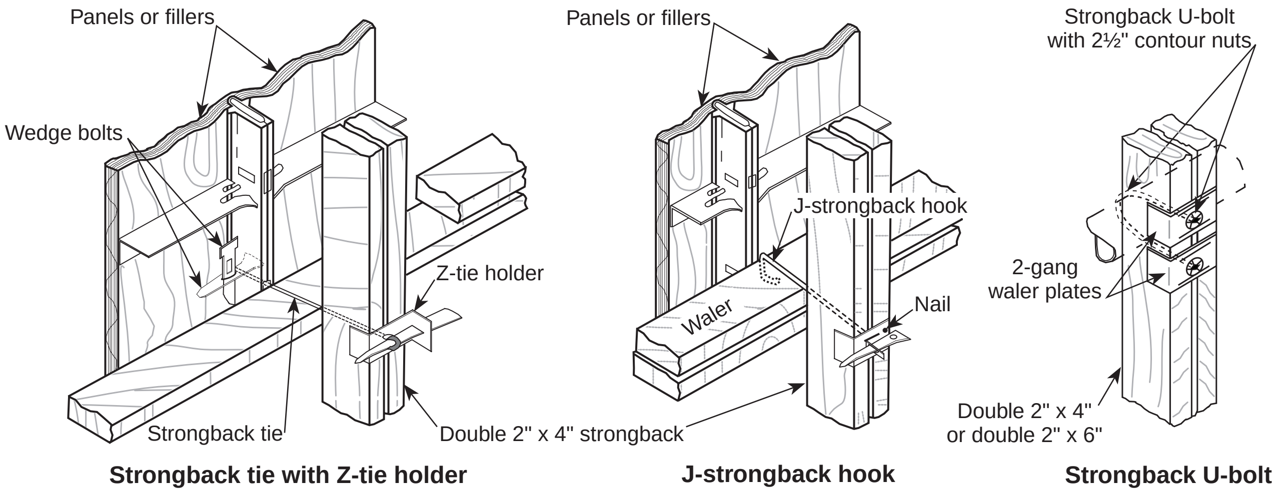


Figure 4-34
Strongback attachments

THREADED TIE BASICS — The following general information applies to all threaded ties:

- The recommended safe load on the special ¼-inch x 20 tie thread is 2,100 pounds at a 2 to 1 safety factor.
- The standard thread length provides 2 inches of adjustment.
- The holding capacity of a toggle tie depends on how well that toggle is anchored.
- The recommended vertical spacing for any type of threaded tie is 1 foot on center for all wall heights.
- Always take extreme care to assure each nut is adjusted so that every tie carries its share of the form load.
- Always use keeper bolts with threaded ties.

Threaded Ties

Threaded ties provide helpful adjustments for battered walls. The ties have a special thread design to provide maximum strength using a maximum diameter thread. The ultimate load capacity of threaded ties is 4,200 pounds. This provides for a safe load of 2,100 pounds at a 2 to 1 safety factor. There are four types of threaded ties: single-end threaded, adjustable single-end threaded, ties threaded at both ends, and the single-end threaded toggle.

***Single-End-Threaded Ties* —** In a typical application, the single-end-threaded tie provides the fractional inch wall tie variation commonly required to form battered walls.

Threaded ties have a special ¼-inch x 20 thread that requires a matching ¼-inch x 20 threaded nut. Spreader action is provided using a *keeper bolt*. The keeper bolt replaces a standard wedge bolt at each threaded-tie panel connection. The tie contains a breakback flat at the threaded end, which requires a breakback tool to break it away. How well the tie breakback performs depends on how deep the breakback flat is embedded in the concrete. With a breakback depth of 1 inch or less, it should twist off readily.

Adjustable Single-End-Threaded Ties — The adjustable single-end-threaded tie can adjust approximately 5 inches in length, with no breakback flat at the threaded end. Use it only when a minimum below-surface breakback isn't required; such as at the backfilled side of a battered retaining wall.

Ties Threaded at Both Ends — A tie with threads at both ends offers twice the range to accommodate variations in wall thickness, while retaining the ability to break it back using a jaw-grip breakback tool.

Single-End-Threaded Toggle Ties — The end-threaded toggle tie provides two basic application connections:

1. Toggle ties can be field-welded to attach to steel piling, structural steel, etc.
2. Toggle ties can anchor to lumber or steel sheathing when the toggle is inserted through a ⅞-inch-diameter hole in the sheathing, and its bearing position secured with an activating wire.

Cone Ties

The following three types of cone ties are designed to use with ¾-inch-plywood job-built forms.

No. 1 Cone Ties — No. 1 cone ties and Z-tie holders are designed for use with job-built forms of ¾-inch plywood, 2 x 4 studs, and double walers. Place the ties before the second adjoining form is erected. In most cases, outside walls are assembled first, the ties are secured, then the inside wall is assembled, using the protruding ties as guides.

No. 2 Cone Ties — No. 2 cone ties and Z-tie holders make it easier to tie to vertical panels opposite job-built forms of ¾-inch plywood, 2 x 4 studs, and double 2 x 4 walers. Normally, it's best to assemble the job-built side first, including ties and bracing. The Steel-Ply panels on the opposite sides automatically align parallel to the previously-walered job-built forms.

No. 2A Cone Ties — No. 2A cone ties and Z-tie holders will connect vertical panels opposite job-built forms of ¾-inch plywood and double 2 x 4 walers directly against the plywood (no studs). The tie loops are perpendicular to each other.

S-Pilaster Tie

The overall length of a pilaster tie holds opposite wall panels apart at a given wall thickness. The breakback flat at one end can be moved

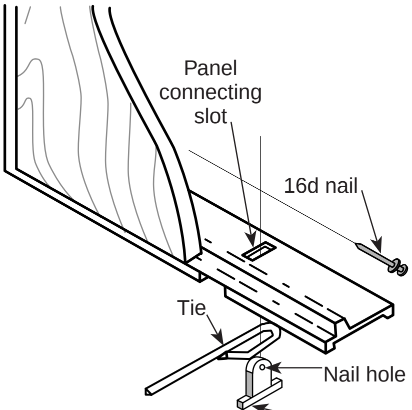


Figure 4-35
Base tie connector

inward to establish a breakback point on the tie just ahead of a brick ledge or other type of boxout. Double pilaster ties have special breakbacks positioned at both ends of the tie.

Base Tie Connector

The base tie connector secures either a panel tie or a flat tie to an end rail or a side rail resting on a footing, or where the panels butt against an existing vertical surface. One end of the tie must be connected to the first form side prior to its placement. The tie is then in position to receive the opposite form side. A base tie connector passes first through the ties, then through the panel connecting slots. The connection is secured by a 16d nail inserted through a nail hole in the nose of the *base tie bolt* (see Figure 4-35).

S-Base Tie

The S-base tie has an upturned open loop at each end which projects up through the bottom rail. Wedge bolts are inserted through the loop end to secure the tie and panel. Use S-base ties for small retaining walls or against existing walls.

Pre-Bent Ties

Unusual wall shapes may require special factory pre-bent ties, like those shown in Figure 4-26. There are many different types available. The connection points for pre-bent ties are predetermined by the design engineer. Check for their locations on the engineering layout provided. *Never* attempt to bend ties on the job. It's a dangerous undertaking for unskilled personnel.

Stacking Forms

When building up forms, panels should normally be stacked on top of panels or fillers of corresponding widths. Place the hardware in the first and third wedge slots on each panel end rail for the best panel face alignment. Put hardware in the middle dado slot when a tie is required. For a more positive connection, always install vertical wedge bolts point down, with the locking wedge bolt on the bottom.

It's best to begin erecting stacked panels at a corner. On the first panel from the corner, install hardware in the first and third end rail wedge bolt slots. From that panel on, most applications only need one wedge bolt connection from the top panel to the one directly below. That one connection should always go through the third end rail slot, as measured from the last panel set.

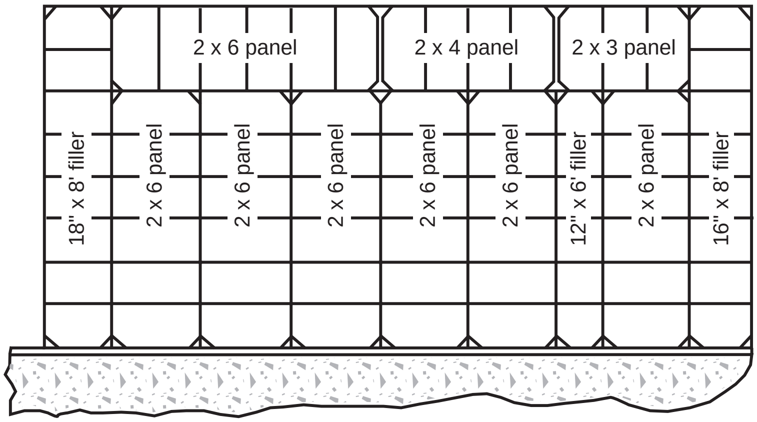


Figure 4-36
Horizontal panels stacked on top of vertical panels

The panels on both sides of a wall form should be the same size so their horizontal stacking joints are opposite each other. This helps place the wall ties, and assures that vertical joint tie locations are available from both sides.

Wall forms that are two or more panels high, stacked bottom rail to top rail, must have walers to align them, placed as close as possible to the stacked panel joints. The most practical position is 6 inches down from the top rail of each lower tier pane. That position puts the waler in place for preliminary alignment, and for bracing prior to placing of the next tier of panels. When the top and bottom tier forms are either 6- or 8-foot panels, the top-of-wall and bottom-of-wall walers may be positioned either 6 or 18 inches from the corresponding end rails, depending on other accessory hardware, such as scaffold bracket locations. The top waler should be as close as possible to the top of the concrete pour. Only one side of the wall form needs waler alignment.

Horizontal panels can be stacked on top of vertical panels. In most applications, the horizontal panels should be the same length as the wall forms on the opposite side. Selecting the correct horizontal panel length is important. The form joints must be located so that they correspond with hardware and tie connections to vertically stacked fillers, pilaster forms, corners, or any other details that require a common vertical form joint (see Figure 4-36).

Forming the Second Lift

There are several ways to support forms when setting them by hand on top of a previous wall pour. One method is to use the concrete-embedded anchors secured to the previous pour's formwork. When the first lift forms are removed, bolt a timber to the anchors. This will provide a ledge to support the next lift of formwork. You can provide good alignment between the subsequent pours by putting the ledge an inch or two below the previous pour.

Another way to support the forms is by leaving the top tier of the previous forms in place, undisturbed. Erect and support the second lift forms as a continuation of the first lift forms.

Form Alignment

You need a form aligner to position forms straight and plumb. The form aligner isn't intended to resist concrete pressure or any other loads. Secure Symons attachment plates to lumber to provide quick and sturdy alignment connections directly to any panel joint. The ground end of the aligner can be nailed to either a Symons steel stake or a lumber stake.

CAUTION: In addition to aligning the forms, all wall and column forms must be adequately braced to safely support any foreseeable lateral loads, including wind, eccentric loading, etc. The contractor is responsible for designing and anchoring the bracing system, including the materials, quantities, locations, and means of attachment. The bracing method should be based on jobsite conditions and the applicable industry standards.

Adjustable Turnbuckle Form Aligner

Symons offers an adjustable turnbuckle form aligner. Nail the top of the form aligner to the end of a piece of lumber. The lower end of the aligner contains a large rectangular slot to accommodate a Symons steel stake. Or, it can be nailed to a lumber stake.

If you use Symons steel Versiform® walers, the attachment-plate end of the adjustable turnbuckle bolts to the strongback with a standard 5/8- x 6-inch Versiform fit-up bolt.

Pipe Form Aligner

The Symons pipe form aligner adjusts from 11'7" up to 20'9", and connects to side rails using the Steel-Ply pipe form aligner adapter at the wedge bolt slot midway between crossmembers.

A pipe form aligner adapter isn't required to connect directly to vertical Versiform waler strongbacks. Either end of the aligner can be installed between the double 5-inch waler channels using a 5/8- x 6-inch fit-up bolt. Use a pipe form aligner shoe at the ground end of the pipe form aligner to anchor it. Drive a concrete anchor bolt or a round steel stake into the ground through the opening in the shoe.

Forming Accessories

There are several accessories available for use with Steel-Ply forms that offer improved safety and convenience when correctly applied with this system.

Scaffold Brackets

Where one or more levels of work platforms makes work above grade or deck levels necessary, install scaffold brackets for safety (see Figure 4-37). The allowable load on a scaffold bracket is 500 pounds. To comply

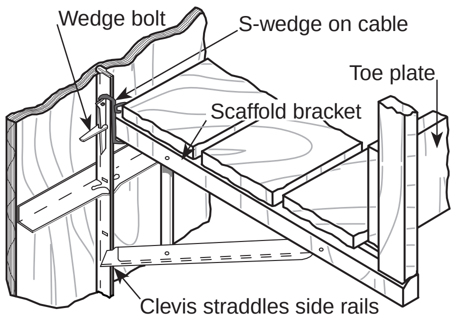


Figure 4-37
Scaffold bracket installation

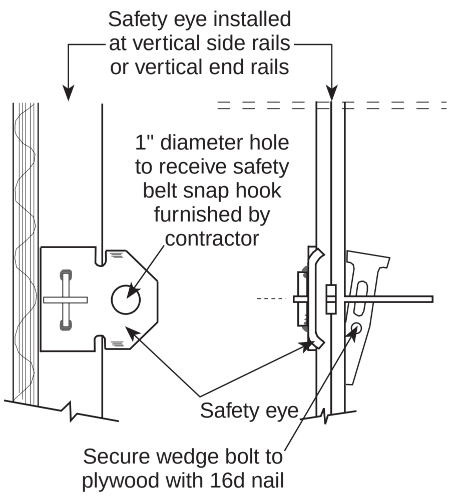


Figure 4-38
Safety eye

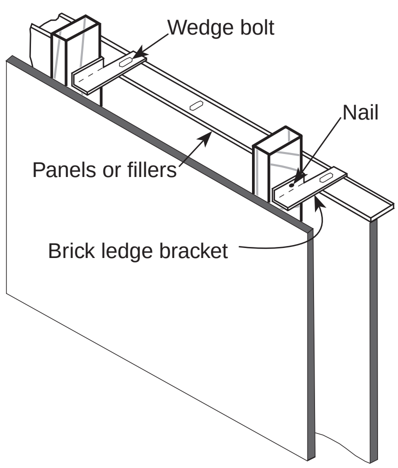


Figure 4-39
Brick ledge bracket attachment

with OSHA standards and all applicable governmental regulations, codes and ordinances, don't space the brackets more than 8 feet apart. Insert a wedge bolt through the bracket slot and panel side rails. Then lock the wedge bolt with an S-wedge cabled to the bracket. Be sure the clevis on the lower end straddles the side rails, as shown in the figure.

Caution: Never attempt to secure a scaffold bracket to ties after the forms are removed, or use the bracket in any manner other than as just described.

Safety Eyes

In addition to scaffold brackets, the installation of safety eyes on Steel-Ply panels provides workers with an easy attachment point for safety belts while working on the forms (Figure 4-38). Safety eye attachments aren't a substitute for work platforms, which are recommended and normally provide safer and more efficient working conditions.

Caution: Do not use a safety eye as a lifting bracket, and never attach one to a single horizontal side rail.

Brick Ledge Bracket

The brick ledge bracket is designed to form brick ledges and support various framed boxouts, such as beam pockets and window openings. The brackets attach to panels or fillers with wedge bolts. The nailer plate end of the brick ledge bracket is 3³⁄₈ inches long, and spans the wide side of a 2 x 4 framing member to create the offset needed (see Figure 4-39).

Beam Pocket

The beam pocket is a reusable tapered steel boxout that leaves a void pocket at the top of the foundation wall. The pocket provides an 8-inch-deep ledge in the finished concrete for a steel or wood beam to set on. Figure 4-40 shows a beam pocket.

Form Extension Bracket

Form extension brackets (Figure 4-41) are a convenient means of extending a standard panel wall height an

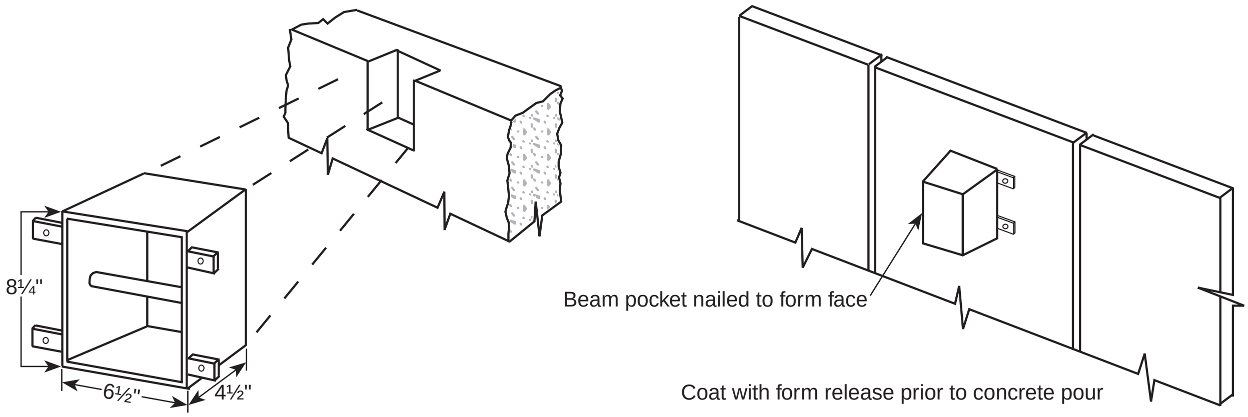


Figure 4-40
Beam pocket

additional 3 to 12 inches on straight or curved walls. These brackets are designed for use with ¾-inch plywood or sheathing boards, and attach with a wedge bolt. The bolt comes up from the top rail of the panel below, and can be locked rigid with an S-wedge. The S-wedge bridges the opposite side slots of the bracket while drawing the connecting wedge bolt tight. There's also a center slot to attach walers.

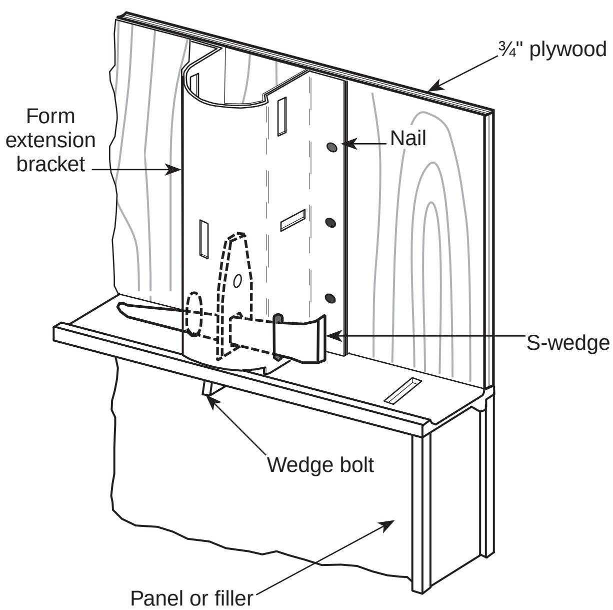


Figure 4-41
Form extension bracket attachment

Cantilever Bracket

A cantilever bracket is used to suspend the form on the opposing side of the wall. This allows you to have different elevations at the bottom of forms so that a slab base can be monolithically poured with the wall, as shown in Figure 4-42. The maximum capacity of the bracket is 700 pounds, and the maximum spacing can't exceed the panel length when forms are hung horizontally, or 8 feet when the forms are hung vertically.

When the suspended forms are horizontal, a long bolt with an S-wedge connects the cantilever bracket to the form side rail. When the forms are vertical, use a cantilever clip with fast-pin to couple the cantilever bracket to the inside forms at the first connecting bolt slot (6 inches from the top rail).

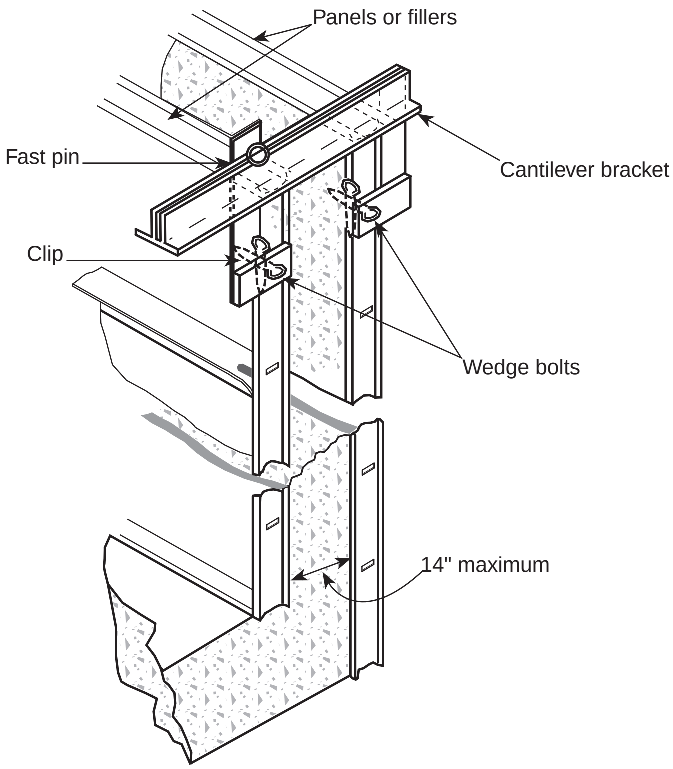


Figure 4-42
Cantilever bracket attachment

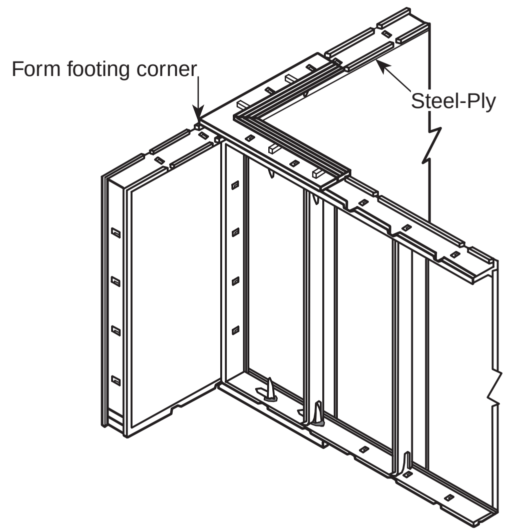


Figure 4-43
Footing corner bracket

Caution: The forms must be tied or braced as required, and the grade must be sufficiently compacted to withstand the imposed loads without settling.

Haunch Support Bracket

Haunch brackets provide a means to form haunches or corbels without any additional lumber support. The haunch bracket connects to the Steel-Ply panels and is designed to support ¾-inch plywood. Slots make securing walers a simple operation.

Footing Corner Brackets

Footing, pad, and slab forming are easy with Steel-Ply footing corner brackets and stake plates. Two footing corner brackets at each corner (one on top, one on the bottom) hold the panels firmly. A wide range of dimensions, in 2-inch increments, is possible. Figure 4-43 shows a footing corner formed with footing corner brackets.

Stake Plates

Position stake plates along the top edge of the Steel-Ply panels for the steel stakes that hold the forms in place against the pressure of the concrete (see Figure 4-44). You can use either ¾-inch round or I-beam

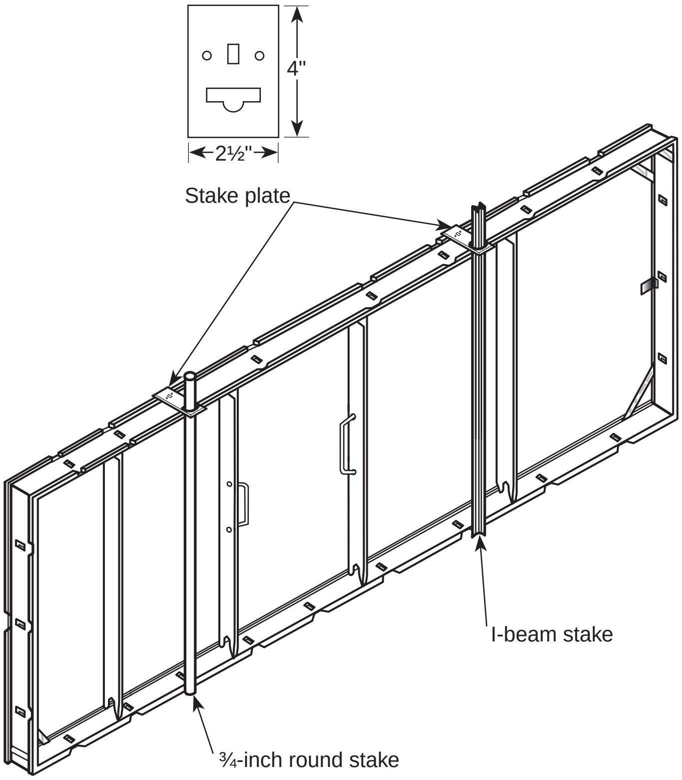


Figure 4-44
Using stake plates

steel stakes with these plates. Place the stake plates midway between the Steel-Ply crossmembers and the end rails to provide good access for a stake puller. Assemble all the components using regular Steel-Ply wedge bolts.

You can use stake plates with job-built wood forms as well. They have two nail holes for this purpose.

Pilaster Forms

Let's look at how to use Steel-Ply forms and accessories in other than straight-wall forming situations, such as forming for pilasters, columns and special corners and walls.

The pilaster form is adjustable in 1-inch increments for pilasters from 1 to 12 inches deep. There are two connecting flanges, one for even increments, such as 2, 4, and 6 inches, and the other for odd increments of 1, 3, and 5 inches.

To determine which end of the flange is the even side and which is the odd, simply measure the space between the first increment slot and the edge of the form. On one end, the measurement is 2 inches, and on the other end 3 inches.

If you need odd increments, place the 2-inch side of the flange nearest the wall. For even increments, flip the pilaster form over, and place the 3-inch end nearest the wall.

Where the pilaster form joins the panel at the wall, *shortstopping* is necessary. This is done by inserting a nail in the horizontal wedge bolt's nail hole when it's placed, then drawing up the wedge so that when the vertical wedge bolt is placed, its insertion forms a snug connection.

On the opposite, or outside end, where the pilaster attaches to the filler, tighten loose fitting wedge bolts by shortstopping or shimming. To shim, slip an extra wedge bolt horizontally onto the connecting wedge bolt, insert them through pilaster and filler, and lock them in place with a third wedge bolt. Figure 4-45 illustrates both shortstopping and shimming.

Each pilaster form displaces 3 inches of wall face area adjacent to the wall tie at its flange-to-panel connection, so the form opposite the

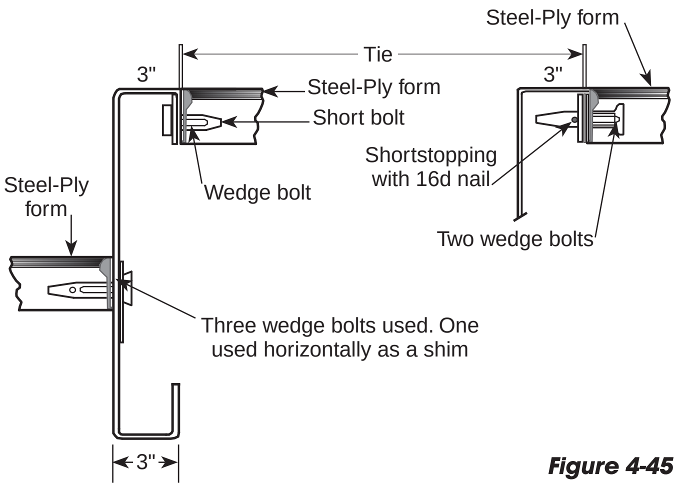


Figure 4-45
Shortstopping and shimming

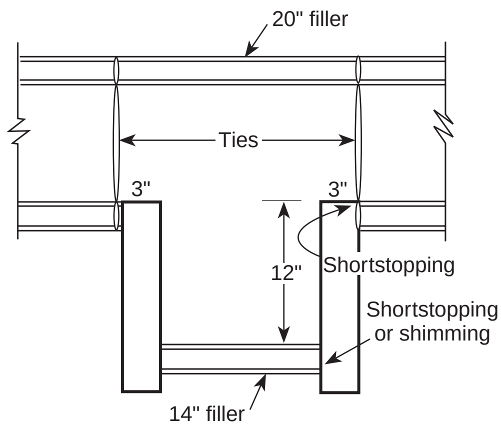


Figure 4-46
Pilaster form

pilaster must be 6 inches wider than the pilaster being formed (see Figure 4-46). Pilasters are also formed using inside and outside corners with the appropriate size fillers (refer back to Figure 4-12).

Pilaster Brace

The pilaster brace, shown in Figure 4-47, helps construct right angle corners on pilasters without using lumber to brace the corners of the pilaster forms.

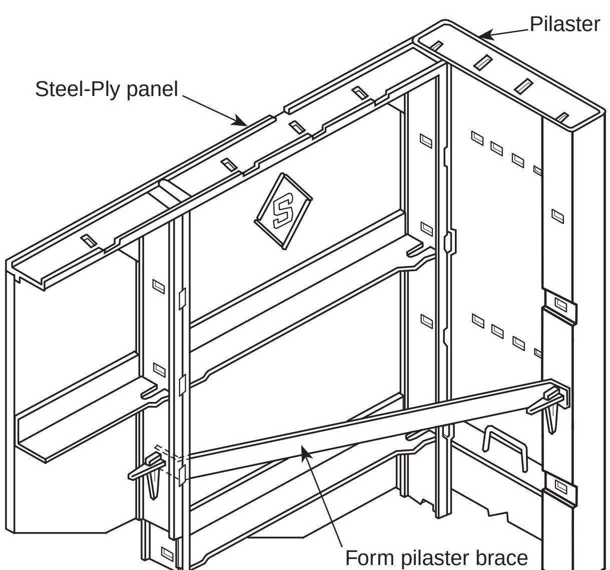


Figure 4-47
Pilaster brace

A pilaster brace is only needed on one side of the pilaster. When stacking forms, two braces are required on the bottom form, and one brace on each additional stacked form. The first brace should be 6 or 18 inches from the bottom of the pour. Additional braces should be 6 or 18 inches below the end rail of each form. Avoid placing braces where they'll interfere with walers or ties. There must be a panel located next to the pilaster form in order to brace the connection. Attach the pilaster braces with wedge bolts.

Column Forms

Pouring concrete into column forms creates its own set of problems. Because of the small confines of the column form, the liquid head rise is faster, causing higher pressure on the form. The side rails must

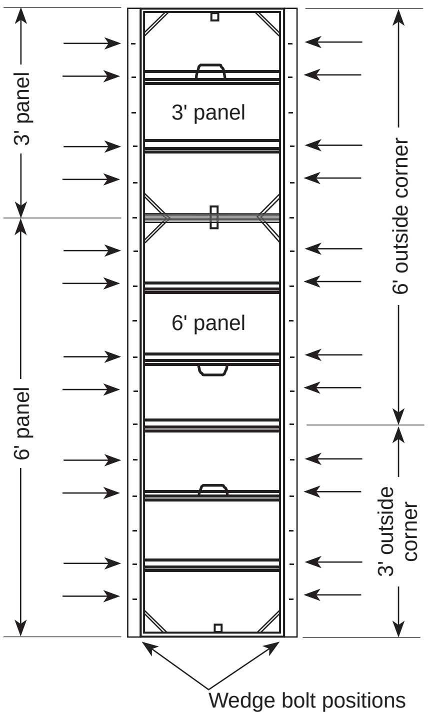


Figure 4-48
Column outside corner connections

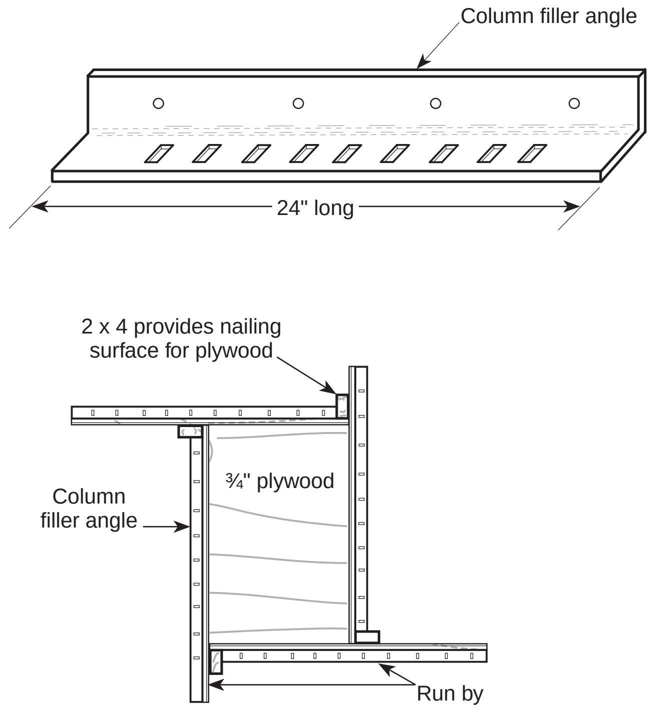


Figure 4-49
Column filler angle

resist lateral side-pull loads that normally aren't involved in longer straight wall panel-to-panel connections. For these reasons, the column outside corners need connecting wedge bolts at slots adjacent to all panel crossmembers. Column forms also need wedge bolts at slots 6 inches from each panel or filler end rail, and at slots 6 inches from the ends of each length of outside corner angle. The wedge bolt positions for column outside corners are shown in Figure 4-48. Stagger the form and outside corner lengths to eliminate common joints.

Column Filler Angle

Use a column filler angle, formed with 10-inch to 24-inch fillers or panels, to extend the top of a column. Use the *run-by* method when the column dimensions are less than 24 inches to save having to cut down panels. You can see an example of a column filler angle in a *run-by* position in Figure 4-49.

Curved Walls

Steel-Ply forms can be used to efficiently form curved walls or tank structures. Use 2-foot-wide panels to form curved walls down to a 15-foot

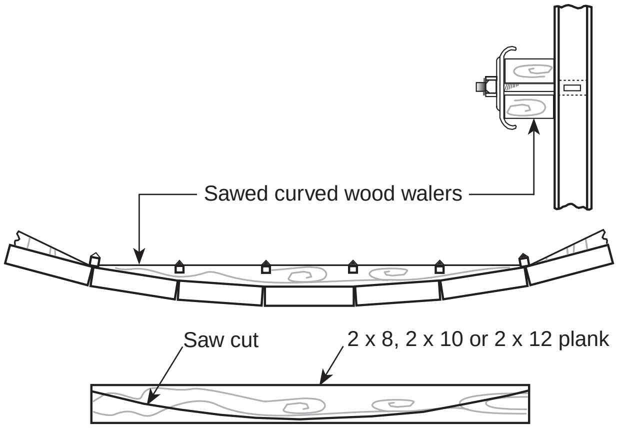


Figure 4-50
Cut lumber walers to the exact curve

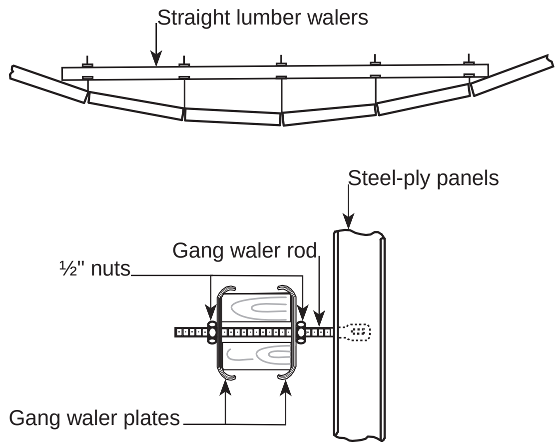


Figure 4-51
Use gang waler rods, nuts and gang waler plates to hold curve

radius (30-foot diameter). You can use standard fillers to form smaller radius walls. For example, 8-inch fillers will form a 5-foot radius.

The outside forms of a curve or round tank require 1-, 1½-, or 2-inch fillers at predetermined joint intervals to keep inside and outside panel tie joints opposite each other. (This is because a larger circumference is covered by the outside forms.) Align the curves using curved lumber or plywood walers sawed to the exact curve from extra wide lumber (see Figure 4-50).

There are several other means of producing a curved surface:

- Use 8- or 14-inch gang waler rods, two nuts and two gang waler plates with straight double lumber walers, as shown in Figure 4-51.
- Use steel angles, channels, and custom rolled pipe to give the desired waler curvature. Attach these to the form using the same connecting hardware methods as straight pipe or channels.
- Install flat dimensional lumber, such as 1 x 4s and 1 x 6s, and flex them to the desired curvature. They can be laminated in two or more thicknesses for stiffness, with staggered joints to extend the curve continuity.
- Make curved plates of 2 x 2 lumber flexed to the required curve. For smaller radius curves, kerf the lumber.
- Cut curved plates from 1 x 6, 1 x 8 or 1 x 10 lumber, using one side of the cut for the inside form and the other for the outside form. Cut small radius plates from 8-foot lengths of plywood.

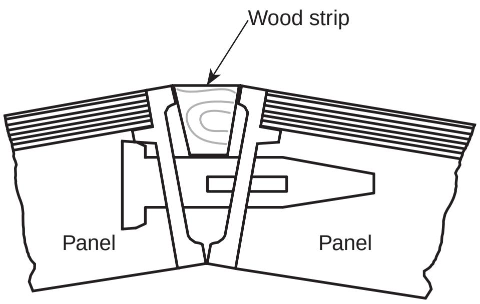


Figure 4-52
Insert wood strips into joint opening

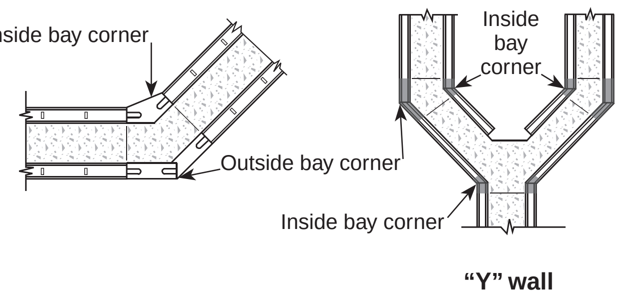


Figure 4-53
Inside and outside bay corners

Inside form joints open up at the face joint relative to the directional angle change between adjoining forms. Insert wood strips in the opening, as shown in Figure 4-52, to prevent excessive grout leakage, and to prevent the wedge bolts from pulling the panels back into a straight line. Also, without the wood strips, joints may need a greater curve to the walers, or more frequent bracing to hold the curve.

On larger radius curves, the face gap is smaller. Making continuous fill-in strips that are less than $^3\!/_{16}$ inch isn't practical. Instead, use short wood spacer shims at 2-foot intervals. These are sufficient to hold the angle between adjoining forms.

Bay Corners

Inside bay corners opposite outside bay corners form 135-degree wall corners. The inside bay corner has a 3- x 3-inch face dimension, and the outside bay corner has a 7- x 7-inch face dimension. Panel ties connect at adjoining panel joints the same as on standard 90-degree corners. You can use bay corners horizontally to form wall haunches and sewage treatment plant "Y" walls. (See Figure 4-53.) Using steel fillers or job-built fillers allows you to adjust bay corners to any wall thickness.

Hinged Corners

In most wall applications, inside hinged corners are used opposite outside hinged corners. An inside hinged corner can be sized down to a 45-degree inside corner. The outside hinged corner ranges from 135 degrees to a sharp 5-degree angle. Always insert connecting wedge bolts toward the adjoining panels to avoid restricting the maximum swing angle of the hinge. *Caution:* Due to the inherent flexibility of hinges, it's important to wale, brace, and block corners as required. Don't use hinged corners in column applications.

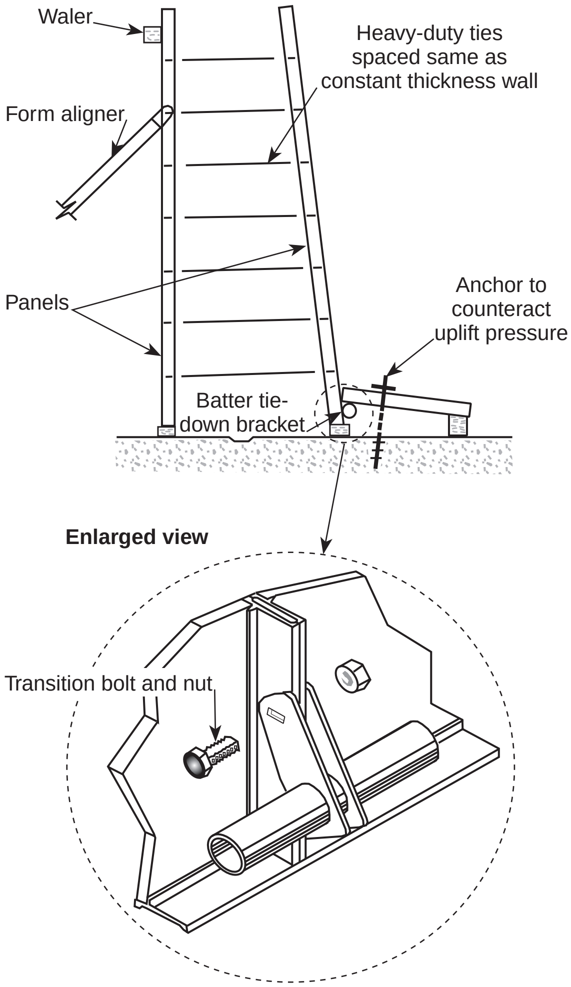


Figure 4-54
Batter tie-down bracket

Bulkheads

Since Steel-Ply panels have plywood faces, you can install bulkheads in the same way as securing bulkheads in any other conventional wood forms. Form bulkheads using outside corners and wall-thickness-sized fillers or panels.

Battered Walls

You assemble battered walls in much the same way as vertical walls, with the following two differences:

1. The tie sizes vary to conform to changes in vertical wall thickness.

2. Normally, the pressure exerted by the freshly-placed concrete reacts at right angles to form faces. On battered walls, the horizontal pressure of the concrete also has an additional upward component, called *uplift*.

The amount of uplift depends on the degree of batter and concrete pressure. If the uplift isn't adequately counteracted, the entire form will "float" out of position. Adding a batter tie-down bracket at the base of the battered wall side form will help minimize the difference in the tie angles relative to both form faces (see Figure 4-54).

Batter Tie-down Loads	
Form slope	**Working load per bracket (in lbs.)**
0:12 to 6:12	8,650
6:12 to 9:12	7,690
9:12 to 12:12	7,450

Figure 4-55
Working load of brackets

Batter Tie-Down Bracket

Attach a batter tie-down bracket to the Steel-Ply side rail 6 inches from the bottom of the form using a transition bolt and ⅝-inch nut. Don't use wedge bolts and long bolts to attach it. Place lumber, mini-walers or a Versiform waler on both legs of the bracket, with the load equal on both legs. The capacity of the bracket is relative to the slope of the wall. The chart in Figure 4-55 gives the working load of the bracket in relation to the slope of the form.

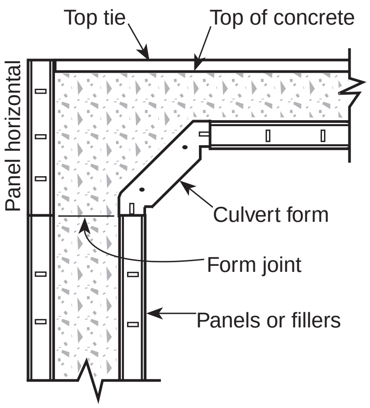


Figure 4-56
Culvert form

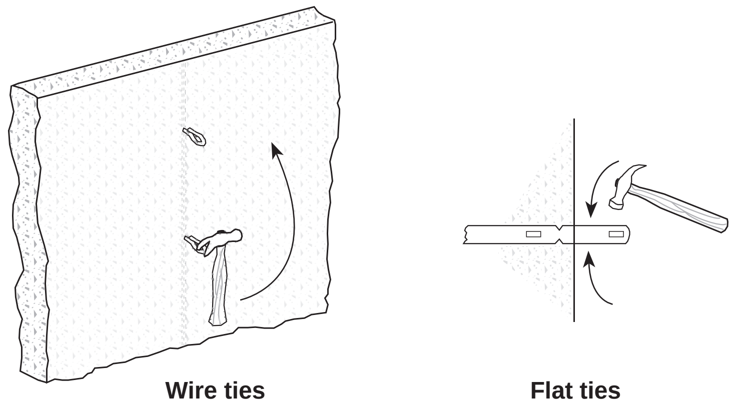


Figure 4-57
Stripping form ties

Culvert Forms

Use a culvert form for the chamfered corners commonly needed for box culverts, as shown in Figure 4-56. On most chamfer-cornered culverts, the roof slab and walls are poured monolithically. You'll usually need panel ties at the horizontal form joint between the culvert form and the top rail of the inside forms. This means that the outside form must also have a horizontal joint at the same elevation, so that the tie dadoes occur at the same staggered positions at opposing form sides. You'll then need a top tie over the deck to the outside form on the other wall side of the culvert. Properly shore the deck forms to support both dead and live concrete placement loads.

Form Stripping

Start panel stripping at any point after removing the walers and other connecting hardware. It's easier to begin stripping the forms at an outside corner, or adjacent to a filler. Collect your hardware in a metal container so you don't lose any of the pieces.

Break the ties back within two days after stripping. With wire ties, a one-half to three-quarter twist will break them back. A firm hammer blow on the edge of the tie will break off flat ties, as shown in Figure 4-57. A blow against the flat side of the tie will simply bend the tie. Be careful when striking ties with a hammer during the stripping process. Again, always wear gloves, safety shoes and safety glasses during both the assembly and stripping processes.

5

INSULATED POLYSTYRENE CONCRETE FORMS

As mentioned in earlier chapters, weather and climate conditions, including temperature, moisture and wind, can adversely affect concrete and its performance. Heat and low humidity will make concrete cure too quickly, so it won't reach its full design strength. If concrete is allowed to freeze during curing, that will also make it weaker. Many of the problems associated with these factors can be eliminated by using insulated concrete forms, called *ICFs* by those in the construction industry. These stay-in-place forms have become popular for use in both hot and cold climates.

As concrete cures, it generates heat. With conventional concrete forms, this heat dissipates too rapidly during cold weather, and chemical additives may be required in the concrete mix to prevent freezing. When you remove a conventional forming system in dry summer heat or wind conditions, again, the concrete loses moisture too rapidly. An insulated forming system holds the heat and moisture within the form longer, so you rarely need additives, and it cures slowly. For that reason, stay-in-place insulated forms produce a stronger, more durable concrete than conventionally-formed "air cured" walls.

ICFs are good for general use in forming foundations, from which a large amount of heat is lost through the ground. And, used above ground, since the forms are left in place, ICFs increase the building's overall insulating properties. This reduces the cost of heating a building in cold weather and cooling it in warm weather, as well as decreasing sound transmission. Insulated forms also create a natural barrier against moisture and termites.

The companies that distribute insulated forms offer installation training throughout the year. Contact the Insulating Concrete Forms Association (ICFA) at www.forms.org for information on these products and their available training classes.

Always refer to local codes before using this type of formwork. There may be different requirements for their use than for standard metal and plywood forms.

Constructing the Forms

ICFs are relatively easy to erect with common tools. The forms are a combination of two layers of foam, separated by plastic or metal ties. You can purchase them pre-formed, or assemble them on-site. The adjoining panels interlock easily to create a superinsulated wall that you leave in place after the concrete pour.

The Footing Forms

To make installation easy, footing forms shouldn't be more than ¼ inch out of level. It isn't hard to build a level footing. The time you spend leveling the forms is nothing compared to the time it takes to make corrections during the wall forming operation. If you have high or low spots in the footing, there are ways to work around them. For instance, you can shave the bottom of the insulated forms to conform to the footing. Or, you can fill low spots in with spray foam or scraps of form material.

"The time you spend leveling the forms is nothing compared to the time it takes to make corrections during the wall forming operation."

Architectural or building code specifications may call for a keyway in the footing. You can form these using a 2 x 4 or 1 x 2. Most codes require rebar embedded in the footing that extends up into concrete walls. If your specifications are unclear, a few questions to the Code office will help. Many times, the local government code requirements are stricter than the standard code. Always check these requirements, because you must build according to the local code regulations.

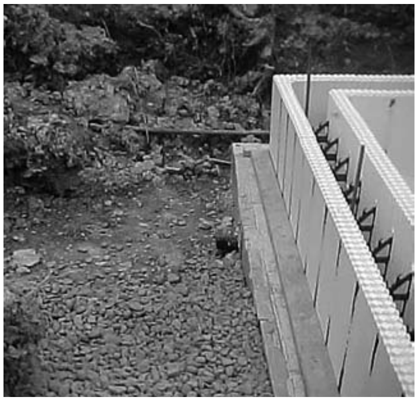


Figure 5-1
Place 2 x 4 forms around the perimeter of the building line

The easiest way to install vertical rebar in footings is to use pieces that have a short 90-degree bend at one end. When installed in the fresh concrete footing, these will stand up much better. The pieces are usually 24 inches vertically. Again, check with local code regulations for their exact length requirement.

The Wall Forms

To start constructing the insulated forms, snap a chalk line to show the exterior of the wall. Use concrete nails to put a 2 x 4 lumber form around the perimeter, with the inside of the 2 x 4 on the building line (see Figure 5-1). The 2 x 4s will hold the first row of insulated foam forms in their correct position, and will be removed after the pour. Most polystyrene systems have ready-made corners. But with some types you'll need to cut the corners. Because these corners are often weak spots, be sure to fill them slowly when pouring the concrete.

After you install the first course of forms, pour the concrete floor against this course. This is best for many reasons. First, it's easier to pour concrete over only one course of wall forms. Second, you can "get on the slab" to finish the surface more easily. And finally, you have a good surface to work on during the remaining operations.

Figure 5-2 shows the first course of forming and a vapor barrier with insulation boards on the subbase for the concrete floor. The interior foundation will be poured over the plastic vapor barrier and insulating board. Now is the time for installing "runs" for a radiant heating system under the slab.

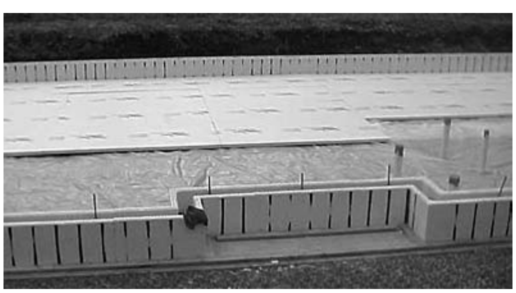


Figure 5-2
First forming course with vapor barrier and insulation boards

Building Up the Forms

When constructing the wall forms, work inward from the corners. Then you can make all the cuts in the sections at openings in the wall. Steel or plastic webs tie the forms together, and cutting weakens the forms. Try not to create a weak spot where pressure from the concrete pour can blow out the form. Most contractors install pressure-treated wood forms at window or door openings. The inside of these forms will later become the rough openings for the door and windows. Screw strips of 1 x 4s across the openings to keep the lumber and polystyrene forms in

Figure 5-3
Screw 1 x 4s across window openings

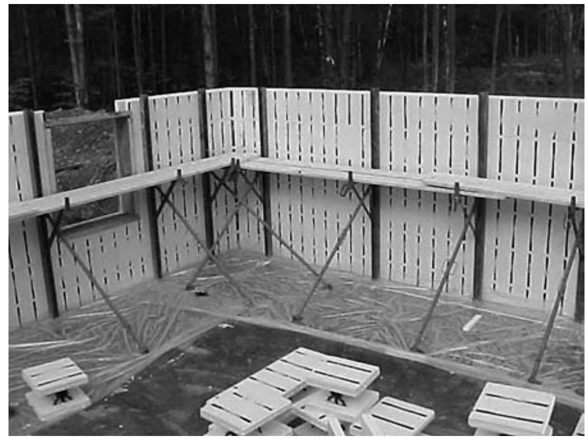


Figure 5-4
ARXX forms with scaffolding

a straight line, as shown in Figure 5-3. Install long screws, lag bolts or nails into the sides of door and window frames to create a mechanical bond between the wood and the poured concrete.

Attach the top two or three courses of foam forms vertically with wire or filament strapping tape.

The forms pictured in this chapter are *ARXX® Insulated Concrete Forms*. ARXX designs and sells its own form alignment/scaffolding system. You can see an example in Figure 5-4. The alignment system is usually erected after the third or fourth course of form units are installed, generally on the inside face of the wall. Screw the vertical sections into the plastic webs with #10 pan-head screws. Then install the braces using clevis pins or bolts. The adjustable braces keep the forms from slipping or getting out of alignment. Another good reason for pouring the floor right after installing the first course of foam blocks is that you can secure the bottom of the braces to the concrete floor using concrete screws or nails. Then align the wall forms using the turnbuckles on the alignment braces.

Figure 5-5
Fill sleeve holes with expanding foam

Utilities and Reinforcement

You can install openings for utilities in many ways. The best way I've found is to install a sleeve that's one size larger than the size needed for the utility. The space around the actual sleeve can be filled later with spray-in expanding foam, as shown in Figure 5-5.

ACI Pour Rate Limitations	
Temperature ˚F (˚C)	**Feet/hour (mm/hour)**
40˚ (4˚)	2.2 (670mm)
50˚ (10˚)	2.75 (840mm)
60˚ (15˚)	3.03 (920mm)
70˚ (21˚)	3.85 (1,170mm)
80˚ (27˚)	4.4 (1,340mm)
90˚ (32˚)	4.95 (1,510mm)

Figure 5-6
Pour rate limitations

Most polystyrene form manufacturers provide brochures explaining how to install reinforcing bars in their forms. Regardless of which product you use, it's easiest to install the rebar into each course as you build the forms.

Placing the Concrete

Pouring concrete with polystyrene forms is slightly different from the way you pour with steel and plywood forms. The concrete has to be fluid enough to fill forms that contain plastic and steel crossmembers. Most contractors use a #1 aggregate, 4,000 pound mix, with a 5- to 6-inch slump. It's less likely to stick to rebar and plastic attachments.

Concrete pour speeds vary. Wall height and length, temperature, and the concrete mix all play a part in the timing. The method of placing the concrete in the forms is also important. Regardless of the type of pump you use, your pour rate can't exceed the limitations set by the American Concrete Institute (see table in Figure 5-6). They provide a 2:1 safety factor. You can find these standards in ACI 318 and ACI 332. (In Canada, see CSA A23.1.)

Pour the concrete slowly, in lifts (or layers) of 2 to 4 feet. If you're using a pump, pour a 2-foot lift all around the form, then go back and do another 2 feet, and then another, until the pour is complete. *This is really important:* Make sure you've set up a delivery schedule with your supplier that allows you to have a continuous pour so you can avoid pouring against cold joints (points where the previous pour has already begun to set). Schedule the trucks to arrive within a time frame that prevents cold joints. Remember, preparation is the most important part of pouring concrete.

Vibrating

Most concrete walls must be vibrated, but vibrating the concrete in foam forms is critical. Vibration consolidates the concrete of one lift into the next. It's a very important part of the concrete pour and requires planning and teamwork to prevent a cold joint. Concrete in foam forms must be vibrated very carefully. I suggest using vibrators with a thin 1-inch shaft, because they usually don't get hung up on the rebar or plastic webs. Don't vibrate the concrete too much or you can blow out the polystyrene forms.

YOU MUST BE SURE each layer of concrete is consolidated so that the reinforcing bars and webs are properly embedded. That'll also eliminate honeycombing. The slump required of the concrete mix is the most critical issue affecting the consolidation of the mix. A low slump concrete makes it harder to properly consolidate the concrete.

Working with ARXX Forming Systems

ARXX offers the following suggestions for contractors using their forming system:

1. Make sure the concrete producer is providing concrete that meets the requirements of the local building code.
2. Minimum compression shouldn't be less than 3,000 psi (20mPa) at 28 days, unless otherwise approved.
3. The water/cement ratio must be less than 0.60.
4. Use Type I (in U.S.A.) normal portland cement. Supplementary cementing materials can be incorporated into the mix design. However, the contractor must insist that the concrete producers supply proof that the final concrete quality won't be altered if portions of portland cement are mixed with supplementary cementing materials — these may increase form pressure and have a lower strength rating.
5. The maximum aggregate size is ¾ inch (20mm). With the addition of reinforcing steel, the working space within the form unit is limited and larger aggregate will require greater care to ensure proper placement.
6. The recommended aggregate size when used with the 6¼-inch form is ⅜ inch (10mm) or ½ inch (13mm), depending on the quantity of reinforcement to be placed in the wall.
7. The recommended aggregate size when using the 8-inch form is ¾ inch (20mm).
8. A slump of 5 to 6 inches (125mm to 150mm) is desirable.
9. Concrete admixtures can be used for special applications, under strict compliance with the engineer's specifications.
10. Due to potential segregation caused by dropping concrete large vertical distances, adjustments to the mix may be required.
11. In the U.S., concrete placement is regulated by ACI 318 or 332. In Canada, it must be in accordance with the CSA A23.1.

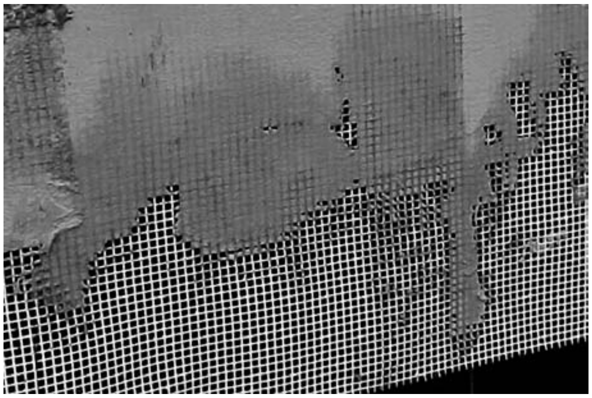


Figure 5-7
Black waterproofing membrane with fiberglass mesh embedded in stucco on a below-grade foundation

Covering the Forms

After the concrete is poured, it's time to cover the exposed polystyrene. This is best done with stucco, a cement-based covering. There have been major breakthroughs in the stucco industry that now enable a renewed use of stucco with ICF products. Stucco used to be limited to areas where there was no danger of freeze/thaw cycles.

The new stucco products are acrylic-based and use fiberglass mesh reinforcement. This results in a material that's more flexible than its cement-based predecessor. Acrylic materials can resist much of the dimensional expansion and contraction changes caused by freeze/thaw cycles. These new products are called *exterior insulation finish systems* (EIFS). We'll look at an EIFS system shortly.

Figure 5-7 shows a below-ground house foundation wall with a black waterproofing membrane coating on the outside of the polystyrene foam foundation. At a point just below grade level, fiberglass mesh is embedded in the base coat of stucco. Then successive finish coats of stucco are applied to produce a texturized surface.

The Outsulation® System

Outsulation®, manufactured by Dryvit®, is an exterior insulation and finish system (EIFS). As the name implies, the system was conceived with the idea of putting insulation on the outside of the wall. The expanded polystyrene (EPS) insulation board used in the system increases the energy efficiency of Outsulation. You can install EPS board in thicknesses from 1 inch up to 4 inches on the outside of your wall, giving an R-value of up to 15.4. Since the insulation is placed on the outside of the studs and sheathing, none of this R-value is lost due to heat transfer through the studs. Up to 30 percent of R-value can be lost with conventional batt insulation because there are breaks in the insulation for the studs.

The Outsulation system can be used with ICF products to produce a polystyrene wall covered with another layer of polystyrene. The boards are applied to the ICF walls with acrylic-based stucco adhesive and then finished with various textured coatings. Finishes are available in a wide variety of colors and textures, from simple stucco to brick, granite, limestone, precast and more, giving the owner unlimited choices.

Figure 5-8
Apply adhesive to the panels

Figure 5-9
Install panels horizontally in a running bond pattern

Installing Outsulation

To install the Outsulation boards, mix a base coat of Primus® acrylic-based stucco adhesive with portland cement, using the specifications provided by the manufacturer. Apply the adhesive mix to the insulation board with a notched trowel. The notches should be ½ inch deep and 1½ inches apart. Apply the adhesive so that it's vertical to the way the panel will be installed. Keep the adhesive off the edges of the panels so that they can be fitted tightly together. Figure 5-8 shows a worker applying adhesive to a panel that'll be installed horizontally.

Press the Outsulation insulation board to the polystyrene (ICF) substrate with enough pressure to make a good bond. The panels should be installed horizontally, in a running bond pattern similar to a brick wall. Be sure that the joints don't line up with the joints of the ICF panels. See Figure 5-9.

The manufacturer suggests that you do this work when temperatures range between 40 degrees and 90 degrees Fahrenheit, as higher temperatures may affect the cure time. If possible, work on the shady side of the structure during peak temperatures. Allow the Outsulation boards to cure for at least 24 hours so that they'll bond well with the CIF panels underneath.

When the panels are cured, lightly sand them with a special trowel to provide a roughened surface to which the finish material can adhere. The trowel needs to have a coarse, rasp-type surface. You can purchase installation tools from Goldblatt Tool Company (www.goldblatttool.com) or Bon Tool Company (www.bontool.com). Some workers make their own tool for rasping the surface using very coarse (10 to 25 grit) self-adhesive sandpaper stuck to a flat trowel or trowel-like tool. Sand the surface in a circular motion, leveling any high spots. Don't sand parallel to the form joints.

Figure 5-10
Hot knife

Figure 5-11
Use a straightedge to create a level groove

Figure 5-12
Base coat and finished groove pattern

Figure 5-13
Applying the finish coat

You can use a tool called a *hot knife* or *hot groover*, pictured in Figure 5-10, to make designs of various shapes in the forms. Notice the groove attachment in the base of the tool. Use a straightedge or steel stud as a level to make a straight cut. You can see the groove resulting from the cut being made in Figure 5-11. Be careful to leave a thickness of at least ¾ inch in the foam panel beneath the groove.

Apply a base coat of stucco to the sanded surface and embed nylon mesh in it. Trowel the surface flat. Figure 5-12 shows a grooved surface, with the base coat and embedded mesh completed up to the corner on the left side. Allow the base coat to cure overnight. If the base coat must be left for a longer period of time, apply a primer before putting on the finish coat.

When the base coat has cured for 24 hours, it's ready for the finish coat. Apply the finish material with a stainless steel trowel, leveling it to a uniform thickness that's no thicker than the largest aggregate in the mix. In Figure 5-13 you can see the finish coat being applied over

Figure 5-14
The final texture is applied

the nylon mesh and base coat. While the coating is still workable, trowel it again, but this time with the rough-surface trowel. Different finishes may require additional coats. For example, a limestone finish requires two coats using a fine aggregate.

The worker must use the same trowel design and the same hand motion to finish the entire building in order to achieve a uniform surface finish. If work has to cease over night, finish the application to a control joint or break in the design, so that the subsequent work doesn't appear as a cold joint. All the installers must be highly qualified and familiar with the techniques required for each application process. The finish design shown in Figure 5-14 is Quarzputz®, an aggregate-textured acrylic-based finish from Dryvit Systems.

There are many different finishes and architectural design forms that can be created using the Outsulation system. The foam can be formed and cut into a variety of shapes to be attached to the exterior of homes, churches, office buildings and hotels.

Insulated concrete forms (ICFs) and exterior insulation finish systems (EIFS) are becoming more and more popular with owners because they offer lower energy bills and good sound insulation. Builders like the fact that their workers learn the construction methods quickly, their work is easier, progresses faster, and there are fewer tools needed to erect these systems.

6

REINFORCING

All concrete structures are stronger when they're reinforced. Reinforcing is generally in the form of steel rods (rebar), steel wire mesh, or reinforcing fibers.

Place rebar for a concrete enclosure where the tensile force is the greatest. For a simple beam, that's at the bottom. And for a cantilever beam, it's at the top near the support. For continuous beams, put the rebar at the top over the support, and at the bottom in the middle of the span. When the bars are at the bottom of a beam or slab, they're called *positive steel*. Bars at the top are called *negative steel*. The terms positive and negative come from the way a beam bends under a load. When the bend is upward, it's said to have a positive bending moment. When it's downward, it has a negative bending moment. Bending moments cause one part of a beam to compress, and the other part to stretch with the tensile stress. The strength of a structural member depends on its ability to resist compressive and tensile stress.

Counteracting Stress

The compression area of a structural member is the part of its cross-sectional area subjected to compressive stresses. Reinforcing bars placed in the compression area of a member are called compression bars. They increase the compression strength of the member. To cut down on the depth of a concrete beam, you can put bars in the compression area.

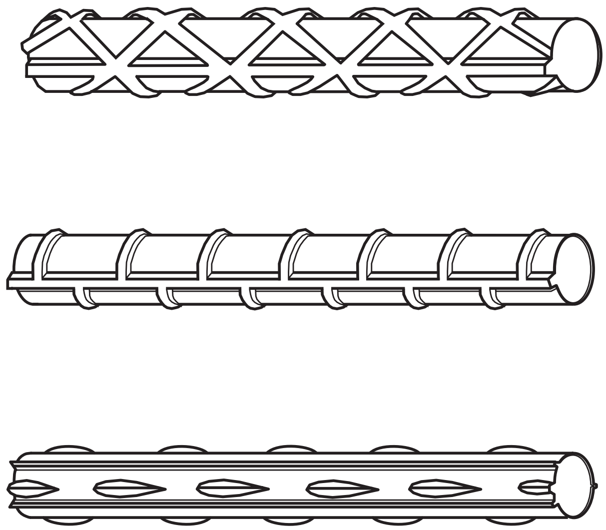


Figure 6-1
Steel reinforcing bars made by different manufacturers

Here are some requirements for placing rebar:

- Make sure all reinforcement is in accordance with the shop drawings. Check bar diameters, bar lengths, lengths of splices, bar-to-bar spacing, and clearances. Check specialty items like intersection bars and additional bars at corners or intersections for conformity to the drawings.
- Make sure the reinforcement is clean. There shouldn't be any rust or scale, dried concrete, oil or grease, or other material on the bars that would prevent a good bond with the fresh concrete.
- Tie and support all reinforcement securely so it won't be displaced during the concrete pour. Face the tie wire ends away from form surfaces.
- All reinforcing spacers, chairs, ties and supports should be ASTM approved. Dowels should be positioned before the pour, not "stuck in" after the pour.

Rebar Grades

Reinforcing bars are manufactured with different deformation patterns depending on the manufacturer. Figure 6-1 shows three types of rebar patterns. The bars are also available in several grades, which vary in yield strength, ultimate tensile strength, percent of elongation, bend test requirements and chemical composition. The ASTM A615 standard specification for deformed and plain billet-steel bars for concrete reinforcing is:

- Grade 40 (40,000 psi minimum yield strength)
- Grade 60 (60,000 psi minimum yield strength)
- Grade 75 (75,000 psi minimum yield strength)

ASTM manufacturing specifications require the bars have permanent, rolled-on grade identifications. There are two systems of grade markings, the Continuous Line system and the Number system. With the Continuous Line system, continuous small longitudinal lines

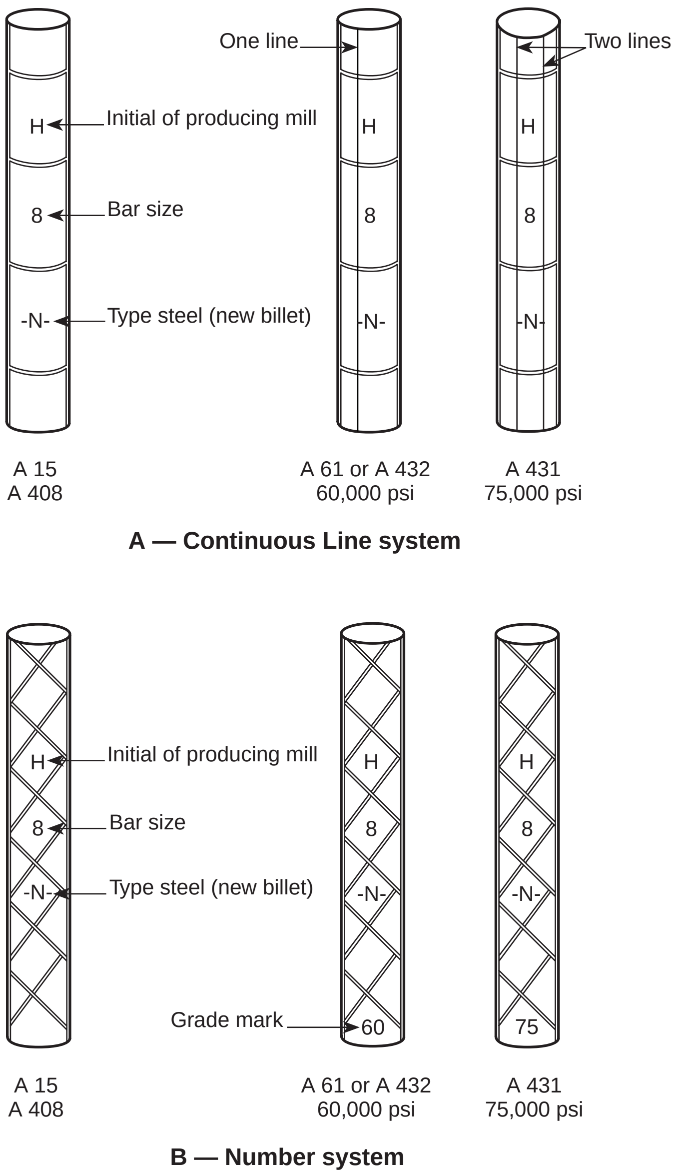


Figure 6-2
Reinforcing bar grade markings

between the main longitudinal ribs indicate the yield strength of the bar. In the example in Figure 6-2A, one line indicates 60,000 psi strength and two lines indicate 75,000 psi strength. Figure 6-2B shows the Number system. Numbers and symbols are rolled on during manufacturing to indicate the type of steel, bar size, grade and mill. The number 60 identifies 60,000 psi and the number 75 identifies 75,000 psi.

Corrosion in Rebar

For years, calcium chloride was used as an inexpensive way to accelerate concrete set and improve its strength. However many structures built using this method now have problems with corroded interior reinforcing iron. When chlorides are mixed in with the concrete ingredients, they're immediately in contact with the steel, and the steel surface begins to deteriorate (rust). Chlorides may also come from the use of deicing salts, and from marine environments. They can enter through the cured surface, where they filter through the concrete to the steel. There's also a chance of chloride contamination from the aggregates or mixing water.

The time it takes for the steel to rust is determined by the quality of the concrete and the admixtures, or the quality and longevity of sealers on the concrete surface. Corrosion is an electrochemical process. The chloride ions attack unprotected steel through defects in the protective layer of concrete and then start the corrosion process. As iron oxidizes, it expands to many times its original volume. The expansion results in cracking, crazing, spalling and staining of the concrete. It's a process that can continue until the structure is eventually ruined. However, there are ways to prevent rebar corrosion. (For information on *corrosion inhibitors* for concrete, see Admixtures in Chapter 1.)

Coated or Uncoated Reinforcing

There are some corrosion-resistant alternatives to black-steel rebar.

***Epoxy-coated rebar* —** Epoxy-coated rebar is much better than uncoated, but it's also more expensive. It can cost one-third more than untreated rebar. Contractors use coated rebar mostly in highly-corrosive conditions, such as bridges or concrete roadways. Coated rebar performs well as long as it's treated carefully during construction. Any scratches or breaks in the coating during handling will compromise its effectiveness.

There are now concrete vibrators that have polyurethane rubber molded to their heads. They're ideal for vibrating around epoxy-coated rebar. Since polyurethane is softer than the epoxy coating, the rubber prevents the rebar coating from being chipped off, preserving the rust preventative characteristics of the epoxy-coated rebar.

***Galvanized rebar* —** Zinc-coated or galvanized rebar has been in use for over 50 years. Zinc-coated rebar can raise the chloride corrosion resistance threshold up to 10 times that of black steel. But the cost of zinc-coated rebar is about twice that of black steel. Be sure workers coat the cut ends of the zinc bars with a zinc-rich primer to keep continuity with the rest of the bars.

***Stainless steel rebar* —** Stainless steel rebar (ASTM Grade 316) has a corrosion resistance threshold about 20 times greater than black steel. But again, stainless steel is also almost 10 times more expensive than black steel.

***Glass-fiber reinforced-polymer rebar* —** Glass-fiber reinforced-polymer rebar is a newer product on the marketplace. The most important thing about these bars is that they're immune to chloride attack and have a tensile strength twice that of black steel, yet weigh only one quarter as much as black steel. They're good for use in salt water or corrosive areas, and in projects sensitive to electromagnetic interference, such as MRI rooms. Their cost is close to epoxy-coated steel. The problem with glass fiber is that bends must be fabricated in the factory. They're available in diameters from ¼ inch to 1¼ inch.

Estimating Reinforcing

Reinforcing bars are indicated on the plans by bar numbers. Figure 6-3 shows the bar numbers with their sizes and weights. You need this information, because reinforcing is estimated by weight: in pounds for small quantities and in tons for larger quantities. Measure the bar lengths

Sizes and Weights of Reinforcing Bars		
Bar number	**Size**	**Weight (lb./ft.)**
2	1/4" round	0.167
3	3/8" round	0.376
4	1/2" round	0.668
5	5/8" round	1.043
6	3/4" round	1.502
7	7/8" round	2.044
8	1" round	2.670
9	1" square	3.400
10	1 1/8" square	4.303
11	1 1/4" square	5.313

Figure 6-3
Rebar sizes and weights

by tabulating the lengths shown on the plans, including allowances for laps and bends. Add up the lengths of all the bars of the same diameter and multiply the total by the appropriate weight per foot. Then extend the total weights of all bars by the unit cost per pound or ton.

Figure 6-4 shows the soft (standard) metric and Imperial standards for ASTM standard reinforcing bars. Although the use of Imperial standards isn't going to change soon, metric may be used more and more in the future. Some projects in New York now ask for the use of both metric and Imperial standards on their plans.

ASTM Standard Reinforcing Bars									
Soft metric size	**Nom. diam. mm**	**Area mm²**	**Weight factors**		**Imperial size**	**Nom. diam. inches**	**Area in.²**	**Weight factors**	
			kg/m	**kg/ft**				**lb/ft**	**lb/m**
10	9.5	71	.561	.171	3	.375	.11	.376	1.234
13	12.7	129	.996	.303	4	.500	.20	.668	2.192
16	15.9	200	1.556	.473	5	.625	.31	1.043	3.422
19	19.1	284	2.240	.681	6	.750	.44	1.502	4.928
22	22.2	387	3.049	.927	7	.875	.60	2.044	6.706
25	25.4	509	3.982	1.211	8	1.000	.79	2.670	8.760
29	28.7	645	5.071	1.542	9	1.128	1.00	3.400	11.155
32	32.3	819	6.418	1.952	10	1.270	1.27	4.303	14.117
36	35.8	1006	7.924	2.410	11	1.410	1.56	5.313	17.431
43	43.0	1452	11.410	3.470	14	1.693	2.25	7.650	25.098
57	57.3	2581	20.284	6.169	18	2.257	4.00	13.600	44.619

Comparison of Steel Grades					
Soft metric			**Imperial**		
Grade	**MPa**	**Psi**	**Grade**	**MPa**	**Psi**
300	300	43,511	40	257.79	40,000
420	420	60,716	60	413.69	60,000
520	520	75,420	75	517.11	75,000

Courtesy: Concrete Reinforcing Products

Figure 6-4
Soft metric and Imperial standards

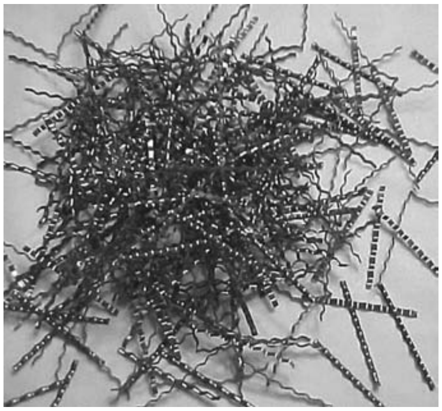


Figure 6-5
Steel fiber reinforcement

Other Concrete Reinforcement

Rebar isn't the only form of reinforcement for concrete. You can also add reinforcing fibers to the mix to strengthen the concrete, or use welded wire fabric to reinforce concrete flatwork.

Steel Fiber Reinforcement

Add steel fibers to almost any concrete mix for structures that requires great flexural strength. You can use them as the sole or primary reinforcement in applications such as slabs on grade, roads, decks and structures exposed to the elements. Steel fibers enhance the static flexural strength, torsion strength, and crack-resistance of concrete. Steel fibers won't prevent cracks, but they will help control them. Figure 6-5 shows steel fiber reinforcement.

Fiberglass Reinforcement

Fiberglass reinforcement reduces shrinkage cracks in concrete and increases its tensile strength during the curing process. There are several different types of fibers used for this kind of reinforcement. These include acrylic, polyethylene, polyester, and rayon. Fiberglass is added to the concrete during the truck mixing process at a rate of one bag per cubic yard of concrete. You can see fiberglass fibers in Figure 6-6.

Figure 6-6
Fiberglass reinforcement

Dimensions and Weight of Welded Wire Fabric		
Spacing	**Wire gauge**	**Pounds per 100 SF**
4" x 12"	No. 6 x No. 6	41.6
4" x 12"	No. 8 x No. 8	29.6
6" x 12"	No. 4 x No. 4	43.8
6" x 12"	No. 6 x No. 6	31.8
6" x 6"	No. 6 x No. 6	42.0
6" x 6"	No. 8 x No. 8	30.0
6" x 6"	No. 9 x No. 9	25.0
6" x 6"	No. 10 x No. 10	20.7
4" x 4"	No. 6 x No. 6	61.9
4" x 4"	No. 8 x No. 8	44.1

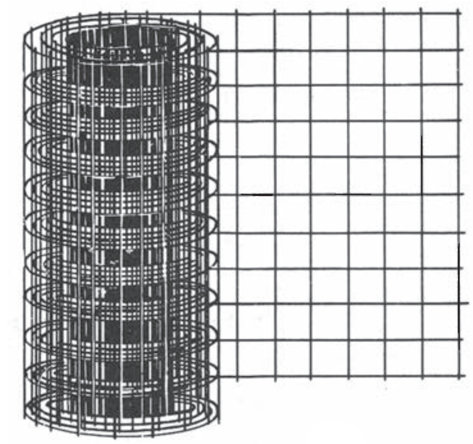


Figure 6-7
Welded wire fabric

Welded Wire Fabric

Welded wire fabric is heavy-gauge wire manufactured in a grid pattern that's used to reinforce and increase the tensile strength of concrete flatwork. The dimensions and weight of welded wire fabric are shown in Figure 6-7. Welded wire fabric comes in both rolls and blankets.

Place the welded wire approximately 2 inches from the top of the slab. Typically, in a 4-inch slab, the wire would be in the center. It's important to make sure the wire is placed correctly. Poor placement can actually reduce the strength of the concrete. For example, placing the wire on the ground and pouring concrete over it would produce a weaker slab.

7

PLANNING FOR THE CONCRETE POUR

When the forms are completed and inspected, it's time to order the concrete. It's important to establish a good working relationship with your concrete ready-mix company. That'll help you get the order you want and at the time you need it. After all, when everything works smoothly, you'll both make money. But remember that you're not their only customer. It's always best to schedule as far ahead as possible for concrete pours, especially for large ones. The concrete company will supply as much as you need if you give them enough notice.

Since concrete ready-mix companies specialize in concrete, they might be able to give you advice on estimating or which admixtures to use on a particular project. For example, if your project site is a long way from the concrete plant, they might suggest adding a retarder to the mix. Sometimes the truck driver may offer advice before he unloads. Remember that all he does is pour concrete — day in and day out. He probably experiences more situations in a month than you will in years. Listen to him if he offers advice. If something comes up that you're unsure about, ask him if he's ever run across a similar problem. He'll be glad to give you suggestions. And it never hurts to offer the driver a small tip for extra services.

Check for Route and Site Delivery Problems

You must carefully plan for concrete delivery. Problems can eat up a lot of time and money. Keep in mind that concrete ready-mix trucks weigh thousands of pounds unloaded and almost double that when loaded. Since concrete weighs about 4,000 pounds per cubic yard, a 10-cubic-yard truck carries almost 20 tons of concrete. Add the 20 to 30 tons the truck weighs and you have an extremely heavy vehicle. Make sure your building site and its access can handle that much weight.

Here are some things to take into consideration before requesting deliveries:

- Small roads to the site may have short bridges that are easily overlooked. Most aren't rated to carry the weight of the truck and its load. Check ahead of time. If this is a problem, map out an alternate route for the delivery.
- The invoice for a concrete delivery will state that they're only responsible for delivery to the curb. Once you ask the driver to continue off the roadway, you're responsible for anything that the truck damages — and for any damages to the truck, too.
- Check the height of overhead wires. Most front-end loaders are almost 13 feet high, and rear discharge trucks are about 12 feet high. If the truck tears down telephone or electric lines, you can be held responsible. Also, someone could get injured or even electrocuted.
- Check to see if there are tree branches in the truck's path. Always get permission to remove them. Don't just cut them down or you may have to replace the entire tree.
- Because concrete delivery trucks are very large, you must consider the size (height and width) and weight restrictions on access roads or driveways into the site. Remember that concrete trucks have a very large turning radius. They're also much longer than most other trucks on the job. And, concrete trucks are top heavy. If the truck rides off a narrow roadway that has a significant drop off, it may tip over. If the truck tips over, it's your concrete, and you'll be responsible for the load. These trucks can also break underground drainage or service lines when driven off the roadway. Carefully positioning the delivery truck is a very important part of the concrete job.

Pre-Pour Inspections

Before placing concrete in forms, take the time to inspect the formwork and any other conditions that will affect the success of the project. It'll be time well spent.

Footings and Foundations

Review the following checklist before pouring footings and foundations:

1. Have you checked the location, dimensions and grade? Place grade stakes in any unformed footings. Don't forget to pull out the grade stakes after the pour.
2. Is the fill well compacted? Never use fill to remedy over-excavation. The proper solution is to thicken the footing or foundation.
3. Be sure the foundation excavation is free of frost, ice or mud. It can be moist, but there must be no standing or running water.
4. Apply a waterproof paper or polyethylene covering on permeable surfaces that could leach excess moisture into the concrete mix and dilute it.
5. Take care to prevent concrete that'll be placed in unformed trench footings from being contaminated by soil. Because dirt and impurities can contaminate the concrete mix and cause voids, unformed trenches are generally not recommended.
6. Make sure the air temperature is within the required range — between 40 degrees and 90 degrees Fahrenheit. If temperatures are lower or higher, make sure the proper precautions are taken.

Forms

Review the following forming items before pouring concrete:

1. Line and grade:
   Check to be sure the height and outline conform to the blueprints.
2. Joints:
   Check to be sure the form faces are tightly joined to prevent grout loss.

3. Reused formwork:
Be sure all holes in the formwork are neatly patched and plugged. The finish on the concrete won't be any better than the face of the forms you place the concrete against.

4. Materials and procedures:
(a) Be sure to use proper methods and procedures in assembling the forming materials.
(b) Make sure the forms will produce the finish specified in the plans.

5. Stud spacing:
(a) The stud spacing should conform to the specs.
(b) Place the studs so there won't be any noticeable bends in the sheathing.

6. Walers:
(a) Space walers so that the joints are offset and don't occur at the same panel.
(b) Don't splice walers in the same panel.
(c) Provide a continuous plate across the top of the form, or place a waler close enough to the top of the form to ensure good alignment.

7. Tie rods and spaces:
(a) The spacing must be sufficient to support the load and maintain alignment.
(b) The ties have to be the specified type. They must be able to be removed or broken off without leaving any metal closer than the specified distance from the concrete surface.
(c) Remove all temporary spacers from inside the forms as the concrete is placed. You may need to install tie wire retrievers on spacers that'll be out of reach.

8. Braces:
(a) Be sure to have enough braces to support the vertical alignment of the forms.
(b) Braces should be at a 45-degree angle or less to the interior of the vertical side of the form.
(c) If a series of braces originate from the same anchor point, tie them together vertically halfway between the anchor point and the form.

9. Shores:
(a) Check that the shoring is tied off in four directions at enough points to prevent the forms from bending or moving after they are leveled.
(b) Nail the shore wedges into position.

10. Nailing:
Place enough nails in the forms to hold the sheathing tight against the studs.

11. Final checks:
(a) Have the forms been oiled, wetted or sealed as required? Remove surplus oil from the forms. Make sure there isn't any oil remaining on steel reinforcement, construction joints or other surfaces that must bond with the concrete. All the forms must be clean before placing the concrete.
(b) Check the forms for any possible movement that could occur during the concrete placement. If possible, place a string or chalk line to use as a reference during the pour.
(c) Are the required chamfer strips and grade strips accurately aligned and securely fastened?
(d) Have the necessary clean-outs been provided for at the bottom of the forms? Are the insides of the forms clear of debris?

Blockout (Recess) Concrete

A blockout is a box form or a designed barrier within the concrete form that will prevent concrete from entering that blocked out section. Sometimes you need to use blockouts in concrete members to embed seats, guides and rails, pinning, and electrical and mechanical systems into concrete placements. Before placing concrete in a blockout, carefully inspect the blockout or recess to make sure all the surfaces are thoroughly cleaned. You don't want there to be any loose material, oil, grease, or anything else that might prevent a good bond between the new concrete and the surface of the blockout or recess. Be sure that when the concrete is poured into the blockout or recess it is properly consolidated, especially in the recesses that include reinforcing steel.

"Before placing concrete in a blockout, carefully inspect the blockout or recess to make sure all the surfaces are thoroughly cleaned."

Normally, concrete for blockouts or recesses is formulated for the same strength as the original concrete. Use expansive formula cement where the cement will be contained on all sides. If the blockout or recess is on the horizontal surface and the top of the blockout or recess is to be finished with a steel trowel, don't use expansive cements. In this case, use epoxy-bonding compounds. Keep in mind that timing is critical when using epoxy-bonding compounds because epoxy hardens extremely fast.

Embedded Items

Make a list of all embedded items, and review it before the pour. It's very expensive to place them once the concrete is cured.

Check the mechanical and electrical drawings and locate anchors, sleeves, conduits, boxes, reglets, etc. These are often left off the architectural prints. Unless otherwise provided in the shop drawings, firmly fix all embedded items in their correct locations before placing the concrete. Be sure embedded items are protected against damage during concrete placement. Grease bolt threads, cover machined or polished surfaces, and plug open pipes or conduits, etc.

Reglets

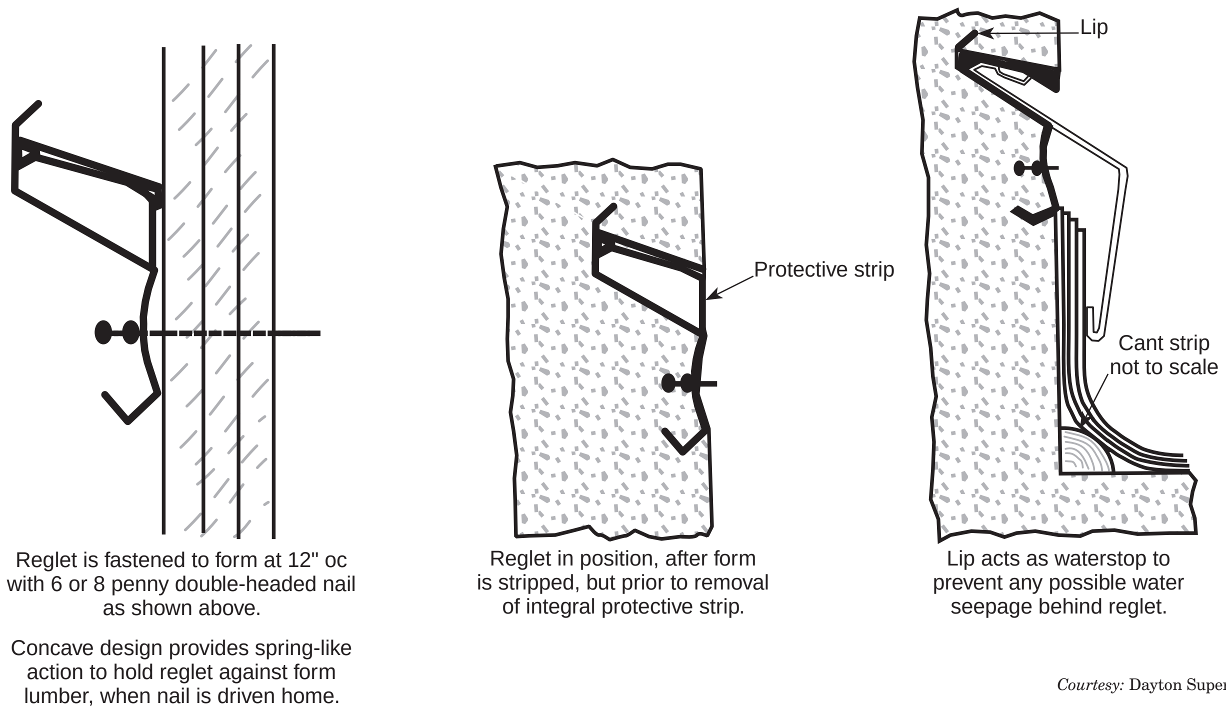
A reglet is a device that's nailed to the inside of the concrete form to provide an attachment point in the concrete for counterflashing after the concrete is poured. There are different types of reglets for different applications. Figure 7-1 shows the installation of a Type B-4 Cushion-Lock® reglet from Dayton Superior (www.daytonsuperior.com.)

Problems Due to Flawed Mixes

Most mix problems can be avoided by careful planning and good time management. Be aware of situations that can damage the concrete mix, resulting in flawed concrete. These problems can be the result of the mixing, or delivery and placement.

False Set

When concrete begins to set just after it's mixed, it's sometimes called *false set* or *flash set*. False set occurs when the concrete starts to lose its plasticity or ease of finishing soon after mixing with water. Remixing the concrete (without adding water) after a few minutes of resting the mixer or a longer mixing time will restore the plasticity of the mixture. It will then set and gain strength normally. False sets don't usually occur when you use ready-mix trucks to transport concrete because of the length of the mixing cycle.



Courtesy: Dayton Superior

Figure 7-1
Installing a Type B-4 Cushion-Lock® reglet

When premature stiffening can't be overcome by additional mixing, it's probably *flash set*. This is usually the result of excessive heat. Once flash set occurs, it can't be offset by adding additional water or longer mixing. The contractor will have to determine if the mix is usable or not. A flash set is sometimes caused by the addition of Type A water reducers.

Concrete Delivery

Ordering concrete for delivery during a heat wave needs extra care. Work with the supplier to calculate the mix appropriate for the conditions. Suppliers guarantee their mixes when they're placed into the ready-mix truck at the batch plant. However, their responsibility ends with the delivery of the concrete to the jobsite. The contractor must be ready for the delivery when the truck arrives. If the ready-mix truck has to sit for a long time before discharging the concrete, problems can occur. Excessive heat in the mix is likely if the concrete is mixed too long. Heat builds up in the drum as the mixer turns and the concrete begins to harden. If this happens, contractors sometimes tell the driver to add water to loosen the mix. But adding water will result in slightly weaker concrete. The best plan is to plan ahead so the truck can unload almost as soon as it arrives.

Checklist for Concrete Pouring

Run through this checklist before pouring concrete to make sure you haven't forgotten anything. It's a good bet that anything you forget will make a dent in your bottom line.

1. Have you made satisfactory arrangements to get concrete into all placement areas without segregation, loss of ingredients, formation of air pockets, or cold joints? Check to make sure the vertical drop isn't in excess of the standard limits. Check to be sure the placement is within the time allowed after mixing. Time varies with ambient temperature.
2. Is all equipment clean and in good operating condition?
3. Is the conveying equipment (crane, buggies, conveyors, pumpcrete pipes, ready-mix trucks) capable of reaching all areas of the concrete placement?
4. Are pumps and hoses adequate? Do they have the required capacity and material?
5. Are temporary openings or special equipment ready?
6. Are all necessary tools on hand and in working condition? Do you have standby tools available? A flat tire on a wheelbarrow or a burnt-out motor on a vibrator can be catastrophic.
7. Are there enough workers available to complete the pour?
8. Are safe access and footing — ladders, platforms, walkways and stagings — ready and set up according to OSHA standards?
9. Are there the required screeds and strike-off? Is a 10-foot straightedge available to check finish slab tolerances?
10. Have arrangements been made to have all equipment for concrete curing and cold weather protection (if needed) on site and in good working order?
11. Review the plans for tests to be made at the plant and at the construction site. Have you made arrangements to make test cylinders and for the proper handling and curing of the test specimens? Is there a flat level surface available for performing slump tests?

If you've checked all the items listed above, you're prepared for the pour. We'll discuss concrete testing in the next chapter.

8

TESTING CONCRETE

Testing concrete materials helps determine their effectiveness in a concrete mix. Fresh and hardened concrete is tested to evaluate the performance of the materials and to control the principal properties of the concrete, such as water-cement ratios, air content, strength and unit weight.

Slump Testing

Slump testing is used both in the field and in the laboratory to determine the consistency of concrete. It isn't an exact method, but it provides sufficiently accurate results. This test isn't recommended for concrete that contains significant amounts of 2-inch or larger aggregate.

Take test samples at the mixer or, in the case of ready-mix concrete, from the discharge chute. Periodically, stop the discharge and collect the samples from the chute for the test cylinders, then begin the discharge again. Extract samples throughout the pour, from the beginning until the end. Record the batch and location of the concrete at the site for future reference. The samples are generally collected in a wheelbarrow. To counteract the segregation of the concrete, mix it with a shovel until it's uniform in appearance, then transfer the concrete into the testing cylinders. Take the samples to the testing site.

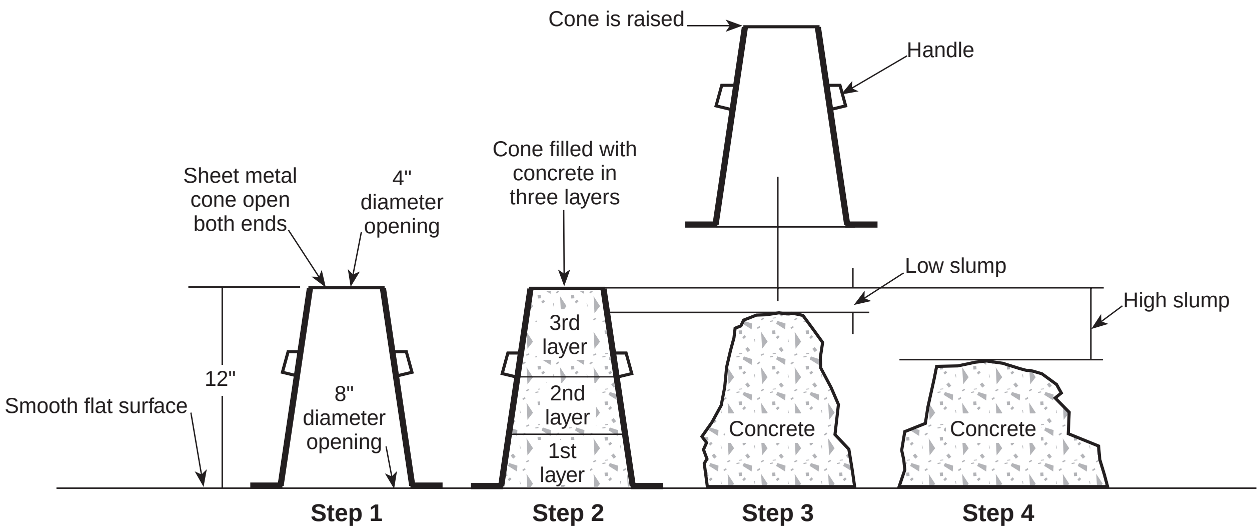


Figure 8-1
Slump test process

The slump tester is a cone-shaped mold made of 16-gauge galvanized metal. The cone should be 12 inches high, with an 8-inch diameter base and 4-inch diameter top. The base and top are open and parallel to each other. Dampen the mold and place it on a flat, moist, nonabsorbent surface. Fill it in three equal layers, rodding each layer before adding the next. Move the scoop around the edge of the mold so the concrete slides off in an even distribution around the mold. Rod the layers 25 strokes each. Use a rod that's approximately 24 inches long and ⅝ of an inch around. The bottom 12 inches of the rod should taper down to ¼ inch and be rounded at the tip. Rod across the mold using even strokes. You need to penetrate each underlying layer so that the bottom layer is thoroughly rodded each time as well.

Figure 8-2
Measure the difference between the height of the mold and the height of the specimen

When all the layers are rodded, trowel off and level the top surface. Immediately lift the mold from the concrete, raising it carefully so that the concrete remains upright. Figure 8-1 illustrates this process. Measure the concrete against the height of the mold as shown in Figure 8-2. Record the height. The consistency of the concrete is determined by its height in inches. The difference between the top of the cone mold and the top of the concrete is the slump.

After the slump is recorded, gently tap the side of the specimen with the tamping rod. How the concrete reacts is a valuable indication of the

Figure 8-3
Test molds

cohesiveness and workability of the mix. A well-proportioned mix will gradually slump to lower elevations and retain its original identity, while a poor mix will crumble, segregate, and fall apart.

Compression Testing

A compression test determines the concrete's maximum resistance to axial loading. In other words, the load the concrete will bear, expressed in pounds per square inch (psi). The laboratory performs the test on cylinders of cement taken from the jobsite. Usually, the specs call for three test cylinders. One will be tested early and the other two at 28 days. The early test tells if the concrete is ready for the forms to be stripped or the structure to be built upon. The tests performed at 28 days determine if the concrete meets the specifications in the contract plans. (Consult ASTM C31 and ASTM C172 for detailed requirements and information on making and sampling concrete for compression tests.)

The standard mold for a compression test is a straight cylinder 6 inches in diameter and 12 inches high (see Figure 8-3). It can be made of sheet metal, plastic or nonabsorbent coated cardboard. You should take the samples at three or more points during the concrete's discharge from the mixer. Don't take a sample at the beginning or end of the discharge. Take mid-stream samples at intervals of no more than 15 minutes, and record the location where the concrete from the sample is poured, the time, date, temperature and any unusual conditions present at the time.

Use a scoop to deposit the concrete into the mold, moving the scoop around the top edge of the mold. Distribute the concrete evenly in the mold using a tamping rod. Fill the mold in three equal layers, rodding each layer 25 times. Rod the first layer throughout its entire thickness. The second and third layers should be rodded down into the underlying layer, but not *through* that layer. The third and final layer should overfill the mold slightly. After rodding each layer, lightly tap the sides of the mold to fill the voids left by the rod. After consolidation, trowel the surface so that it's level with the top edge of the mold.

Move the cylinders to a storage place in an area not subject to vibration. Place the molds on a smooth, level surface. Cover the tops so that no moisture will be lost. Store the cylinders at a temperature of 60 to 80 degrees F and make sure they aren't moved for 24 hours after casting.

The first 24 hours are the most important. Failure to protect the specimens from extreme temperatures during this initial period can cause them to lose 20 to 50 percent of their 28-day strength. If the cylinders "dry out" that can also result in strength reductions.

After 24 hours, take the cylinders to the laboratory and store them in a moist room at 73.4 degrees F, plus or minus 3 degrees, until the time of the test break. Carefully protect the specimens from jarring or sharp blows when transporting them to the laboratory.

Because faulty concrete would have to be replaced at great expense to everyone involved, including the concrete supplier who is responsible to insure the correct mix, there are very few errors in the mix proportions. Government inspectors check both at the batch plant and the jobsite to ensure that the mixes being used will result in the required compressive strength.

9

PUMPING CONCRETE

When planning your concrete pour, always keep in mind that there will be situations where the ready-mix trucks can't deliver the concrete directly into the forms. If there are space or weight limitations, they'll need to transfer the concrete into smaller concrete pumping units that can maneuver closer to the area where the concrete needs to be placed. This is also the case if the forms are higher than the top of the truck's chute. Since concrete falls down the truck's chute by the force of gravity, if the forms are higher than the chute, the concrete will have to be pumped up to the forms.

Pumped Concrete

Pumped concrete can be used for any pour. However, due to the extra cost, contractors generally pump concrete only when necessary. There are two types of concrete pumps. One is trailer-mounted (shown in Figure 9-1) and the other is truck-mounted with a boom (Figure 9-2). The boom truck can deliver to places the ready-mix truck can't go, and the trailer-mounted pump can get into places the boom truck can't go. The trailer-mounted pump can be used with many different lengths of metal pipe and joints that can reach into even the smallest areas.

Figure 9-1
Trailer-mounted concrete pump

Figure 9-2
Truck-mounted concrete pump with boom extended

Pumping Units

Concrete pumps range from small units exerting pressure from 250 to 300 psi to large pumps capable of 1,000 psi. The effective capacity of the pump depends on its complete system — the type of line used, the length and number of bends in the line, the pumping height, and the concrete mix.

Pump Lines

Pump lines are usually a combination of rigid pipe and heavy-duty flexible hose. Rigid pipe that's acceptable for concrete pumping is made of plastic or steel and comes in sizes from 3 to 8 inches in diameter. Flexible hose can be made of rubber, spiral-wound flexible metal, or plastic. The hose is useful for curves, difficult placement areas and as a connective material for pump cranes that must be flexible while in motion. However, your delivery pipeline should be primarily rigid pipe, with flexible pipe used only where necessary. By its nature, flexible hose tends to kink, so you want to use it sparingly. The concrete should flow through smooth pipe with as little resistance as possible, so try to lay your pipeline out with a minimum of bends.

Recommended Mix

Concrete mixes for pumping are basically the same as those you use in other placement methods, except you should put more emphasis on grading the fine aggregates. Pumped concrete has to be smooth and well unified because coarse mixtures don't pump well. If the mixture isn't properly proportioned, pressure exerted by the pump can separate mortar from the coarser aggregates and cause a blockage in the line. Also, the cement content may be somewhat higher for pumped mixtures than those placed by other methods.

Fine aggregates have a higher water demand, which in turn requires a higher amount of cement. Don't compensate for pumping problems resulting from poorly-graded aggregates by adding extra cement. Instead, use admixtures to improve workability. Water-reducing, high-range water-reducing, and air-entraining admixtures usually improve pumping and workability, as do pozzolans.

Planning the Pour

Properly planning your pumping operation — pump location, line layout, placing sequence and concrete supply — will save you both time and money. Locate the pump as close to the placement area as possible. But make sure that the location makes concrete delivery to the pump easy, and that it allows you to pump the concrete through rigid lines using as few bends as possible.

Shotcrete and Gunite

Shotcrete and *Gunite* are terms used to describe pneumatically-applied mortar or concrete. *Gunite* is actually a trade name for "dry-gunned" concrete, but the term has come to be used to describe *any* spray-applied concrete. When applying Gunite or dry-gunned concrete, the cement and sand are injected into an air stream that sends it to the spray nozzle. The operator adds the water at the nozzle so he has complete control over the water-cement ratio. This allows the concrete to be placed dryer than in most "wet gunning" applications. Dry-gunned concrete is also referred to as "dry-mix."

Shotcrete is most often associated with the "wet-gun" or "wet-mix" application. The wet concrete mix is pumped to the nozzle where air is pneumatically applied to carry the concrete mix to its target location.

Sprayed concrete, *spraycrete*, *air-blown mortar and concrete*, and *gunned concrete* are other terms used to describe pneumatically-applied concrete. But I prefer to use the term *shotcrete* to describe *all* pneumatically-applied concrete.

Wet Mix vs. Dry Mix

Although shotcrete can be applied by using either the dry- or wet-gun process, differences in the equipment cost, maintenance requirements, operational features, placement characteristics, and product quality may make one technique more attractive for a particular application than the other. Figure 9-3 shows a comparison of the features of each type of application. Let's look at some of the advantages of each.

- *Bond strength* — The bond strength of shotcrete to existing materials is generally higher with dry-mix applications. However, both wet and dry mixes provide much higher bonds to existing materials than conventional concrete applications.

Shotcrete Processes	
Dry-mix process	**Wet-mix process**
Mixing water instantaneously controlled at the nozzle by the operator to meet variable field conditions.	Mixing water controlled at plant and measured at time of batching.
Longer hose lengths possible, if necessary.	Normal pumping distances necessary.
Limited to accelerators as the only practical admixture.	Compatible with all ordinary admixtures. Special dispensers for addition of accelerators are necessary.
Use of air-entraining admixture not beneficial. Resistance to freezing and thawing is poor.	Air entrainment possible. Acceptable resistance to freezing and thawing.
Intermittent use easily accommodated within prescribed time limits.	Best suited for continuous application of shotcrete.
Exceptional strength performance possible.	Lower strengths, similar to conventional concrete.
Lower production rates.	Higher production rates.
Higher rebound.	Lower rebound.
Equipment maintenance costs tend to be lower.	Equipment maintenance costs tend to be higher.
Higher bond strengths.	Lower bond strengths, yet often higher than conventional concrete.

Figure 9-3
Comparison of features of dry-mix and wet-mix shotcrete processes

- *Frost resistance* — You can only use air-entraining admixtures in wet-mix shotcrete. A properly-mixed air-entrained batch will help provide frost resistance. But when properly proportioned and applied, dry-mix shotcrete can have a compressive strength exceeding 7,000 psi. That strength has allowed it to perform well in *moderate* exposures to freezing and thawing.
- *Application rates* — Typically, you would apply dry-mix more slowly than the wet-mix process. Dry-mix shotcrete is applied at a rate of 1 or 2 cubic yards per hour. Wet-mix shotcrete is applied at a rate of up to 7 or 8 cubic yards per hour. Production rates for both applications can vary depending on obstacles, rebound (see next item), or other unforeseen delays.
- *Rebound* — Rebound is the shotcrete material that “bounces” off the surface being shot; it’s part of the material waste. In ideal circumstances, rebound for conventional dry-mix shotcrete is a minimum of 20 percent of the total material that passes through the nozzle. Wet-mix shotcrete rebounds a little less than that.

Reinforcing Shotcrete

Unreinforced shotcrete is a brittle material that can crack and crumble under stress or strain. Fibers added to the mixture allow the material's form to change without breaking, and increase its energy absorption and impact resistance. The reinforcement adds to the material's ultimate strength. Three forms of fiber are used to reinforce shotcrete: steel, glass, and synthetic materials.

- Steel fibers were first used in the late 1950s. The steel fibers manufactured today are much better and easier to handle than earlier fibers.
- Glass-fiber-reinforced shotcrete (GFRS) contains chopped glass fibers with a resin binder. Applying glass-fiber shotcrete isn't a conventional operation. You need a special gun and delivery system. This "spray-up" process is used to make lightweight panels for structure cladding and for special architectural features, like simulated rock structures for animal exhibits in zoos. It's usually applied in a plant. Guidelines for the use of glass-fiber spray-up are provided by the Prestressed Concrete Institute (PCI) (1981).
- Synthetic fibers are made of nylon, polypropylene, polyethylene, polyester and rayon. Polypropylene fiber is used most often. Adding synthetic fibers to shotcrete decreases shrinkage cracks in the material.

Fiber-reinforced shotcrete is used for tunnel linings, surface coatings on rock or soil, slopes, embankments, or any other surface that may be easily cracked or deformed.

Silica-Fume Shotcrete

Silica fume is a very fine material that's a byproduct of the production of silicon alloys. It's added to concrete and shotcrete to increase its strength and cohesion, enhance bonding, and decrease permeability. The added bonding strength provided by silica fume allows thicker layers of shotcrete to be applied to vertical and overhead surfaces in a single pass. When fresh shotcrete may be subjected to flowing water, silica fume makes the material more resistant to "washout" or disintegration. It significantly reduces rebound, and may also improve shotcrete's resistance to aggressive chemicals.

Silica-fume shotcrete is widely used in tunnel construction, often combined with fibers to control shrinkage cracking. It's also used to cap landfills and other waste areas that need to be sealed from surface water.

Using Shotcrete

In most cases, you would use shotcrete instead of conventional concrete to lower your costs or to make the job easier. For instance, you might use shotcrete when formwork is too expensive or impractical to use. It's also a good choice for work areas that are difficult to access, when you need to apply concrete in thin layers or in varying thicknesses, or when you can't use normal casting techniques. Because placing shotcrete only requires a small portable unit, you can often use it where there's limited space to make repairs to a structure.

Shotcrete's excellent bonding characteristic makes it an important asset in design considerations. Because it's applied pneumatically, it fills cracks and adheres to irregular surfaces — resulting in a uniform finish. Within limits, it can support itself in vertical and overhead applications. Using shotcrete should always be based on your experience, as well as a careful study of its performance in similar applications. Proper planning, skill, and supervision are necessary requirements for any successful shotcrete application.

Shotcrete Repair Applications

Shotcrete can repair damaged surfaces of concrete, wood, or steel structures as long as there's access to the surface needing repair. The following are examples of common repairs using shotcrete.

Bridges — You can use shotcrete for bridge deck rehabilitation, but it isn't generally economical for major full-thickness repairs. However, it's very useful and cost-effective for beam repairs of varying depths, caps, columns, abutments, wingwalls and underdecks.

Buildings — Shotcrete is commonly used to repair building damage caused by fire and earthquakes. It can repair earthquake damage to structural members like beams or columns. It can strengthen walls and encase structural steel for fireproofing. It's also used in general damage and deterioration repair.

Marine structures — Marine structures can be damaged from the deterioration of both concrete and the reinforcement. Damage can be the result of:

- freeze/thaw action
- impact loading
- structural distress
- physical abrasion from the action of waves, sand, gravel and floating ice

- chemical attack due to sulfates
- corrosion of the steel

These problems occur in most marine structures, including bridge decks and their supports, piles, beams, piers, navigation locks, guide walls, dams, powerhouses, and discharge tunnels. In many cases, you can use shotcrete to repair the damaged surfaces of these structures.

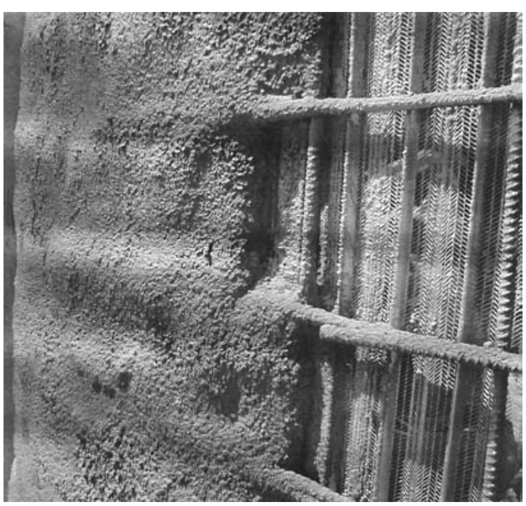
Spillway surfaces — Surfaces subjected to high velocity flows may be damaged by different kinds of erosion. Using shotcrete is advantageous because of the relatively short outage needed to complete repairs.

Underground excavations — Shotcrete is used in underground excavations through rock. It has been used successfully to advance tunnels through loose soils. Shotcrete can be used to seal rock surfaces, provide temporary support and permanent linings, or channel water flow. It can also supplement or replace conventional support materials, such as lagging and steel sets.

Slope and surface preparation — Shotcrete is often used for temporary protection of exposed rock surfaces that would deteriorate if exposed to air. It can also permanently cover slopes or cuts that may be prone to deterioration or erosion. Slope protection should always include proper drainage to prevent damage from excess uplift pressure. As mentioned earlier, shotcrete can be applied to the surface of landfills and other waste areas to prevent surface water penetration.

New Structure Applications

Shotcrete isn't the fastest way to place concrete, but where thin sections and large areas are involved, it can be efficient and effective. Figure 9-4 shows shotcrete being applied to a wall reinforced using Shot-form™, a product designed by Alabama Metal Industries Corp. (amico-stayform.com) for use with shotcrete. Here are some examples of shotcrete applications in new construction:



Courtesy: AMICO®

Figure 9-4
Shotcrete applied over Shot-form™

Pools and tanks — Shotcrete is used extensively in the construction of swimming pools, and more recently, in the construction of large aquariums.

Floors and walls — Shotcrete floors in tanks and pools installed on well-compacted subgrades or undisturbed earth have generally given good service. Vertical and overhead construction for walls, slabs, columns and other structural members can also be completed with shotcrete.

Domes **—** Techniques using inflatable air forming systems have made the construction of shotcrete shells or domes practical. These large structures have been used for residential housing, warehousing, bridge, and culvert applications.

Properly-applied shotcrete is a structurally sound and durable construction material with excellent bonding characteristics. It bonds well to existing concrete, rock, steel, and many other materials. It has high strength, low absorption, and good resistance to weathering and some forms of chemical attack. Many of the physical properties of sound shotcrete are equal to, or better than, those of conventional concrete or mortar having the same composition. But beware: improperly-applied shotcrete can create worse conditions than if the surface were left untreated. Be sure you plan and supervise the application carefully, and *always* use experienced shotcrete workers.

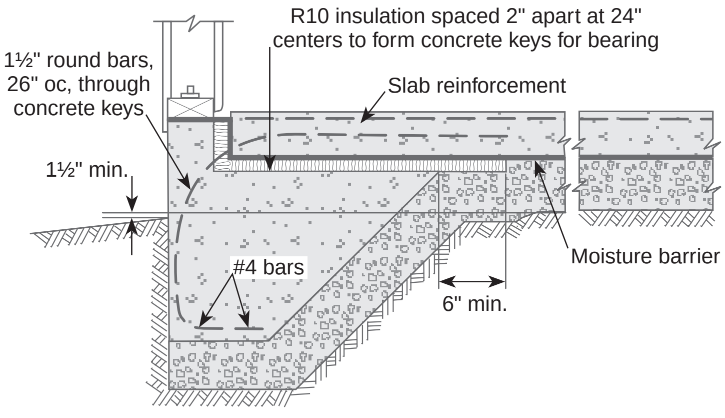
10
CONCRETE SLABS

Concrete slabs are poured in all sizes, from equipment pads to building foundations. Though the term *slab* is used for both a concrete foundation and a concrete floor, a slab foundation isn't the same thing as a slab floor. There are several important differences:

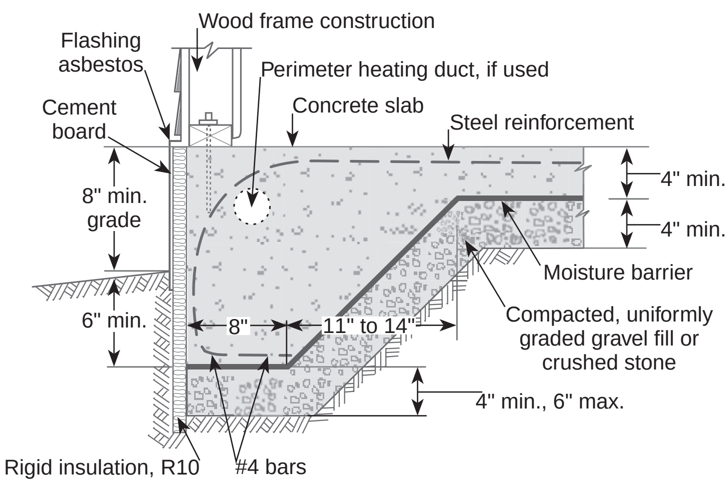
- A slab *foundation* is cast as a single reinforced unit.
- A slab *foundation* is both foundation and floor.
- A slab *floor* is cast separately from the foundation.
- A slab *floor* is insulated from the foundation by one or more layers of rigid insulation.

Slab Foundations

A well-designed and well-built foundation will easily carry the load of the structure that'll be placed on it. The structure is anchored to the slab foundation with bolts embedded in the concrete when the foundation is poured. The weight of the slab itself should be enough to anchor the building to the ground. This is just one of the factors that the architect or engineer will take into consideration during the design process. He'll also have to consider the structure loads, the type of soil beneath the slab and its drainage characteristics, and the climate. Leave the foundation design to an expert. Get help from a structural engineer who knows local soils and has the expertise to analyze all of the variables involved in building design. This is true even for lightweight buildings, like a garage, that will have a slab base.



A Floating slab



B Monolithic slab

Figure 10-1
Foundation slabs

Types of Slabs

There are two types of slab foundations commonly used in construction — floating slabs and monolithic slabs (see Figure 10-1).

Floating slabs, shown in Figure 10-1A, are used mainly for single-story buildings. A floating slab is one that includes both the slab and the perimeter foundation, separated by insulation. They don't have the traditional footings down to the frost level. The slab is placed in two pours; the thickened edge is poured first, followed by the floor slab, which is placed on top of a moisture barrier. The floor-to-eave height of a building on this type of slab shouldn't be more than 12 feet. The floor-to-gable peak height of a structure on a floating slab should be less than 20 feet.

Monolithic slabs, shown in Figure 10-1B, are formed in a continuous pour with no construction joints, usually in large pans with thickened edges. They're only suitable for warm climates. And, even in mild climates, most building codes will only allow you to use a monolithic slab for a small structure, like a garage or an equipment pad.

Preparing the Site for a Slab Foundation

Concrete slabs should be poured on solid earth or on compacted crushed stone. Before you pour a slab foundation, make sure the soil beneath the slab is well-compacted to prevent the slab from cracking later. If any fill has to be added to meet the correct grade, make sure it's compacted as solidly as the undisturbed soil beneath it.

Be sure the soil beneath the slab has proper drainage. In most cases, it's a good idea to compact about 4 inches of gravel on top of the soil and slope adjoining grades away from the slab. These precautions will minimize the chance of frost/heave damage.

Check the plans to see if there'll be floor drains or utility lines running under the slab. In the case of floor drains, the slab must slope toward the drain. In colder climates, where radiant heat may be installed in the floors, you'll need to prepare for it.

Reinforcing Slab Foundations

How much reinforcing you use, the way you distribute it in the foundation, and how you lap it, all depend on the specifications and the type of reinforcing material. Always consult your local building codes before pouring concrete.

Here are some things to remember when you use welded steel wire fabric for reinforcing:

- Use structural grade or better materials.
- Distribute the reinforcement evenly in both directions.
- Lap all pieces at least 6 inches.
- Use at least 20 pounds of reinforcement per 100 square feet of concrete.

If you're working with plain or deformed reinforcing bar or rod:

- Use structural grade or better materials.
- Use bars or rods that are at least ½ inch in diameter, size No. 4.
- Place rebar at least 18 inches on center.
- Distribute reinforcement evenly from the slab's center to the thicker outside edges. Refer to Figure 10-1.
- In general, plan to use at least 30 pounds of reinforcement per 100 square feet of concrete.

Moisture Barriers and Insulation

There are two materials commonly used as a moisture barrier: a membrane-type barrier product (there are many to choose from) or asphalt roofing felt (at least 35-pound felt). Both will effectively separate the concrete foundation slab from the surrounding soil. Whichever you use, be sure to lap the edges at least 6 inches.

Place a layer of insulation between the vapor barrier and the slab. The most common material used is extruded polystyrene.

Concrete for Foundation Slabs

Use a minimum 3,000 psi concrete for slab foundations. It should have air entrainment for easy finishing. Most suppliers can also add fiberglass or steel fibers to the mix for added protection against cracking.

Forming Up a Slab Foundation

Your engineer will consider the structure's use and weight in the slab design. He'll select materials and accessories for the slab formwork based on design tables that take into account the live and dead loads that it must support. The weight of the formwork plus the concrete is considered the dead load. The live load is the weight of the workers, equipment, material storage and other items that must be supported by the formwork.

For more information on the general objectives of formwork design, contact the American Concrete Institute. There are several helpful publications available from their online bookstore, www.concrete.org, or you can contact their bookstore directly at the address below:

American Concrete Institute
P.O. Box 9094
Farmington Hills, MI 48333-9094
Phone: (248) 848-3800
FAX: (248) 848-3801

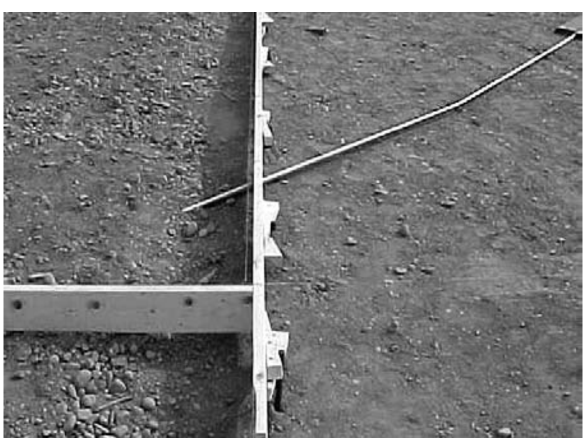


Figure 10-2
Laying out a straight form

Constructing the Forms

Figure 10-2 shows the form for a long slab. To ensure that the forms were as straight as possible, the contractor ran a string line 1 inch out from the inside edge of the form. He drove stakes into the ground 1 inch outside the string line. He then lined the wood forms up 1 inch in from the string line, and nailed wedges between the form and the stake to help remove any bowing in the wooden forms. Notice the conduit running under the form. It's a good idea to always lay out conduit and plumbing lines before setting forms. That way the forms won't be disturbed after they're laid out.

Figure 10-3
Circular slab form

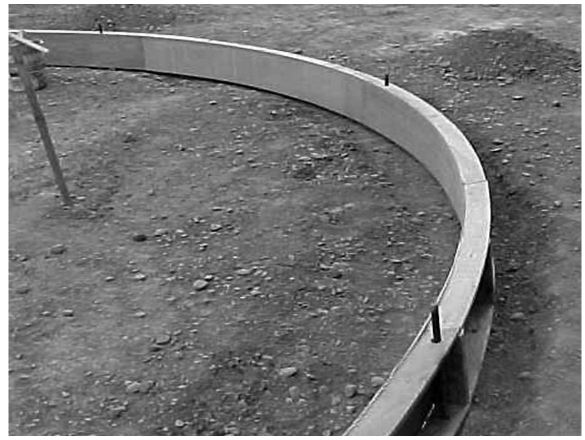


Figure 10-4
Circular form, close-up view

Circular Forms

Make circular forms using metal factory-built flexible forms, or build them out of thin plywood and 2 x 4 or 2 x 6 structural lumber. Figures 10-3 and 10-4 show a circular plywood form. The easiest way to build the form from lumber is to lay out the form on a level surface. The top and bottom of the form are made of ⅝- or ¾-inch plywood for strength. Depending on the size of the circle, lay out the pieces of plywood and draw a line around the circumference. Do this by stretching a tape or string line from the center of the circle to the outside edge. Then swing the tape or string around the circumference of the circle, marking the edge as you go. Add the width of the form material to the radius of the circle and draw another line around the circumference. That gives you the cutting line for the top and bottom pieces of plywood material. Screw or nail the top and bottom together with 2 x 4s cut to the right length to ensure the correct thickness (height) of the form. Then attach thin plywood (also cut to the proper height) to the inside circumference of the top and bottom to make the smooth edge for the circular concrete slab. To connect a straight slab to a circular slab, lay out the forms as shown in Figure 10-5.

Figure 10-5
Circular slab connecting to straight slab

Using Screed Joint Forms

Key-Loc® Joint is a galvanized steel joint system that can be permanently left in concrete slabs.

The interlocking stake and joint hold sections firmly together to form an effective load transfer device for concrete slab joints. The stakes secure the joints and prevent them from floating or rising up during the pour. The system also serves as a contraction joint, an edge form and a screeding rail. Key-Loc Joints come in 10-foot lengths, for slab depths of 4, 5, 6 and 10 to 12 inches. The supporting ratchet-top stakes are available in lengths of 12, 15, 18, 21 and 24 inches.

Many contractors prefer this system to wood forms because wood forms are more difficult and time-consuming to install, they're subject to imperfections, and they must be removed, cleaned and stored. Also, wood forms, and some removable metal slab forms that are wide at the top, can allow the concrete to ride up on top of the form while it's being screeded, causing a hump in the pour. This makes more work for the finisher when the finishing process begins.

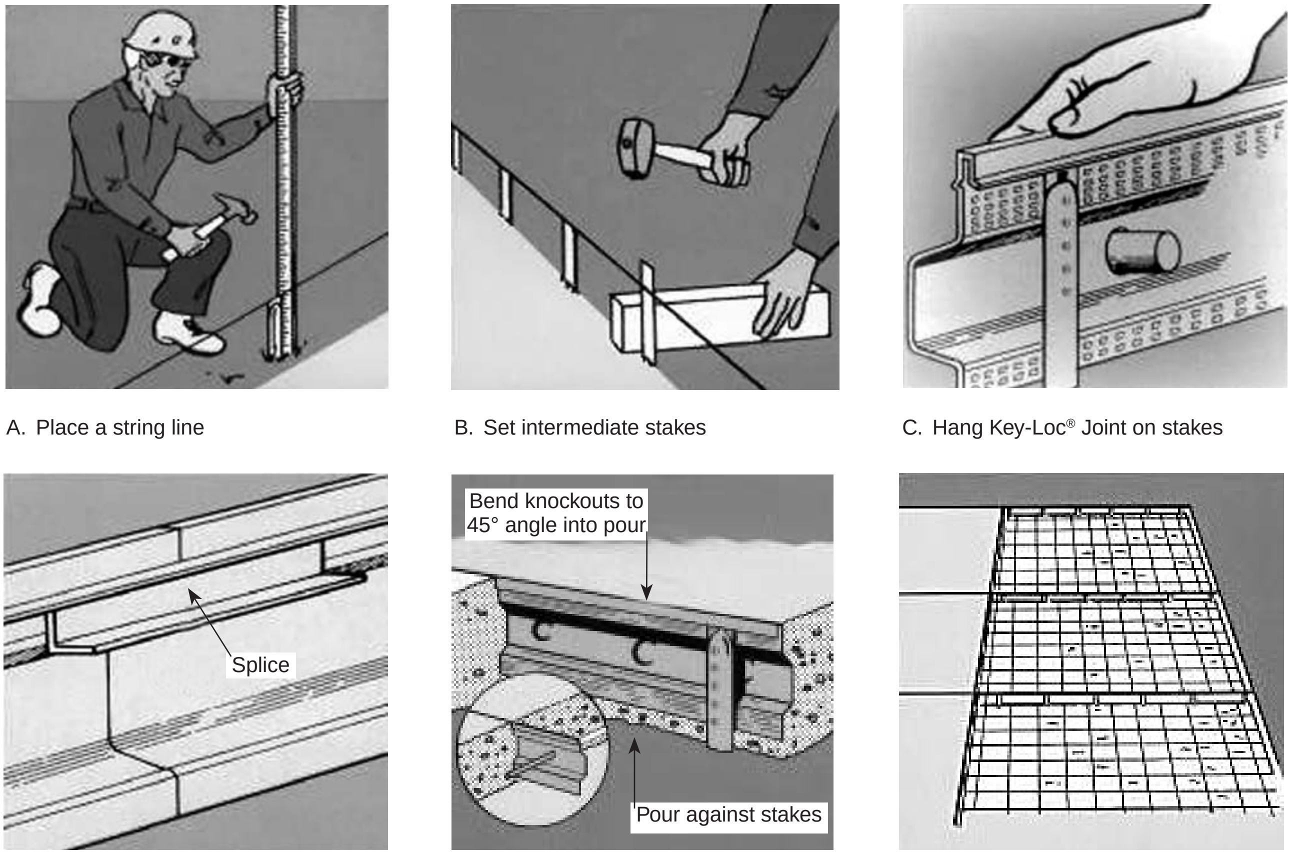
In contrast, the Key-Loc Joint system:

- is fast and easy to install
- provides knockouts every 6 inches for wiring, cable and plumbing runs
- provides a keyway for the next pour
- allows you to pour the entire slab in one day, eliminating checkerboard pouring
- allows you to screed and finish the slab with a straight, uniform contraction joint securely embedded
- is a permanent installation, requiring no removal, cleaning or storage

Setting Up a Screed Key Joint System

Use the following steps, illustrated in Figure 10-6, to set up a Key-Loc Joint System.

1. Stretch a line over the entire length of the slab form. Drive stakes at approximately 20-foot centers for the line (Figure 10-6A). Secure the line at the top of the stakes with tape.
2. Set intermediate stakes for the Key-Loc Joints at the finished floor elevation on approximately 2-inch centers, with five stakes per 10 feet of material. If required by the soil bearing, place additional stakes for support. Make sure that the stakes are perfectly aligned. Use a 2 x 4 to aid in vertical alignment (Figure 10-6B).
3. Hang the Key-Loc Joints on the steel stakes, and push downward. This automatically interlocks the stake and the joint (Figure 10-6C).



A. Place a string line
B. Set intermediate stakes
C. Hang Key-Loc® Joint on stakes
D. Install splices
E. Bend knockouts
F. Pour concrete in strips

Courtesy: Form-A-Key Products

Figure 10-6
Key-Loc® Joint installation

4. Install the snap-in joint splices (Figure 10-6D). The splice provides perfect alignment of the joint ends.
5. There are knockouts at 6-inch centers along the joint for dowels, conduit or rebar penetration. Bend the knockouts to approximately 45 degrees into the pour to act as anchors, especially if Key-Loc is used as a shut-off (Figure 10-6E). Install stake clips when it's necessary to pour on the stake side first.
6. If the concrete slab is wide enough, pour it in sections, as shown in Figure 10-6F. Place supports against the forms while you pour the adjoining section. Screed each new pour to the top of the old pour. Once you pour and finish a strip, there are no additional steps for cutting, joint treatment, form stripping, edge damage or concrete surface damage. Spalling and edge curling are minimized. This saves you time and money.

Pouring Concrete Slabs

Review the following items before pouring slabs on grade:

- Check for capillary water barrier. You don't want water to seep underneath and into the concrete after it's poured.
- Make sure that runs for electrical conduit and piping systems are below the slab.
- Make sure the vapor barrier membrane is the specified thickness and it's sealed with tape at laps and penetrations.
- Make sure the control joints are laid out so that they don't exceed the maximum placement given in the specifications.
- Be sure there are provisions for isolation joints at columns.

Checklist for the Pouring Operation

1. Check the requirements for placing concrete on or against concrete that has already set. The old surface may need to be covered by a layer of fresh mortar or it may need to get a slush coat of neat cement grout followed by a specific topping.
2. Is the time between mixing and final placement of the concrete in forms within the time allowed by the specifications?
3. Is the concrete temperature at placement within the specified limits?
4. Check the method of placement during handling of concrete to prevent segregation of aggregates.
5. Check the height that concrete is allowed to drop freely, and the method used to guide the concrete into place.
6. Is the concrete going to be placed rapidly enough to prevent cold joints?
7. Check specifications to see if chutes can be used in addition to the ready-mix truck equipment.
8. Are form ties and supports checked frequently and adjusted to prevent or correct movement of the forms?
9. Are layers of concrete to be placed horizontally? Will the layers be placed so they don't exceed a specific thickness?
10. Is the rate of placement within safe limits? Forms can be over-stressed by a too-rapid rise of fluid concrete.

11. Check the specifications to see if vibrators are allowed.
12. Is each layer of concrete vibrated until it's completely consolidated?
13. Insert vibrators vertically through the full depth of each layer and at uniformly-spaced points. Overlap the vibrator's visible circles to ensure complete coverage.
14. Don't overdo vibration — this may cause segregation. And, don't use vibrators to transport concrete in the forms.
15. Use hand compaction tools, as practical, to help achieve smooth, dense surfaces. Use hand compaction or vibrating screeds to consolidate thin slabs. Unless high slump concrete is specifically designed and approved, such as for thin reinforcement walls, all concrete should be consolidated by hand compaction tools or vibrator.
16. Don't excessively work the concrete surface in completing a lift. Allow only enough consolidation work to completely embed the coarse aggregate.

Small Concrete Pours

Plan your concrete pours carefully. When the truck arrives, there's no leeway for delay. It generally requires at least two people to screed the concrete along the forms for a small concrete slab. So here's an invaluable rule of thumb for placing concrete: If you think you're going to need two people, *have three people available*. Think about it. If you need two workers to place a concrete project and only one shows up, you have a big problem. The concrete may already be on the way. You can either send it back and be charged for it anyway, or you can take on the nightmarish job of trying to place the concrete short-handed.

The same rule applies to wheelbarrows or other essential equipment: If you need one wheelbarrow to move the concrete, bring two wheelbarrows. Having two wheelbarrows is always a good practice. Since most concrete weighs about 150 pounds per cubic foot, you'd find it very difficult, if not impossible, to push a loaded wheelbarrow with a flat tire. That's why most contractors *over prepare* for a pour.

When pouring small slabs, your crew will have to work together as a team, more so than on any other construction job. Screeding concrete is one of the most difficult tasks in a concrete slab pour. The concrete has to be pulled over forms to get it to the correct level. But it's a lot easier if the finishers on each end of the screed coordinate their actions, as shown

Figure 10-7
Screeding the concrete on a small pour

Figure 10-8
Power-driven concrete buggy receiving concrete

in Figure 10-7. And, the workers ahead of the finishers need to quickly spread the concrete so there isn't too much cement in front of the screed as the finishers pull it along.

It's essential that your workers wear proper safety equipment — like boots, gloves and safety glasses — when placing concrete. Freshly-mixed wet concrete is extremely alkaline. It can burn eyes and even cause chemical burns to skin with prolonged exposure. In addition, people who work with portland cement on a regular basis may acquire contact dermatitis, or an allergic reaction to the material. The simple solution is to wear protective clothing and avoid any direct skin contact with cement or concrete.

Large Concrete Pours

The size of a concrete pour depends on many factors: the weather, the type of pour, and the availability of labor and materials. But the most important factor is to never pour more concrete than you can finish in a given amount of time.

Large concrete pours usually require power equipment, like the power-driven concrete buggy shown in Figure 10-8. These haul much more than wheelbarrows and are a lot easier on your workers' backs. Be careful operating concrete buggies. They can run over forms, electrical stubs and other important items embedded in the forms. Some contractors place sheets of plywood on the ground to make it easier to drive the concrete buggy and to prevent the machine from digging up the subbase. Make sure you always have a trained operator running the buggy.

Figure 10-9
Laborer pulling concrete with a come-along

Figure 10-10
FInisher using a power screed

Figure 10-9 shows a laborer pulling concrete with a *come-along*, a long-handled rake with a wide concave surface and a flat edge. There's a *wet screed* on each side of him. On large pours, when there are no forms to level the concrete to, the finisher will flatten out a strip of concrete and use a leveling rod and transit or laser level to determine if it's at the correct elevation. Using a transit requires a helper, but a laser level allows the finisher to do this on his own. Once it's determined that the wet screed is at the correct elevation, it can be used to level off the other concrete.

Using come-alongs, workers pull the concrete as close to the screed level as possible. They work just ahead of the finisher, who screeds and levels the surface, using either a hand-held screed or a power screed. In Figure 10-10, the finisher is pulling a vibrating power screed along the wet screed. A power screed levels faster than hand screeding, but the operator must be careful not to let the excess concrete get on forms and the power screed ride up on that excess. Also, a power screed must move along and not be kept in one place long when it's operating because it could cause separation — excess fine cement and water coming to the surface. The vibrating screed in the photograph is lightweight and won't dig into the wet screeds. It consolidates the concrete as well as leveling it. Using a vibrating power screed takes a lot of skill, but produces faster screeding of the concrete surface.

After the concrete slab is screeded and the mason determines that it has reached its initial set, you can start the floating. A large pour will require a bull float, like the one in Figure 10-11. Hand-float smaller surfaces, as well as against the outer surfaces of the formwork and around pipes or blockouts. This floating operation levels out the ridges left from screeding.

Figure 10-11
Bull floating

Figure 10-12
Riding power trowel

You must now wait until the mason decides the concrete surface is ready for the finish troweling. This operation is done with a thin-blade trowel, either by hand or with a power trowel for larger areas.

A riding power trowel with two or three blades, like the one in Figure 10-12, can be used to trowel a very large pour. However, you'll still need to hand finish concrete in places where the power finisher can't reach.

The floating and troweling operation just described is just one application. This sequence may need to be repeated before the concrete finishing is complete. The job specifications may require it, or the mason may want to go over the slab a second time to make it smoother.

You might also be required to furnish a final finish other than the typical smooth floor. There are many different finishes, including special textures or patterns. Since concrete can be stamped to look like other materials, the final surface design is limitless.

Finishing Lightweight Concrete

There's a lot of information available about finishing normal concrete surfaces, but not too much about how to finish lightweight concrete surfaces. Not knowing the differences can ruin a concrete job. Here are some steps to follow to successfully place and finish lightweight concrete.

The Mix

- The mix must be low slump. It should never be over 3 inches, because with higher slumps, bleeding is excessive and coarse particles will float to the top. There's also a danger that the surface could tear when dry (peel away and expose the aggregate).
- The air entrainment must be cohesive enough to hold together for troweling and prevent segregation (separation of the materials).
- Use no less than a five-bag mix per cubic yard in any lightweight concrete that's to finish as a floor.

Finishing

- Use a magnesium Darby or bull float. They will slide over the rough particles and not tear them out.
- Float and trowel as soon as the surface water has disappeared.
- If the surface water persists, use a rubber hose to drag it off.
- If the surface doesn't dry, use a dry shake of one part concrete sand and one part cement. Never use pure cement. I don't recommend this process except in extreme cases. It's likely to lead to cracks on the surface.

11
CONCRETE JOINTS

Cracking is one of the most common and least understood problems of concrete work. But in most cases, cracking can be reduced by using proper control methods. Concrete expands and contracts with changes in moisture and temperature. This must be taken into consideration during the design, forming, placement and curing processes. When concrete is initially poured, it's at its largest volume. When it's hydrated and dry, it's at its smallest volume. The majority of cracks occur during the first few days, while the concrete is in its "green" state and hasn't developed its design strength. Any change in conditions during the curing stage between green and dry affects the concrete, making it shrink or expand slightly — and possibly crack.

Good workmanship helps prevent cracking. One common cause of cracking is adding too much water to the mix. As the diluted mix settles, the excess water bleeds to the top and evaporates, leaving voids. The new concrete becomes porous, weak and unable to withstand the stress of shrinkage without cracking. Cracks can also be caused by improperly placed reinforcement, loose forms, or an unstable subgrade. Pouring new concrete on vegetation or on frozen or muddy ground will almost guarantee cracking.

Installing Joints

Most concrete pours require joints. Joints provide space for the concrete to expand or contract during changes in its volume. Architects and engineers design joints into their structures to allow for this movement. The

Figure 11-1
VoidCap being used
with Flexcell expansion joint material

joints permit the concrete volume to change or move without losing its integrity. That makes the pour stronger and minimizes cracking. Proper joint spacing also gives the concrete a neat and uniform appearance.

Small cracks generally don't affect the structural integrity of the concrete. But it's still a good idea to minimize the number. Contractors do this by placing joints at windows, doors and walls. They also place a joint at the point where concrete pours are stopped for any reason, like at the end of the workday or when other construction operations need to be completed before the pour continues. When they resume the pour, they seal the joints to prevent unwanted substances from seeping into the joint and damaging the concrete.

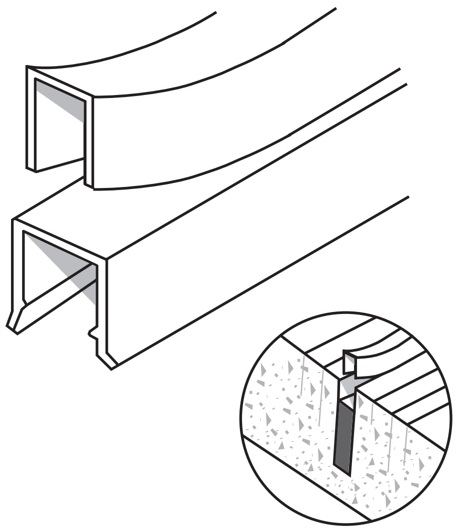
Control Joints

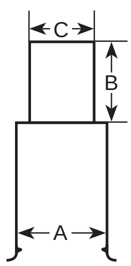
There are different types of joints placed in concrete. The first is a control joint. These joints usually divide a concrete slab into uniform sections. They're used to regulate unavoidable or unpredictable concrete movement. The amount of movement or the shrinkage depends largely on the water content of the concrete mix. If the water content is excessive, even the best joints can't control cracking.

Control joints are positioned to provide the maximum placement of volumes of concrete between joints. A rule of thumb for a concrete mix with ¾-inch aggregate poured 5 inches thick is to place control joints every 10 feet. In a large pour, the control joints will form 10-foot squares. This placement practice is easily visible in sidewalks. Many commercial or government building projects will stipulate the location of control joints in their specifications. You can use a cutting machine to cut control joints into the concrete after the first day of curing. A cutting machine can slice all the way through the concrete, or just to a depth that'll cause any cracking in the concrete to occur *beneath* the cut. Place strips of plastic or wood in the cut to keep dirt out while the concrete cures. When the concrete is sufficiently cured, remove the strips and fill the joints with a sealer to keep out water and foreign material.

There are also different materials that you can use for joints. One is a fibrous, compressible, flexible board, such as *Flexcell®*, that can be purchased in ½-thick pieces, 4, 5 or 6 inches wide, in 5- or 10-foot lengths. This type of material is often used in sidewalk construction (which we'll cover in Chapter 14). Figure 11-1 shows Flexcell expansion joint placed in a slab, and topped with another product called *VoidCap*.

VoidCap is a polystyrene expansion cap with a removable top manufactured by Superior Profiles. It can be placed over all types of expansion joint materials. When the concrete is poured, the top of the VoidCap is level with the surface of the slab. After the surface is finished, the top portion of the VoidCap can be removed, leaving a ½-inch-deep void (see Figure 11-2). You then fill the void with any type of self-leveling caulk to seal the joint and protect it from moisture.





VoidCap measurements			
No.	**A**	**B**	**C**
21A-VC-375	3⁄8"	1⁄2"	3⁄8"
21A-VC-500	1⁄2"	1⁄2"	1⁄2"
21A-VC-750	3⁄4"	1⁄2"	3⁄4"
21A-VC-1000	1"	1⁄2"	1"
21A-PVC50	1⁄2"	1⁄2"	1⁄2"

Courtesy: Superior Profiles

Figure 11-2
VoidCap expansion cap

Construction Joints

Use construction joints where you stop work for scheduled or unscheduled interruptions. While a construction joint is like a control joint, it isn't considered a *true* control joint. Construction joints may be included on the drawings to coincide with structural features and reinforcement locations. They can also be planned ahead to be located at the site of a needed control joint. Construction joints are made using a bulkhead of wood or a steel form. The surface of the joint should be vertical and smooth. Construction joints are sometimes joined together using dowels or a keyed form.

Cold Joints

Cold joints are concrete joints that begin to set before the next pour is made. The amount of time it takes before a cold joint develops depends on a number of factors. But as a rule of thumb, consider two hours the maximum time that you can leave cooled concrete uncovered before a cold joint will form. You can prevent the onset of a cold joint by delaying the set using a mist of water or some other method of keeping the concrete moist. In warm climates the set time may have to be reduced by 50 percent or more because concrete sets up faster in warm weather. Use a retarder in the mix to extend the set time.

If a cold joint forms, stop the concrete placement and install a bulkhead. The cold joint should be treated like a construction joint. You'll know you have a cold joint when your concrete vibrator won't sink into the concrete under its own weight, or a hole remains when you remove the vibrator. There isn't any permanent damage to the concrete at this point. Most masons will fill the hole with concrete and allow the concrete to continue to set.

Isolation Joints

Install isolation joints, or expansion joints, to provide a space for concrete to expand and relieve stresses due to vertical movement of the concrete slab. They're usually placed where a floor meets a wall, a column, or another type of slab, such as a foundation for machinery. An isolation joint is always the full depth of the slab.

Pre-Pour Joint Checklist

Review the following checklist before pouring concrete:

1. Are all joints (expansion, contraction, and construction) located as specified on the contract drawings or as otherwise approved?
2. Have construction joints at fresh concrete been properly prepared? Check the requirements for air-water cutting, wet sandblasting, roughing, wetting, etc.
3. Check the location of bulkheads for construction joints in structural members (like columns, beams or slabs) with the specs or blueprints.
4. Are preformed fillers installed and securely fastened in expansion joint locations?
5. Make sure expansion joints are free from irregularities or debris that would interfere with their free movement.
6. Check all expansion and contraction joints. No reinforcement or other fixed metal should run continuously through any joint intended to allow for expansion or contraction.
7. Waterstops should be secured in their proper locations, undamaged and accurately spliced.
8. Do you have the option of sawing contraction joints after the concrete has set? If you plan on doing this, have you correctly located the joints and do you have the approved equipment on hand and the qualified personnel available?

Sawing Concrete Joints

For the last 50 years, hand-tooled or wet-cut gasoline-powered concrete saw control joints have been the dominant methods used for reducing cracks in concrete.

Courtesy: Soff-Cut Company

Figure 11-3
Cutting control joint with a Soff-Cut electric saw

Traditionally, concrete sawing has taken place the day after placement. But sometimes that's too late to stop cracking. The most critical period is between the time the concrete is finished and the next day. The concrete saw operator cuts the control joints to between one quarter and one third of the slab thickness to relieve internal stresses in the new concrete. However, waiting even a *little* too long to cut the control joints after the concrete's been placed opens up the possibility for random cracking. The slab may appear unharmed after cutting, but cracks from early unrelieved stresses can show up months later. The results are costly callbacks and repairs.

Soff-Cut® Saws

One way to prevent the delay in cutting control joints is to use a lightweight Soff-Cut saw. You can cut control joints between one and two hours after the finishing operation and final set. And, the control joints don't have to be deep. You can minimize the chance of random cracks with a cut as shallow as 1 inch.

The type of saw cut you make in the concrete depends on the depth of the concrete and the project specifications. For residential and light commercial and industrial pours, you can use a small walk-behind electric concrete saw, like the one shown in Figure 11-3.

The Soff-Cut early-entry dry-cut system reduces random cracking because you can finish and cut your joints the same day. And since you don't need water, there's less mess with a Soff-Cut saw. After cutting, you just dust a little dry concrete powder on either side of the cut and you're done. You don't have to come back a second day. Contractors can place a slab, finish, saw, and leave.

Control Joint Spacing

Space your control joints, based on slab thickness, as follows:

4-inch slabs (10.16 cm) — 10-foot spacing (3.05 meters)
5-inch slabs (12.70 cm) — 13-foot spacing (3.96 meters)
6-inch slabs (15.24 cm) — 15-foot spacing (4.57 meters)

Finishing Joints

1. Check the joints for the correct dimensions.
2. Make sure joints are clean and dry before sealing.
3. Inspect the joints to make sure each joint is completely filled with sealer — the sealer should be flush with the joint.

Sealing Joints

There are three types of joint sealers used for most concrete slab joints. The first is a flexible epoxy sealer that has good chemical and water resistance. The second is a silicone sealant that has high flexibility and high temperature resistance, but isn't as strong as the epoxy sealers. The third is a polyurethane sealer that provides excellent flexibility, as well as impact resistance and durability. Polyurethane sealants come in one-part and two-part systems.

The method used to seal the joints should be determined by the location of the slab and the type of traffic the joint will be exposed to. It's generally up to the contractor, unless the project specifications require a particular type of sealer. Install sealers after the concrete has had a chance to shrink as much as it's going to. Be sure the joints are dry and clean; then apply the joint sealer according to the manufacturer's instructions.

12

CONCRETE FINISHING

You can avoid most finish problems by following sound mixing and placing procedures. A good concrete job always begins with the correct concrete mix placed on a well-compacted subgrade. The subgrade should be dampened sufficiently to prevent a too-rapid loss of water from the concrete into the subgrade.

Concrete shouldn't be "flowed" into place — always wheel, shovel or pour it into the forms. An inexperienced contractor may want to add water to the mix to make the concrete flow. But don't do it. This can cause the larger aggregate to settle to the bottom, creating a concrete flow with a disproportionate percentage of sand and cement, weakening the mix and causing future problems.

Your ready-mix supplier can advise you on the proper mix for a particular job. A concrete floor that'll be subjected to heavy mobile machinery will need a stronger mix than one where you expect normal wear, like a basement floor. When ordering concrete, if you have a question about the right mix, ask the supplier for advice.

Finishing is the process of leveling, smoothing and compacting newly-poured concrete. The degree of finishing depends on the desired appearance and the type of surface serviceability that'll be required of the concrete. Ideally, the amount of surface manipulation needed to produce the finish should be kept to a minimum.

After the concrete is screeded and leveled to the top of the form, finish the surface. For regular concrete, dress the surface with a magnesium float or power float once the sheen (bleed water) is gone. Don't begin the finishing operation on a concrete slab while there's bleed water on the surface. Working the water back into the concrete will create a high water-cement ratio in the surface layer and reduce its strength. Never dust with dry portland cement mix to help absorb bleed water. On a large slab, you can pull a garden hose across the surface to drag off excess water. Using air-entrained concrete can reduce excessive concrete bleed and allow you to work the concrete sooner.

Begin your final steel troweling when finger pressure just barely dents the surface. The troweling will produce a ringing sound.

Checklists for Finishing

The following checklists will help you organize the procedures for different types of finishes. Remember that freshly poured concrete must always be protected from rain, snow and excess drying from wind and heat.

Finishing Unformed Surfaces

1. Check the specifications for the type of surface finish required.
2. Make sure the screed runs are set to grade.
3. If possible, use a bullfloat across any screed marks. A hand-held screed sometimes leaves ridges that will make the floating operation harder to complete.
4. Start floating as soon as the screeded surface has stiffened enough to allow floating without drawing excessive fine cement to the surface. (There should be no free water on the surface at the start of floating. *Do not* dust with cement or other material to dry the surface or enrich the cement.)
5. Trowel the surface as soon as the floated surface has hardened sufficiently to prevent drawing more fine cement to the surface, but while the surface is still workable. Make sure that floating erases any imperfections left by edging or jointing tools. If required by the plan, make sure the new surface matches the adjacent surface.
6. Remove the screed runs as soon as the concrete has stiffened sufficiently. Removing forms or screed runs too soon can cause the edges to break off.
7. Straightedge the fresh concrete to remove screed marks.

Monolithic Finish

Generally, floors and roof slabs get a monolithic finish. Use the following checklist for areas receiving this type of finish.

1. Make sure that coarse aggregates are forced away from the surface before beginning the screeding and straightedging.
2. The timing of the floating and troweling is important. Float the surface as soon as it will bear the weight of a man without making a deep imprint. Trowel the surface as soon as the moisture worked up from the floating operation disappears. Don't allow additional water or dry cement to be used.
3. Make sure that an adequate number of steel-trowelings is done to ensure a smooth, even surface finish, free from trowel marks. This is an experience call. After the first steel-troweling, the surface may require a second troweling.
4. Don't permit the use of trowels cleaned in form oil, silicone, or similar bond-breaking materials unless those materials have been completely removed from the trowel.
5. Where required by the specifications, trowel in abrasive aggregate for a non-slip finish.

Finishing Formed Surfaces

When the forms are removed, you may have some additional finish work to do on surfaces that were poured against forms.

1. Check the specifications for the surface finish required.
2. Do you have approval for the surface finish?
3. Repairing defective areas and removing fins, form marks and holes should be done immediately after the forms are removed. Check the specifications.
4. Check to be sure the areas to be patched are clean. Have honeycombs and rock pockets been cut back to solid material? Has loose material been removed?
5. Check specifications to determine the required treatment of any areas containing defective concrete.
6. Make sure concrete patches are completely cured.
7. Check the surface finish to insure it's within specified smoothness tolerances.

Smooth Finish for Formed Concrete Surfaces

1. Check the specifications for any areas requiring a smooth finish.
2. Plan the operation to finish areas at natural breaks (where the concrete pour ended).
3. Make certain that the cement grouting operation isn't delayed. The grout should be allowed to age with the concrete.
4. Make sure you use the proper mix of cement in the grout so it blends with the finished surface.
5. Apply grout to completely and solidly fill all pits, voids, and surface holes.
6. When it's dry, scrape the excess grout off with a trowel. Leave the grout flush with the surface and then clean the surface to remove any grout film.
7. Plan the curing to prevent grout from becoming dry during the setting period.

Checklist for a Rubbed Finish

1. Check for exterior exposed-to-view areas that require a rubbed finish. The surface texture may be specified as an *architectural finish*.
2. A rubbed finish is done with a carborundum stone and water after the surface has first received a smooth finish.
3. Make sure no mortar or grout is used during this operation.
4. Make sure the rubbing operation removes all form marks and similar blemishes.

Finish Problems

Flaws in the concrete finish are generally caused by poor mixes, poor finishing or poor curing procedures. And once they show up, it's usually too late to correct them. That's what most concerns contractors — some concrete flaws are permanent. Depending on the severity of the flaw and the decision of the owner, the contractor may have to replace the concrete.

Most flaws reflect a lack of skilled workmanship and inadequate attention to detail during the preparation and placement process. Let's look at some of the most common problems and how they can be avoided.

Dusting

Dusting is the formation of a fine, powdery material on the surface of hardened concrete. It's not a structural problem, but it *is* a problem.

As concrete settles, bleed water comes to the surface. If there's too much bleeding — caused by excessive water — it will carry aggregate fines to the surface. This creates a weak wearing surface characterized by dusting and crazing. (We'll cover crazing shortly.)

Placing concrete over a plastic membrane on the subgrade can reduce its curing time. But polyurethane sheeting prevents the subgrade from absorbing excess water. This may increase bleeding and produce a surface layer prone to dusting.

In addition to having excess water in the mix, dusting can also be caused by troweling the surface before the bleed water has disappeared, or applying dry cement to the surface to aid in finishing.

Using concrete with a low water-cement ratio will help reduce the incidence of dusting. A relatively dry mix, with not more than a 4-inch slump, placed on a dampened subgrade works well. The water content shouldn't exceed 5½ gallons per sack of cement. Keep in mind that weather has a considerable influence on dusting. Use lower slump ratios in cold weather and higher slumps in warm weather, if conditions permit.

Once dusting occurs, it's too late to change the mix, but you can try to control the dusting. To protect concrete from dusting, apply a chemical floor hardener. You can do this soon after the finishing process. There are different products on the market to control dusting on both new and old concrete. Check the manufacturer's directions on how and when to apply the hardener.

Crazing

Crazing is indicated by fine random cracks on the concrete surface. The cracks are very shallow ($\frac{1}{16}$ to $\frac{1}{8}$ inch deep) and most are no longer than 1 inch. They show up in the first days after a surface has been steel-troweled. The cracks are unsightly and may appear to indicate a poor concrete job, but crazing rarely affects the structural integrity of the concrete.

Crazing is usually the result of improper finishing or curing. If the concrete is floated too soon or a jitterbug is used, the larger aggregate can be pressed down, causing too much fine aggregate and cement to come to the surface. The surface will then have a high water-cement ratio that may cause dusting or crazing. Some contractors sprinkle (or dust) dry cement on the wet concrete to thicken the mixture and produce a smooth, dense surface. But a cement-rich top on the surface of the slab will shrink more than the base course as it dries. *Avoid dusting with cement powder — or creating an overly-rich cement-sand surface*. These practices both cause rapid surface drying, and the inadequate curing will result in excessive shrinkage, inducing crazing.

You may be able to prevent crazing by beginning the curing process as soon as possible after finishing the concrete. When you can no longer see a watery sheen on the surface, use a light intermediate troweling to produce a smooth slab. Protect the concrete from hot sun or drying winds during the finishing process. Take care to not overwork the surface. Overworking is guaranteed to cause dusting and crazing. Fog, spray or mist the concrete to lower temperatures and increase humidity.

Excessive Bleed Water

Excessive bleed water occurs when you have a poor concrete mix with too little fine sand. The coarse aggregate settles down into the form and the water is forced up, causing excessive bleed water to settle on the surface. The only method I know to safely remove this excess bleed water is to carefully drag a hose across the concrete surface and push the water off.

Sand Streaking

Sand streaks are long, fine, brown- or sand-colored lines in the concrete. They are caused by bleed water washing away the cement and fine sand, leaving exposed aggregate and muddy brown streaks on the surface. Sand streaking occurs when the concrete mix is too wet, or it's over-vibrated. It can also be the result of loose form joints that allow the water in the mix to escape.

Sand streaks can be avoided by using a stiffer concrete mix and making sure that your form joints are tight. The use of air-entrained concrete will also greatly reduce sand streaking.

Bug Holes

Bug holes are voids in fresh concrete wall surfaces caused by air, water or debris that's been trapped against the form. Always check the inside

Figure 12-1
Bug holes in concrete wall

Figure 12-2
Rubbing concrete

surface of your forms to make sure there isn't any old cement or other debris attached that would protrude into the concrete and leave a hole, indentation or rough surface. You can see a rough, bug-holed wall where the form was pulled off in Figure 12-1.

Air pockets and bug holes can also be caused if the concrete vibrator operator allows the vibrator to come in contact with the sides of the concrete forms. As the vibrator pulls away from the form, it can leave a void.

Rubbing Concrete

As mentioned in the checklists earlier, rubbing is a finishing technique used to repair bug holes and honeycombing and provide a smooth textured surface on fresh concrete. Rub the concrete surface as soon as possible after removing the forms. You can use a carborundum stone, a rubber float or a burlap bag, depending on the condition of the concrete's surface.

With a carborundum stone, use a light water spray and a circular motion to bring a coat of fresh mortar from the concrete to fill in the bug holes or honeycomb. The carborundum stone roughens up the surface of the new concrete and the loose fine cement mixes with the water to create the mortar.

If you're using a sponge-rubber float or a burlap bag, make a rich mixture of portland cement containing 1 part sand and 1½ parts of portland cement and rub that into the concrete. Figure 12-2 shows fine cement being rubbed on the surface of an exposed wall. You can also see a carborundum stone sitting on top of the wall.

Review the checklist for rubbed finishes covered earlier in this chapter.

Scaling

It's very easy to tell if concrete has frozen and then thawed — the surface peels off. It usually starts in small spots and gets bigger and bigger. Slight scaling won't expose the large aggregate, but severe scaling will. In severe scaling, the surface finish is gone and the larger aggregate become exposed as if the surface were designed as an exposed-aggregate surface. Not using air-entrained concrete may be the cause. However, even air-entrained concrete will scale if it isn't properly protected. Another possible cause of scaling is finishing the concrete while there's still bleed water on the surface. Improperly cured concrete has a weak surface that can scale if it's exposed to freezing and thawing in the presence of moisture and deicing salts.

Air is entrained into concrete as protection against freezing and thawing. But be aware that if the slump is greater than 6 inches, the air content decreases and the protection is reduced.

Spalling

Spalling is the cracking, breaking, chipping or fraying of concrete along edges or joints. It can be caused by improper curing and overworking the wet concrete during finishing, excessive bleeding during finishing (especially in cold weather), inadequate or delayed curing, or improper jointing and sealing.

A spalled concrete surface can be just a small defect, or it can result in a huge repair problem. Concrete spalling may first appear as the result of a blow to the surface of the concrete, some unforeseen environmental exposure, or a freeze/thaw cycle. Typically, it's a more severe problem than scaling. Spalling usually penetrates deeper into the core of the concrete structure and often extends to the surface of the metal reinforcement. Once the metal reinforcement is exposed to the elements, damage to the concrete is compounded.

In most cases, spalling seriously affects the appearance of the concrete, as shown in Figure 12-3. It can also jeopardize the strength and serviceability of the concrete structure.

Figure 12-3
Spalled edge of concrete wall

Blisters

Concrete can form blisters if the steel troweling operation is performed too early in the finishing process. A steel trowel seals the fresh concrete surface. If the troweling is done while the concrete that's deeper down in the slab is still in the process of releasing water and air, blisters will form on the surface. Using air-entrained concrete can prevent blisters. Air-entrained cement contains millions of tiny air bubbles that make smooth-finishing easier. It reduces the rate of bleeding and helps produce a dense impermeable surface.

Popouts

Popouts are often the result of overworking the concrete and allowing some aggregates or other materials to drift up to the surface. These material fragments can later break out of the surface. Aggregates containing impurities or foreign materials can also damage the surface by creating a porous weak spot or discoloration. Popouts are most commonly produced by one of the following:

- unsound aggregate pieces that have a high rate of moisture absorption
- foreign materials (such as calcium chloride lumps or quicklime)
- a chemical reaction between aggregates and the alkalis in cement

Unsound Aggregates

Aggregates, such as laminar rocks, cherts, flints, and impure limestone particles, can promote the formation of popouts. Most of the damage is done during freeze-thaw cycles.

Foreign Materials

Common foreign materials found in concrete are soft sandstone, ochres, clay lumps, glass particles, shale, lignite, and coal. These materials damage the concrete by expanding while wet, causing the concrete to rupture. Lignite or ochres in the concrete can cause staining or pitting.

Chemical Reaction

Alkali-silica reaction (called ASR) can occur in concrete many months or even years after it was poured. It usually shows up as *map checking* — many fine lines crisscrossing the concrete surface. Occasionally a white powder (silica gel) will appear on the surface. Alkali in the aggregates may be the cause. Concrete suppliers are constantly checking their aggregates for excessive alkali content.

Plastic Shrinkage

Plastic shrinkage shows up in the form of small cracks in the surface of the concrete. The cracks are usually almost parallel and appear soon after the finishing operation. Plastic shrinkage is caused by a high rate of water evaporation from the surface of freshly-placed concrete. You can prevent these cracks by using moist aggregates in the mix, dampening the subgrade and the forms before your pour, and using sun shades and wind breaks to reduce evaporation. You should also minimize your placing and finishing time and use evaporative retardants. Since surface water evaporates more quickly than the water in the underlying concrete, keeping the surface wet prevents most of this type of cracking.

Plastic shrinkage cracks generally don't affect the strength of the concrete. However they are indeed cracks, so they alarm many contractors. The factors that cause plastic shrinkage are temperature, humidity and wind. Take extra precautions to protect concrete pours in hot weather or if there's a significant drop in humidity. Wind blowing across concrete is probably the least thought-about or noticeable cause of plastic shrinkage — but it can have a major effect on the drying time of the surface.

Concrete Cracks

Most concrete pours have a tendency to crack. It's almost impossible to prevent the occurrence of some sort of cracking in a concrete project. You have to plan ahead and try to avoid at least the most obvious sources of cracking.

There are two main areas we need to look at in preventing cracks. First, concrete expands and contracts with changes in moisture and temperature. And second, concrete is only stable if it's constructed on a solid surface and supported on the sides. Any deflection or movement in the support can cause cracking. Engineers are expected to come up with designs for construction that eliminate cracking. The following cause most of the cracks in concrete:

- plastic shrinkage
- improper joint construction
- external restraints
- freezing and thawing
- settlement cracks

We can try to prevent or reduce cracking by using the following preparation measures:

- *Prepare the subgrade* — Remove all the topsoil and fill hollow spots in the subgrade. Compact the soil or granular fill beneath the concrete by rolling, vibrating or tamping. Slope the subgrade to provide drainage. Never pour concrete on grass or other vegetation. The vegetation will rot, forming voids in the concrete — and the concrete *will* crack.
- *Formwork* — All forms should be constructed and braced so that they can withstand the pressure of the concrete that'll be poured into them. If polyethylene is used in the forms under the pour, you run the risk of excessive bleeding of the concrete. The best method to prevent this is to put about an inch of sand over the polyethylene — and make sure the sand is damp.
- *Admixtures* — Use heat-reducing and shrinkage-reducing admixtures.

Reinforcing Steel

Cracks can appear near or around reinforcing steel that has begun to rust. Oxidized steel can expand up to 400 percent of its size. The oxidation of rebar will begin if there's significant deicing salt or other chlorides present on or in the concrete — especially if the rebar is placed within 1 inch of the surface. It can also occur where cracks, crazing, spalling or plastic shrinkage allows moisture or chlorides access to the steel. Proper concrete finishing and quick repairs to surface flaws will help prevent this problem. Figure 12-4 shows a section of concrete that has cracked over rusted rebar that was laid too close to the surface of the slab.

Figure 12-4
Oxidized rebar in concrete slab

Crack Repair

Customers aren't as tolerant of random cracking as they were 50 years ago. And there are only a couple of remedies once it occurs. You can seal the cracks with epoxy or sealant, or you can remove the cracked section of slab and start over, with no assurance that the slab won't crack again. This can be a tremendous cost to the contractor and cause a huge delay in a building project. It's far better to take precautions to avoid concrete cracks than to have to repair them.

Form Removal and Maintenance

Use the following checklists to help you follow up on form removal and protecting the concrete after the pour.

Removing the Forms

1. Make sure that the concrete is sufficiently hard and strong before removing the forms. Check the specifications to see if there's a minimum set-up time required before form removal.
2. For best patching results, patch immediately after form removal so that the patches can cure with the parent concrete. Specifications usually limit the time for patching to the first 24 hours after form removal.
3. Make sure the form removal operation won't damage the fresh concrete or cause spalling or chipping of the edges. Repairs are costly.
4. Form removal can be hazardous. Use extreme caution when removing and storing forms.

Form Maintenance

Clean the forms immediately after they're removed. This is the only way to remove all the concrete that sticks to the forms.

Correct storage is very important to long form life. Store plywood forms in a dry, covered area. Lay them flat with supports between them to provide air circulation. The covering should also allow air to circulate. Some contractors apply a coat of form-releasing agent to stored forms.

Concrete forms are often mishandled on construction sites. Throwing the forms off trucks, into excavations, or into piles can damage them, making them harder to install. Smart contractors invest in booms and cranes to save loading time and labor. The side benefit is fewer form maintenance problems.

Always apply a form-release agent to the forms before the pour. Don't use diesel fuel, waste oil or similar fluids. Many of these products will discolor the concrete or leave a residue that makes finishing the surface difficult. Properly-applied factory-designed form agents are the most important step in preventing concrete buildup on the forms and making the forms easier to remove. Oil the face of the form before each pour.

Figure 12-5
Using worn, splintered forms can result in a poor job

It's a good practice to oil the back of the form before the first pour and periodically after that to prevent concrete from building up on the backside.

Avoid Damage

Damage from nail holes is very common — but not serious. Form builders should take time when nailing and removing nails to avoid splintering the face of the form and causing unnecessary damage.

Vibrating concrete can increase form deterioration. Try not to let the vibrator touch the form surface. This can damage the forms. Insert the vibrator near the tie location so it'll absorb a majority of the added pressure. Be careful when running the vibrator around the wall ties. Hitting or damaging them can cause tie failure. *Don't* use the vibrator to push cement through the forms. This can damage the fibers in the wood form. Once you've vibrated the concrete, don't revibrate it. Doing this increases the concrete's pressure on the forms.

Pump concrete in at corners or filler locations whenever possible. If you pump concrete into the center of a panel, the panel may bend. If you submerge the pump hose in the concrete, it increases the pressure on the forms and ties. The general rule of thumb is that you should place concrete in formwork that's 8 feet or less at a maximum fill rate of 8 feet per hour. If you place concrete higher than 8 feet, reduce the rate of fill, or do it in lifts. A low slump mix exerts less pressure on formwork than a high slump mix.

Properly maintaining your forms will save you time and money. Figure 12-5 shows the result of concrete poured in badly-splintered forms. It'll take more labor to finish off that surface than it took to erect the forms and pour the concrete. And it's all because the forms weren't well maintained.

13

CURING CONCRETE

As we discussed earlier in the book, when cement is mixed with water it undergoes a chemical change that transforms it into "solid rock." It's then said to have *hydrated*. So hydration is nothing more than a chemical reaction between cement and water. The outside of the cement particle hydrates and forms a cement gel (glue). As water continues to soak through this cement gel, more hydration takes place in the cement particle. Aggregate mixed in with the cement becomes part of the newly-formed "solid rock" mass. Nothing can stop this reaction except lack of water or subnormal temperatures. Keeping concrete damp and at a temperature of approximately 70 degrees Fahrenheit is what makes up the *curing process*. This process continues for as long as there's moisture present — which can be days, months, or even years.

This transformation process is most rapid in the first 28 days, with the curing action being particularly critical during the first few days after the pour. Should the concrete be allowed to dry out in these initial stages, it becomes permanently inferior. If too much water evaporates from the mix, the reaction stops — and you can't force water back into the cement gel. So, curing is just this simple, and just this vital: Keep the temperature at about 70 degrees and ensure there's enough water in the concrete mix to allow the cement gel to firm.

Cement Curing Times			
Type	**3 days**	**28 days**	**3 months**
I	100%	100%	100%
II	80%	85%	100%
III	190%	130%	115%
IV	50%	65%	90%
V	65%	65%	85%

Figure 13-1
Curing times for different cements

Curing and Concrete Quality

The quality of concrete is only as good as the cement-water paste ratio that binds the aggregates together. The strength of the paste is adversely affected most often by the following two factors:

1. *Too much mixing water.* This has the same effect as diluting paint with turpentine. The more you add, the thinner and weaker it becomes.
2. *Too little curing*. When concrete is permitted to dry out, the chemical reaction between the water and the cement stops. This chemical reaction is what gives concrete its strength.

A well-proportioned concrete mix contains about twice the amount of water needed for cement hydration. The water not used in the hydration process is used to make the concrete workable, and also takes into consideration the evaporation that naturally occurs in the first few hours of the pour. The durability of concrete is a result of how much water the concrete can absorb during hydration. If the concrete quality is good to start with and it's been properly cured, the concrete will be solid. There won't be any pores remaining into which water can later penetrate and freeze, causing scaling or cracking.

Since evaporation occurs at the surface first, the surface is the part most affected by the length of the curing time. Ideally, the surface should be moist-cured for 28 days to achieve its maximum strength. Figure 13-1 shows curing times for different types of cement.

Curing Methods

Careful curing results in a good, uniform concrete pour. For most cures, that'll only involve leaving the forms on for the prescribed period of time and keeping the concrete moist. The timing for form removal can vary from 3 to 7 days, depending on the weather and if an additional curing procedure is scheduled after the forms come off. All curing compounds should be applied as soon as possible after the final troweling of the surface.

You can keep concrete moist for curing in a number of different ways:

- supplying additional moisture through sprinkling or wet coverings

- preventing moisture loss by covering the wet concrete with waterproof paper or plastic film
- applying a curing compound

Form curing without additional moisture is never acceptable.

If you're concerned about evaporation, you can wet down the surface and then use polyethylene sheeting or waterproof paper to hold the moisture in for curing. This is a fairly high-maintenance method you'd only want to use for small slabs and simple shapes. These coverings are easily torn by wind and equipment, so you have to constantly make sure they're sealed around the surface to promote curing. You'd also have to devise a way to keep the sheeting off the concrete's surface to prevent mottling.

Applying a membrane-forming curing compound will reduce the evaporation of moisture from concrete. These can be clear or white pigmented. Using a white-pigmented compound will help reflect the sun.

Apply membrane curing compounds as soon as possible after finishing. They take a considerable time to dissipate from the surface. By their nature, they require a lot of sunlight to dry out and turn into a powder. You must wait for the membrane to dissipate before applying floor sealants, hardeners or coverings.

The best cure for colored concrete is a clear membrane. Using a water cure or covering colored concrete flatwork may cause variations in the color. Only use membrane curing seals on colored concrete or on concrete scheduled for other treatments, such as sandblasting or bush hammering. In other situations, the membrane may interfere with the application of sealers or sealant.

Curing Checklist

Use the following checklist to help keep your curing process on track:

1. Check the details of permissible curing methods and the number of days they require. Is the approved curing medium being properly applied immediately after placing and/or finishing?
2. Where you're using moist curing, is it continuous, not intermittent?
3. Are you keeping the wood forms wet that are left in place during the curing period?
4. When using waterproof paper or other approved covering, are laps and edges sealed? Is the paper in full contact with the surface being cured?

5. When using a curing compound, make sure adequate mixing is done and that there's uniform coverage.
6. Don't use a membrane compound on concrete that's to receive paint, tile, roofing, or a hardener, unless the curing compound is approved for these uses.
7. If you're using a sprayed membrane:
   a. Is it continuous for full coverage, without gaps that permit moisture loss?
   b. It must be reapplied if subjected to a heavy rainfall within three hours of application, or if it's damaged by construction operations at any time during the curing period.
   c. It must be protected to prevent damage from pedestrian and vehicular traffic or anything else that would cause disruption of the membrane's continuity.
   d. The surface should not be allowed to dry. If the concrete surface is dry, apply a membrane moisturizer with a fine spray of water before spraying with membrane.
8. Make sure joints that will receive sealant are plugged to prevent coating with the membrane curing compound.

Hot- and Cold-Weather Pours

The curing and setup time for concrete can be greatly affected by weather conditions. Heat, wind and frost all take a toll on concrete placement and must be taken into consideration when planning your pour. Let's look at some of the difficulties you may encounter due to weather.

Hot-Weather Pours

Warm weather is generally the best time to pour concrete. But when temperatures rise from warm to hot, you may be looking at problems in the placement and curing process. High heat increases the rate of cement hydration and accelerates moisture loss through evaporation. The negative effects of hot weather on freshly-mixed concrete include:

- increased water demand
- change in slump
- accelerated setting time
- lowered plasticity
- difficulty in controlling the air content

As the concrete hardens, it may also have lowered strength levels at 28 days and later ages, drying shrinkage, and an inconsistent surface appearance. And finally, a rapid drop in the temperature from a hot day to a cool night may cause thermal cracking in newly-placed concrete slabs.

Elevated temperatures, high wind velocity, and low humidity affect fresh concrete in two ways. First, the high rate of evaporation from heat and wind may lead to early plastic shrinkage or drying shrinkage, resulting in cracking later. And second, it can reduce the amount of surface water available for proper hydration to occur. Accelerated hydration can lead to cracking in massive concrete structures.

Minimizing the Problems

You can't always prevent damage to concrete during very hot weather. However, the type of construction, the characteristics of the concrete materials you use and your experience can help minimize problems. Discuss early preventive measures when you're planning the job. The finishing crew can make or break the quality of a concrete pour. Experience counts — especially when there are circumstances affecting the concrete placement that are less than ideal. Be sure you go over with your crew the workmanship details required in mixing, placing, protecting and curing hot-weather pours.

You need to anticipate any problems that could occur. The potential for thermal cracking, either from overall volume changes or internal restraint, should be taken into account. When there's a significant temperature difference between the surface and the core of a new pour, it causes strain and stress on the concrete, known as *internal restraint*. Know the maximum temperature limits you can safely consider for your cement content, the selection and amount of chemical admixtures and pozzolans in the mix, the cement hydration, and your joint spacing. Check to see if you'll need additional steel reinforcing. And, find out how the heat will affect the stripping time for your forms.

Here are some suggestions that can help you reduce hot-weather pour problems:

1. Use only the concrete materials and proportions that are recommended by the manufacturers and suppliers of ready-mix concrete.
2. Plan your pours for early in the day, using cooled concrete. Early morning deliveries will have aggregates that have cooled overnight, as well as water that hasn't yet been exposed to direct sunlight and high temperatures, so it'll also be cooler. If necessary, in very hot weather, you can pour at night. That may be an extreme measure, but it might be your only option for a successful pour.

3. Use a concrete consistency that permits rapid placement and effective consolidation.
4. Transport, place, and finish the concrete in the least amount of time practical.
5. Protect concrete from moisture loss at all times during placement, finishing, and curing.
6. Use water-reducing admixtures for hot-weather placing and to assist in pumping concrete.

Cold-Weather Pours

If you're pouring concrete and the temperature falls below 40 degrees Fahrenheit, that's considered a cold-weather pour. Proper cement hydration is seriously retarded below 40 degrees.

In low temperatures, the set time is extended and the concrete slab can suffer from *carbonation*, a reaction between carbon dioxide in the atmosphere and the moisture in the drying concrete. Carbonation is most likely to occur when the temperature drops below 40 degrees and the relative humidity is about 50 percent. Carbonation suspends the strength development of the concrete; resulting in a low strength, low abrasion-resistant surface.

Plan ahead for cold weather — don't wait for freezing temperatures to set in before you act. Have the equipment and materials you need to head off problems at the jobsite before you begin any work. Waiting until after the pour can be disastrous. Make sure any surface that comes in contact with the concrete is at a temperature that won't cause freezing or delay the setting time of the concrete.

Protection Systems and Techniques

Concrete should cure for six to seven days to reach its desired strength. You must protect it during this early hardening period and ensure that the temperature remains favorable so the concrete doesn't lose moisture. Don't use water curing in cold weather if there's a likelihood that the concrete could freeze. You'll need to use other methods to keep moisture in the concrete. You can use membrane-forming curing compounds or cover the concrete with impervious paper or plastic sheets. The protection system you use depends on several factors. These include the weather conditions, the shape of the structure, and the mixture proportions.

In some cases, just covering the concrete with insulating materials to conserve the heat of hydration may be all the protection that's necessary. Figure 13-2 shows a commercial blanket covering an exposed new slab.

Figure 13-2
Blanket covering and straw protect new slab

Figure 13-3
Forced-air curing system

The straw around the edge holds the blanket in place. Commonly-used insulating materials are:

- polystyrene foam sheets
- urethane foam
- foamed vinyl blankets
- mineral wool or cellulose fibers
- straw
- commercial blanket or batt insulation

When temperatures are less than 40 degrees Fahrenheit, you may have to build enclosures and bring in heating units to maintain the desired temperature. You can use live steam, forced hot air, or a combination of the two as your heat supply. Steam provides an excellent curing environment, but a less-than-ideal working environment — and it can cause icing problems around the perimeter of the enclosure. Figure 13-3 shows a forced-air curing system using propane heaters.

Keep in mind that concrete exposed to cold weather won't dry too quickly unless the protection system actually increases the likelihood of rapid drying. So whichever heat supply you use, position the heaters and ducts to evenly distribute the heat over the work area. You want to prevent localized overheating and premature drying of the surface. Also, be sure to properly vent combustion heaters to prevent a reaction of carbon dioxide in exhaust gases with the exposed surfaces of your new concrete.

Another option is to use admixtures to reduce the setting time. Accelerating admixtures, Type III portland cement, or increasing the amount of cement in the mix can all shorten the setting time and still allow the concrete to achieve its required strength — as long as you take proper precautions. You can use fly ash and other pozzolans and ground granulated blast furnace slag as a partial replacement for portland cement. These materials, when used with accelerating admixtures, can provide good concrete performance in less time during cold weather.

Reducing the setting time can mean shorter protection periods, faster reuse of forms, earlier removal of shoring, or less labor in finishing the flatwork. However, don't use these techniques to speed up the strength development of mass concrete, since they also tend to increase the internal temperature of the concrete. Increasing the internal temperature of concrete when it's hydrating can cause internal stress.

Early hydration can occur only when high humidity is maintained. Accurate and flexible curing procedures are essential, especially when pouring thin concrete sections.

Protection Checklist

Provide protection for concrete to make sure its appearance and strength isn't harmed by running water, premature or excessive loading, blows, freezing, extreme heat, or excessive temperature differentials within the concrete. Use the following protection checklist:

1. Take precautions to protect surfaces from rain, snow, or flowing water.
2. Check coverings and cold weather heating equipment. Keep combustible materials away from heating equipment.
3. When removing concrete protection, make sure the damp concrete won't be subjected to freezing temperatures or excessive heat.
4. Check the specifications for requirements governing the timing of form removal.
5. Make sure you protect new concrete surfaces from other construction activities.
6. Be sure the concrete isn't stressed before it reaches its designed compressive strength. Watch for loading against new walls or heavy objects placed or stored on new floor slabs.

Sealing Concrete

The main function of an exterior concrete sealer is to protect new concrete from freeze/thaw damage, and to prevent chloride-induced corrosion of the reinforcing steel. For interior slab floors, sealers prevent dusting, the

Figure 13-4
Concrete sealer spray application

absorption of liquid spills, and create a surface that's easier to clean. Sealers are classified as either *penetrating* or *film forming*.

Penetrating Sealers

Penetrating sealers are absorbed into the structure of the concrete slab. These sealers can penetrate as deep as ⅛ inch, depending on the density of the concrete and the finish on the slab. Penetrating sealers produce a durable sealing film embedded within the concrete that's relatively unaffected by abrasion or deterioration caused by ultraviolet light.

Film-Forming Sealers

Film-forming sealers remain on the surface to form a protective barrier. Very little of the sealer penetrates the surface. In addition to sealing out water, these products often offer some protection against chemicals, and prevent the absorption of grease, some oils and other types of liquid spills. The main purpose of film-forming sealers is to prevent dusting. Urethanes and epoxies are two of the most commonly-used sealers of this type. Epoxy sealers can have better chemical resistance, while urethanes typically have a greater resistance to abrasion. These types of sealers often require retreatment after long periods of exposure to traffic.

Concrete Sealers	
Thickness of coating applied (1,000 mils = 1 in.)	**Coverage per U.S. gallon 100% solids system**
¼" = 250 mils	6.4 ft^2
3/16" = 187.5 mils	8.5 ft^2
⅛" = 125 mils	12.8 ft^2
= 100 mils	16.0 ft^2
1/16" = 62.5 mils	25.5 ft^2
= 50 mils	32.0 ft^2
1/32" = 31.25 mils	51.0 ft^2
= 20 mils	80.0 ft^2
1/64" = 15.625 mils	102.0 ft^2
= 10 mils	160.0 ft^2
= 5 mils	320.0 ft^2
= 1 mil	1,600.0 ft^2

Figure 13-5
Sealing coverage per gallon

Apply film-forming sealers to freshly-poured moist concrete, using a roller, brush or low-pressure spray. Figure 13-4 shows an exterior sealer being applied to a newly-poured concrete sidewalk using a hand-held pump and sprayer. The application should take place immediately after the bleed water sheen has disappeared. Don't apply acrylic sealers where epoxy, polyurethane or urethane coatings will be used.

You can also apply sealers to hardened concrete. Figure 13-5 shows the sealing coverage you can expect to get per gallon of sealer, based on the thickness of your application.

[Blank Page]

14 SIDEWALKS AND DRIVEWAYS

Sidewalks and driveways are usually the last masonry jobs on a project. Many contractors schedule this work last because the final grade has been established and most building materials have been used up or removed from the site.

Sidewalks

A sidewalk can be just about any design, shape, color or texture. Most are around 4 feet wide. The exceptions are service walks, which are 3 feet wide, and walks for large buildings, which can be very long and several feet wide to match the proportions of the building.

Forming Up

The forms for sidewalks are usually made of 2 x 4 stock. Use only straight, sound stock, in lengths as long as possible. The fewer connecting points there are in the form, the easier it is to keep straight.

Place sidewalk forms so that the top edge of the form will act as a guide for the cement finisher to complete the top of the sidewalk. On large sidewalks, you may want to use a power screed, like the one shown in Figure 14-1. The motor on the power screed vibrates the two 2 x 6 boards laid across the forms. It's very important to have stable

Figure 14-1
Power screed vibrates
2 x 6s as they're pulled over slab

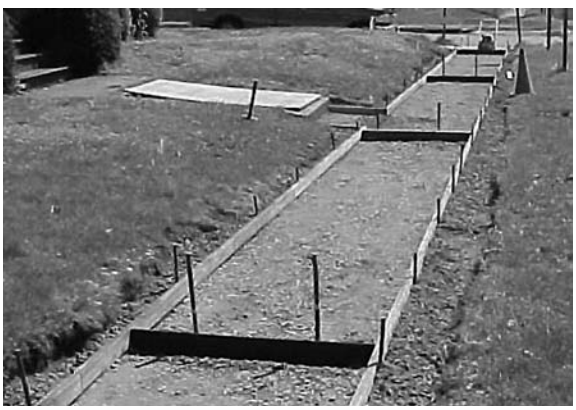


Figure 14-2
Sidewalk forms with expansion joints

Figure 14-3
Corner forms with handicap incline

forms when you use a power screed. This type of screed both smoothes the surface of the walk and helps to consolidate the concrete. Since screeding concrete is the hardest part of your concrete work, a power screed is a labor- and time-saving tool.

Make your sidewalk forms straight and true, and slope them to provide proper drainage for the finished concrete surface. For sidewalk drainage, the slope across the width of the surface shouldn't exceed ¼ inch for each foot of width.

Brace the formwork by driving stakes into the ground on the outside of the form and then nailing the stakes to the form. You may need additional bracing, especially if the bottom of the form doesn't sit solidly on the ground. In that case, use gravel or earth to form a solid base for the edge of the forms. Figure 14-2 shows a sidewalk form braced with steel rods.

Turning Corners

At the intersection with a street, the curb and sidewalk are usually curved to match the curve of the street corner. There are metal prefabricated forms you can use that can be adjusted to the radius of the corner (see Figure 14-3). These forms allow you to build an incline or ramp into the walk that meets the top of the roadway, making the sidewalk handicapped accessible. Some codes also require that you place grooves in the concrete, like those shown in Figure 14-4, to help the blind detect the roadway and ramp ahead.

Sidewalk slabs need expansion joints to provide for the expansion and contraction of the concrete caused by changes in weather and temperature throughout the year. Place the expansion material for the joints into the forms prior to pouring the concrete. Look again at Figure 14-2. You can see the expansion joints in this sidewalk are placed every 20 feet. The material used for these joints is asphalt-impregnated homasote. It comes in 4-inch widths and 8-foot lengths, which you can cut to fit.

Figure 14-4
Sidewalk grooves indicate street corner with ramp for the blind

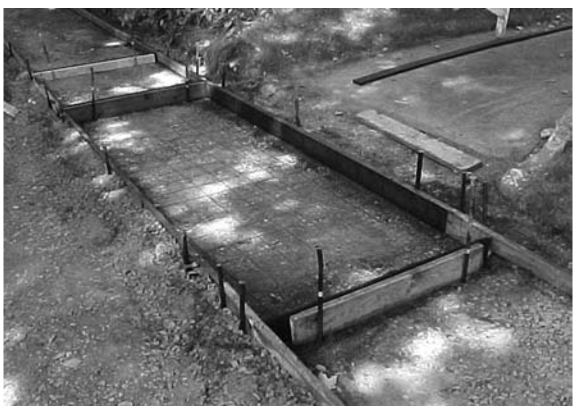


Figure 14-5
Forming for sidewalk crossing driveway

Figure 14-6
Sidewalk forms nailed to adjacent asphalt parking lot

Intersection with a Driveway

Where a driveway crosses a sidewalk, the driveway thickness, usually 6 inches, must be continued across the sidewalk to the street in order to bear the weight of delivery trucks. At the junction where the sidewalk meets and passes over a driveway, use 2 x 6s to form up that section. Place expansion joint material on both ends of the 6-inch-deep sidewalk section where it meets the 4-inch sidewalk sections. You also need expansion joint material at the intersection where the sidewalk meets the existing concrete driveway, as shown in Figure 14-5.

If the project calls for concrete to be poured against an existing asphalt driveway or parking lot, the best way to form it is shown in Figure 14-6. Nail the wood forms into the blacktop. Notice how the slab will be thickened at the intersection with the blacktop. The thickness will gradually be reduced to the 4-inch thickness of the sidewalk. This is a monolithic-type pour, with the curb and the sidewalk constructed as one integral structure. There's no need for expansion joint material at the intersecting point between the concrete and the asphalt.

Pouring

If you have to pour over a damp subgrade, fill the base under the walk with coarse granular fill. After placing the coarse material, compact the area with a vibrating compactor. Make sure there aren't any roots, debris or vegetation that'll later rot and create voids under the concrete. These voids will expand and eventually cause cracks.

Sidewalks don't usually require reinforcement. But check the building code for regulations in the area where you're working to be sure.

Finishing

Soon after screeding the surface with the top of the form, smooth it with a bullfloat, as shown in Figure 14-7. Push the bullfloat across

Figure 14-7
Smoothing concrete surface with a bullfloat

Figure 14-8
Finisher using a magnesium hand float

Figure 14-9
Finisher using a darby

the surface, perpendicular to the direction that the screeding was done. Raise the float at the edge so it doesn't dig in and then pull it back across the surface. This will smooth out the ridges caused by screeding and bring some of the "fat" (cement and sand) to the top to allow better finishing. It's best to bullfloat the surface just once. Repeated bullfloating will bring too much fat to the surface and make the concrete less resistant to wear and tear — as well as delay the finishing operation.

Once the surface is bullfloated, allow the concrete to set and begin to harden. How long you wait to begin finishing depends on the temperature, wind, sun, and how much water has been added to the mix. A high slump (wet) mix will take longer to set. Concrete that has accelerators added may set faster. For these reasons, the cement finisher shouldn't leave the work site. Once the concrete starts to set he must begin finishing. It's almost impossible to stop the set at that point — even trying to stop it will harm the psi rating or the surface finish, or both.

Only the finisher can determine when to start the finishing operation. He'll use a simple test to check the rate of setting: like pushing his finger or a tool into the concrete to see how far it penetrates. Typically, when the surface has lost its sheen and starts to set, it's time to start the floating. The finisher will use either a magnesium hand float, as shown in Figure 14-8, or a darby, as shown in Figure 14-9, to float the surface. A darby (a longer hand float) allows him to reach greater distances. The finisher always works the floats from *outside* the new concrete.

Control Joints

When the surface is floated, the finisher makes the control joints. He'll usually place them so the concrete is divided up into even squares. A 4-foot-wide walk will have a joint across the concrete every 4 feet. The joints are usually predetermined before the concrete is poured. One of the joints may come at an expansion joint, as shown Figure 14-10. It's a good idea to check the layout of the expansion joints before pouring the concrete. You want to make sure that they'll fall

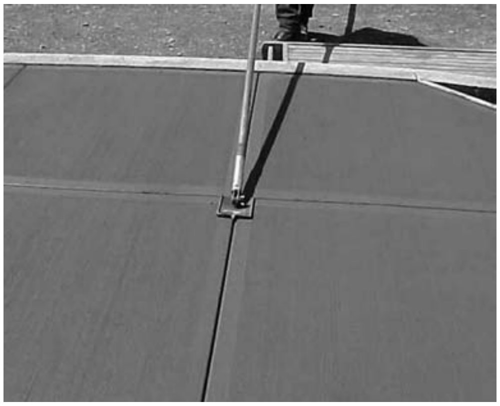


Figure 14-10
Control joint at expansion joint

Figure 14-11
Finishing the edge

Figure 14-12
Finishing with a Fresno trowel

in with the 4-foot segments so that the sections are sized consistently. Having a larger or smaller section would be an obvious mistake to anyone walking on the concrete later.

Edge Finishing

The next operation is to finish the corner or edge of the sidewalk, as shown in Figure 14-11. You need to round the edge off to prevent spalling or chipping. You may want to do this once right after the bullfloating, and again after the trowel or broom finish. This operation must be completed before the concrete starts to set because the finisher may run into problems with stones too close the top, high or low spots, or wet or dry spots. If the concrete has set too much, the finisher won't be able to get a smooth corner on the edge. The timing for each of these operations is determined by the finisher, who evaluates the concrete as it sets, taking into consideration temperature, humidity, wind and other variables that affect set time and finishing sequences.

Final Finishing

The finisher must watch the concrete to determine when to start putting on the final finish. In Figure 14-12, the finisher is using a Fresno trowel, which is like a hand steel trowel. It allows you to attach the bullfloat handle to extend the reach and put a more dense finish on the sidewalk. The balance of the walk can then be steel-troweled by hand.

Most, if not all, sidewalks have some sort of rough finish so they don't become slippery for pedestrians when it rains. Exterior walks that will be exposed to the elements usually have a broom finish. In Figure 14-13, you can see the finisher "broom" the surface. He must be careful not to do this too early or he'll pull a lot of fat up off the surface, and that could necessitate a repeat of the floating operation to smooth the surface again. That means lost time and a weakened surface. Again, it's the finisher's job to continually monitor the surface to determine when it's time to do the broom finish.

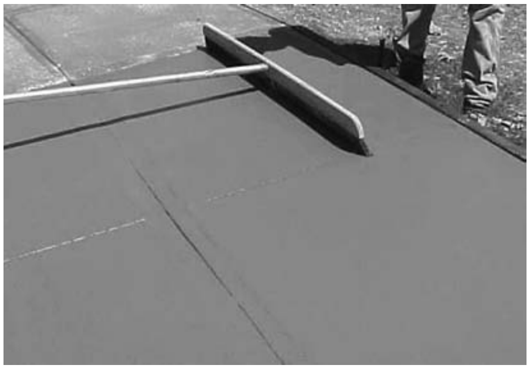


Figure 14-13
Applying a broom finish

Figure 14-14
Bridge for finisher built
over freshly-poured sidewalk

Figure 14-15
Trench, string line and
dry concrete ready for granite curb

On large concrete walks, you may need to make a sturdy bridge for the finisher to work from. Figure 14-14 shows such a bridge spanning a wide sidewalk. This photo also shows the squared pattern of the control joints and the broomed surface finish. The aesthetic value of a well-finished concrete walk can't be overstated. It's under constant public scrutiny and any mistake will stick out like a sore thumb.

Granite Curbing

Granite curbing is often used as a form for concrete sidewalks. Companies who specialize just in curbing usually install granite curbs. There aren't a lot of special materials or methods used in this type of form operation — except for the curbing itself. Use a transit to get the exact location of the base of the curbs (refer to Chapter 2). In Figure 14-15, a trench has been excavated at base level for the granite. You can also see a string line the length of the curb stretched along the trench. In this particular project, 2,500 psi dry concrete (no water) was placed in the trench. In most areas of the country, ground moisture is sufficient to set concrete up enough to support ground level structures, such as curbs. The granite curb was laid in the dry concrete mix with the top of the curb set and aligned with the string line, as you can see in Figure 14-16.

Figure 14-16
Granite curb placed
on top of dry concrete base

Figure 14-17
Score the top of the granite curb

Cutting Granite Curbing

If you need to cut a section of granite curb to make it fit, follow these steps:

1. Score the top of the piece with a stone chisel (Figure 14-17).
2. Score the face of the granite curb with the chisel (Figure 14-18).
3. Strike the backside of the granite curb, opposite the place where it's been scored, with a maul (Figure 14-19).

If done properly the front will be a straight cut. The back will sometimes flake to the sides, but this isn't important since the back won't be seen after the sidewalk is poured.

When all the granite curbs are in their correct positions, place a normal 2,500 psi concrete mix behind each section, as shown in Figure 14-20. This concrete is left unfinished, and later covered with soil. This will hold the granite sections in place until the blacktop and concrete make the granite a permanent structure. The moisture in the new 2,500 psi concrete will help start the hydration process of the dry base concrete. In areas with low ground moisture, a very fine water mist will set up the base concrete under the granite curbs. But too much moisture will allow the units to settle and cause problems. The final step in this granite curbing operation is filling in the end joints with a rich portland cement mixture.

Figure 14-18
Score the face of the curb

Figure 14-19
Strike the back side of the granite curb

Figure 14-20
Concrete is placed behind granite curb sections

Curb Machines

You can also use a curb machine to place concrete curbs. But these machines require a lot of preparation. They're usually used for large city street and residential tract projects where curbs have to be at precise elevations for street drainage, water lines, and other exacting utilities. Curb machines need a flat, solid surface to operate on, and control lines set by laser levels for their computerized machinery to follow. Figure 14-21 shows a curb machine following a string line to get the correct elevation for the top of the curb.

Sometimes all of the curb can't be formed and poured by machine. Even on a project where you're using a curb machine, you may have to place some of the curb manually. Set forms on each side of the starting and stopping points and hold them in place with metal U-shaped rods. Then place the concrete by hand. You may have to hand-form and pour curbs next to utility poles or other obstructions while the curb machine continues on ahead. If the concrete used for the manual curb is from the same delivery truck and is poured at the same time as the machined curb, it will become a strong, integral part of the curb. Figure 14-22 shows a section of curbing that will be hand-placed in front of a power pole.

Figure 14-21
Curb machine following string line

Figure 14-22
Hand form & place concrete around obstructions

Driveways

Concrete driveways should be at least a 4,000 psi mix and include some sort of reinforcement. Even in warm climates where there's no freeze/thaw factor, a slab can be cracked by the weight of vehicles driving over it. Check with the local building or code enforcement department to see if they have any special requirements for driveways. If the driveway is in a location where there are sidewalks, there'll probably be requirements for the junction of the walk and driveway.

The concrete mix should have a 6-percent air content and a 4- to 5-inch slump. You can use superplasticizers to produce higher slumps. Calculate any other additives for the specific project, taking into consideration weather and other working conditions.

The only placing and finishing operations for driveways should be screeding and floating. Use a wood float — steel troweling isn't recommended. Don't begin any finishing operations while there's moisture or bleed water on the surface. All the concrete should be placed within 90 minutes of the time the truck was loaded.

Don't *add* water to the concrete surface to assist in finishing. In hot weather, add chemicals to protect the concrete. Refer back to the section in Chapter 13 on hot-weather pouring. Prolonged mixing time or waiting time on the job can result in a loss of air content.

Once the water sheen disappears, do the edging and jointing. The usual final finish for driveways is a broom texture.

Grade, Slope, and Drainage

Make sure that you pour the driveway on a properly-prepared grade that's uniform in both material composition and compaction. Slope the grade away from the building to assure good drainage. Slightly crown the surface to allow water to drain off to the side. On a 10-foot-wide driveway, you can get good drainage using a slope of ¼ inch per foot. This will make one side of the driveway 2½ inches higher than the other. The builder and owner will have to decide on the finished elevations for each side of the slab. You may need fill on the high side.

A pitch or slope of ¼ inch on a 20-foot-wide driveway will make the high side 7 inches above grade. That'll create a noticeable slope. The solution is to split the drive down the middle with an expansion strip. Dividing the slab in two and having the crown in the middle with the slope to both sides will make it much easier to build. For the desired pitch, the center of the drive should be 2½ inches higher than the outside edges.

Control Joints

Place the control joints a maximum of 10 feet apart and at least 1 inch deep. Use isolation joints at points where the new drive will meet existing slabs, buildings, and other fixed objects. The isolation joints should run the full depth of the slab.

You'll need reinforcement for your driveway pour. Check your local building codes to see what they require. Refer back to Chapter 6 for information on concrete reinforcement.

15

FORMWORK FOR STEPS

Concrete steps are far superior to wooden steps for outside approaches. This is especially true where the grade level changes, like on a terrace, or where steps are embedded into the ground. Concrete steps are usually preferred for outside cellar hatchways, especially where the steps are subjected to hard use. Since concrete steps aren't subject to rot, they're more permanent than wood — and they're easier to clean and maintain. You can also embed iron handrails and non-slip metal nosings into the fresh concrete to provide a safer stairway.

Stair Layout

Let's first review stair terminology: the horizontal portion of the stairway, where you place your foot, is the *tread*; the upright section that's perpendicular to the tread is the *riser*. The treads and risers on a wooden stairway are supported on each side of the stairway by a *stringer* or *carriage*. Concrete steps aren't constructed using a stringer or carriage, but the same principals apply.

All the risers should be the same height, and all the treads the same depth. Because we assume that all steps will be of equal height, if any are higher or lower than the others, we may stumble or fall. A comfortable riser height is generally 7 to 7½ inches, with treads a *minimum* of 10 to 10½ inches. Stairs with longer treads or shorter risers will seem awkward to the normal person. However, many large outdoor steps,

Risers & Treads		
Rise	**Tread**	**Total**
6"	11"	17"
6½"	11"	17½"
7"	10"	17"
7¼"	10"	17¼"
7½"	10"	17½"
7½"	10½"	18"
7"	11"	18"
8"	10"	18"

Figure 15-1
Tread and riser combinations

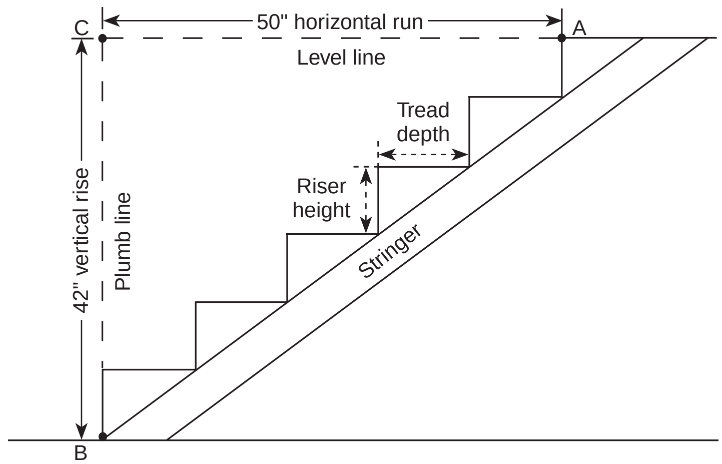


Figure 15-2
Finding the rise and run

such as those leading up to public buildings, will have 6-inch risers and treads of 11 or more inches in depth. Also, many basement stairs in confined areas of older homes, as well as outside basement exit stairs, may have short runs with 8-inch risers and 9½-inch treads. Today, many codes require a minimum 10-inch tread. Be sure to check your code if you're making changes to older stairs. The number of treads is always one less than the number of risers, because the top tread is at the upper ground or floor level.

If you're building a stairway that has an exit door that opens at the top of the stairway, you must provide a landing at the top of the stairs. The landing should be long enough so that the door, when fully opened, doesn't extend over the first step.

The Rise and the Run

You must know the vertical rise and the horizontal run of the stairway before you can determine how many steps you'll need. The total rise of the stairway is the vertical distance between one floor or ground level and the next. The run is the total horizontal distance that the stairway will, or can, cover. The shorter the horizontal distance is, the steeper the stairs will be. An industry rule of thumb for determining comfortable tread and riser combinations is: The depth of the tread and the height of the riser should total at least 17, but not more than 18 inches. Figure 15-1 shows examples of tread and riser combinations based on this formula.

Let's look at the design layout for a simple stairway, like the one in Figure 15-2. Point A in the drawing represents the head of the steps and the upper sidewalk level. Point B indicates the starting point of the steps at the lower sidewalk level. The distance between points A and C is the horizontal run of the stairs. The distance between B and C is the vertical rise of the stairs. Since the stairway in this drawing has a wall on one side, here's how you could plan the stairway layout:

1. Extend a level line on the side wall from point A to a point above B, as shown.
2. Drop a plumb line from the level line to intersect point B, and mark that line on the wall. This establishes point C.
3. Measure the horizontal distance between points A and C. This is the total run of the staircase (50 inches).
4. Measure the vertical distance between points B and C. This is the total rise of the stairs (42 inches).
5. To find the riser height for each stair, divide 42 inches, the total rise of the stairs, by 7 inches, which we've determined is a comfortable height for a stair riser. The result, 6, is the number of risers required.

   Note: If the total rise of the stairs includes fractions of an inch, lay the total rise off in equal divisions using a calculator to get the height of each riser and the number of risers required.
6. Now you need to determine the depth of the treads. Divide the horizontal run (50 inches) by the number of risers, less one (6 – 1 = 5). Remember that there's always one fewer tread than riser. So, our tread depth will be 10 inches (50 ÷ 5 = 10). Our tread depth and riser height add up to a comfortable 17 inches. That falls into the range of tread and riser combinations shown in Figure 15-1.

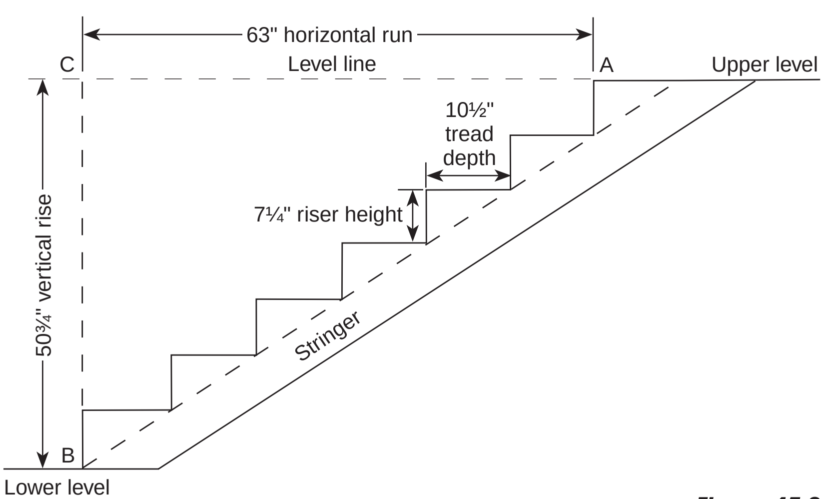
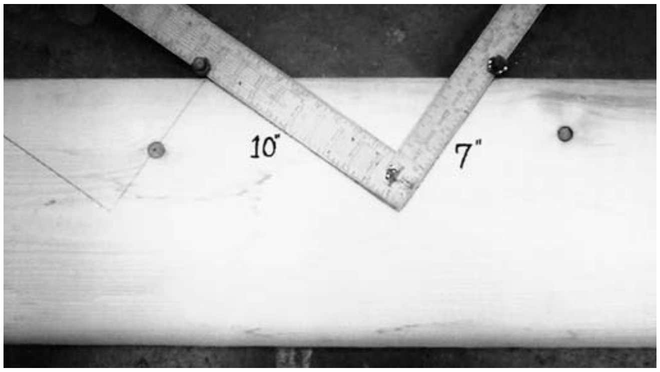
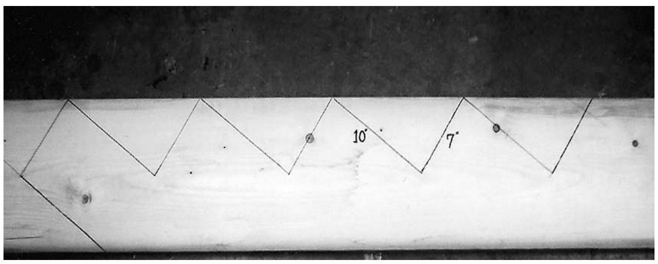


Figure 15-3
Stair layout

Let's look at the stairway in Figure 15-3. It's not quite as simple. The vertical distance is 50¾ inches and we have no more than 63 inches available for the horizontal run. Divide 50¾ inches by 7 inches to find the number of risers we need (50.75 ÷ 7 = 7.25). That gives us 7¼ risers — but we have to have an even number. If we use a riser height of 7¼ inches instead, that'll give us exactly 7 risers (50.75 ÷ 7.25 = 7).



A — Use framing square to mark tread depth and riser height



B — Repeat pattern for each tread and riser

Figure 15-4
Lay out treads and risers on a 2 x 12

Now let's determine the tread depth. Divide the total horizontal run of the stairway by the number of risers, less one, to get a tread depth of 10½ inches ($63 \div 6 = 10.5$). In this case, if we really want 10-inch treads, we could use them. Multiply the 6 by 10 inches and you'll get a horizontal run for the stairway of 60 inches ($6 \times 10 = 60$). That's a little short of the maximum 63 inches available — but since we could use *less* than the maximum distance, it would work. If you don't have any flexibility in your plans, you may have to use some odd tread depths. Just remember to keep all your treads equal depths and all your risers equal heights, and keep both at comfortable levels for stepping.

How to Make and Use a Pitch Board or a Cut-Out Stringer

If you're building a stairway with a wall on one side, as is often the case, you can mark your layout on the wall using a pitch board. It works like a stencil, allowing you to transfer your tread and riser measurements onto the wall to guide your layout. Let's make a stringer and pitch board for the stairway in Figure 15-2.

Making the stringer and pitch board:

1. Make your stringer or pitch board using a piece of 2- x 12-inch stock and a steel square. Mark your riser height (7 inches) on the tongue and the tread depth (10 inches) on the body of the square. Lay the square on the board so the 7 on the tongue and 10 on the body are on the edge of the board, as shown in Figure 15-4 A.
2. Mark the lines along the tongue and body of the square. Repeat for each tread and riser (see Figure 15-4 B).
3. Cut along these lines. The final result will be your stringer and pitch boards (see Figure 15-5).

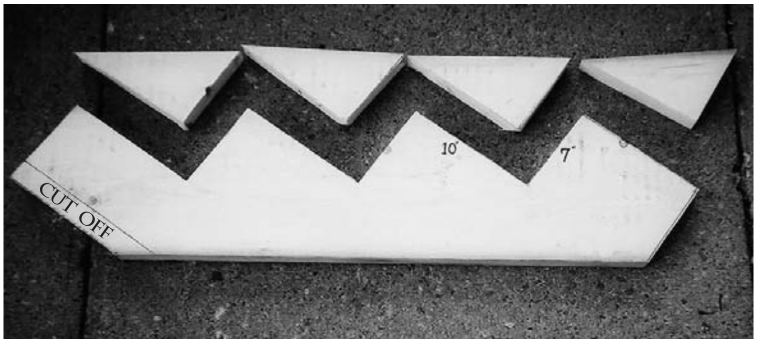


Figure 15-5
Stringer and pitch boards cut from a 2 x 12

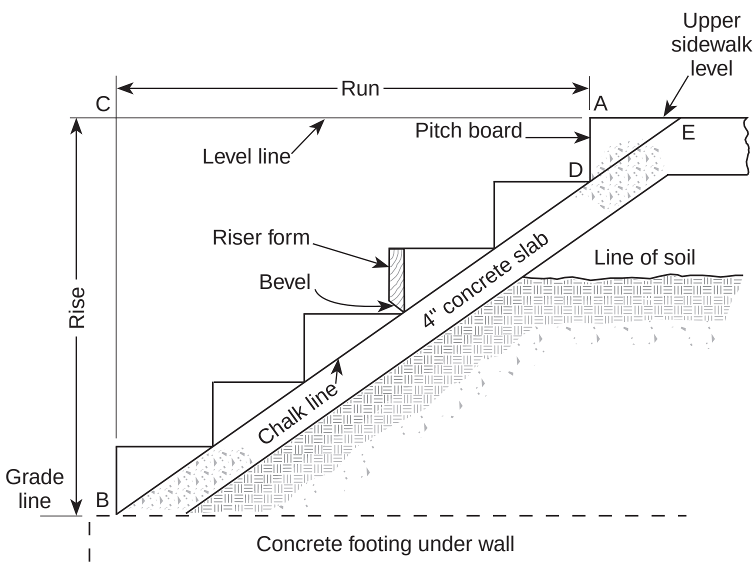


Figure 15-6
Using a pitch board

Using the stringer or pitch board:

1. Look at the stairway in Figure 15-6. Begin your layout by dropping a plumb line down from point A, a distance equal to the height of your riser, to locate point D.
2. To mark the pitch of the steps, connect points B and D in Figure 15-6 by snapping a chalk line on the face of the concrete side wall. Extend this line from D so it meets the upper sidewalk level at E.
3. If you're using the pitch board, place it on the concrete side wall so that the 10-inch tread aligns horizontally with point E of Figure 15-6, and lays flush on the line BDE of Figure 15-6.
4. Mark the wall by scribing along the outside edges of the pitch board. The 10-inch edge represents the tread of the steps and the 7-inch edge represents the rise.
5. Repeat this procedure down the line BDE, in Figure 15-6, until all the steps have been marked.
6. If there's a side wall on both sides of the stairway, repeat steps 1 through 5 on the opposite wall.
7. Check the tread marks on each wall to see that they're level with each other. If so, the riser marks should also be plumb.

Figure 15-7
Place landings on a long inclined stairway

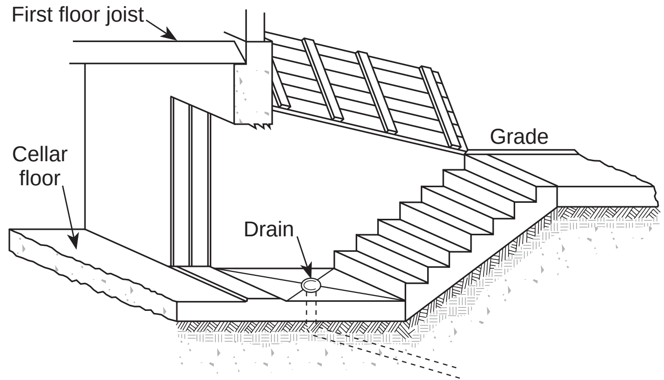


Figure 15-8
Hatchway steps

Landings

When constructing steps for a long incline, you need to place landings where people can pause to rest. Check the local building code for the landing levels your code requires. In Figure 15-7, you can see that the landing is constructed *before* the steps. The top level of each landing should correspond with the level of the steps. In other words, the landing is just a continuation of a step. Most landings are 4 feet deep and the same width as the rest of the stairs. Since you construct the landings for steep stairs first, make sure you set them at the correct elevation. Use a string line to set the forms and align the steps and landings from top to bottom. Be sure to place reinforcing for each landing, as shown in Figure 15-7.

Forming Up Steps

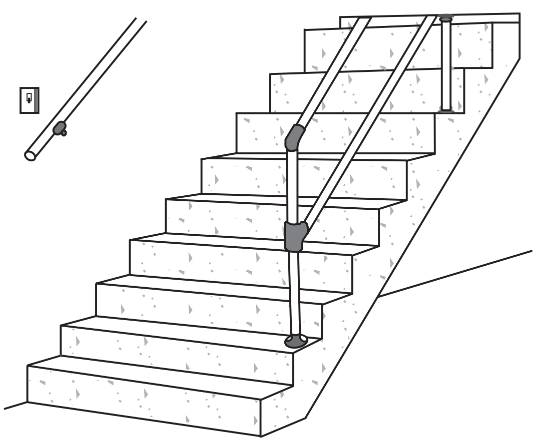


Figure 15-9
Open concrete steps

There are two general types of concrete steps. One type is built on the slope of the ground, as shown in Figure 15-8. The other type, in Figure 15-9, is supported at the top and bottom, with open space under the stairs.

Steps on Sloping Ground

Steps on sloping ground are sometimes built between concrete side walls. Make the forms for the walls from panel sections. The alignment, bracing and spacing is the same as in the construction of a regular continuous wall. After the concrete in the sidewalls is hard enough to permit the forms to be

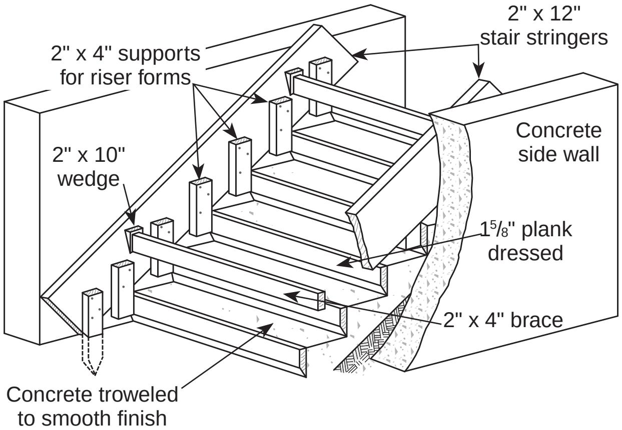


Figure 15-10
Forms for steps with concrete side walls

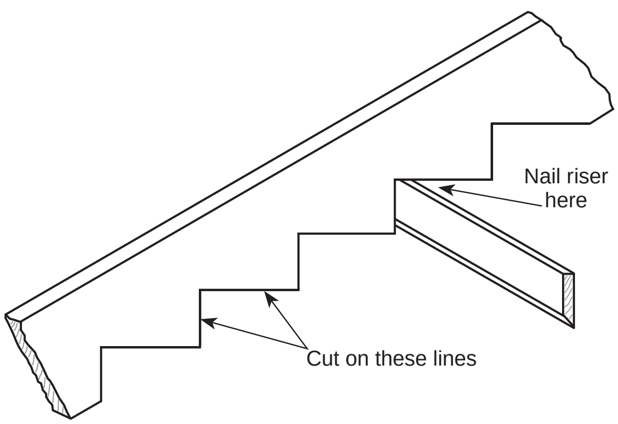


Figure 15-11
Cut-out stringer

removed, carefully remove the inside form for each sidewall. Then build the forms for the tread and riser layout between the side walls, using the following guidelines and the illustration in Figure 15-10.

1. Mark your layout in chalk on the side walls. Place 2 x 12 stringer planks in position against each wall so the underside of each plank just clears the nosing of each step, as marked on the wall. You can also use cut-out stringers, like the one in Figure 15-11, for this type of stairway.
2. Cut two or more 2 x 4 braces to wedge the stringers tightly into position against the side walls, as illustrated in Figure 15-10.
3. Cut riser forms from pieces of 1⅝- x 7-inch dressed plank to fit between the side walls. Bevel the bottom edge of each riser form.
4. Nail short pieces of 2 x 4 to the stringers to provide a nailing surface for the ends of the riser boards (see Figure 15-10). Fasten the 2 x 4 blocks the thickness of the riser boards back from the riser marks on the side wall. The bottom of the blocks should be about 1 inch above the tread level marked on the side wall so the tread surface can be finished while the forms are still in place.
5. Nail the riser boards to the 2 x 4s, keeping the top and bottom edges of the riser boards even with the tread marks on the side wall.
6. Brace the stringers firmly at the bottom so the weight of the concrete won't force them down.
7. Check the tops of the riser boards to make sure they're level. Recheck all members of the forms to be sure they haven't moved, or won't move from the pressure of the concrete.
8. If necessary, you can dig out each step in the slope of the ground so the concrete won't slide along the step bed as it's poured.

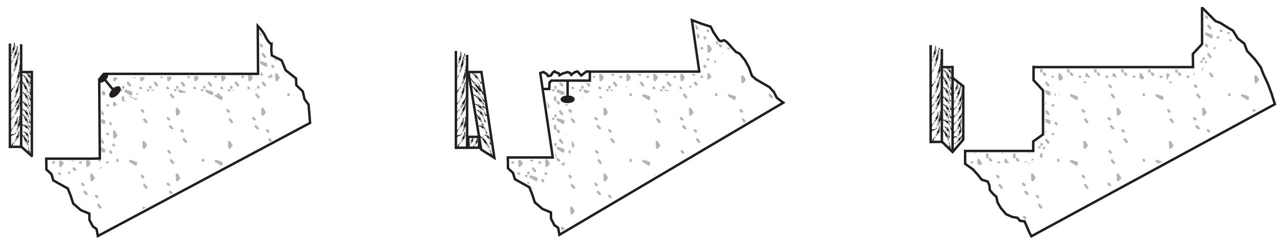


Figure 15-12
Riser form styles

Figure 15-13
Make riser forms ahead of time

When you build steps on sloping ground, the soil must provide good drainage so water doesn't accumulate under the stairway. If the soil is clay, place a well-tamped layer of cinders beneath the 4-inch concrete step bed. If you look back at the hatchway steps in Figure 15-8, you can see that they also have a drain built into the landing at the base of the steps to catch surface run-off.

Riser Forms

There are several different styles of forms for concrete stair risers. Figure 15-12 shows the most common types. The style shown in A is made from a straight board, and forms a plain-faced concrete riser. In the middle example, B, the same type of board is used, but it's tilted to form an undercut face in the concrete riser. The third illustration, C, shows a two-piece riser board that gives the concrete riser face an ornamental or panel effect. Bevel the bottom edge of all riser boards to allow the mason to trowel the tread face back to the face of the riser while the forms for the risers are still in place.

You can make riser forms ahead of time out of 2 x 6 or 2 x 8 lumber. It's less time-consuming to build all the riser forms at the same time, early in the construction. That way the risers will be uniform and easier to install. Figure 15-13 shows simple pre-made forms.

In Figure 15-14, you can see pre-made riser forms being nailed to a layout form on a stairway job. Notice the reinforcing that's been placed in the bottom of the form area. Because of the steep incline on this job and the pressure that will be exerted on the forms, the workers in Figure 15-15 are adding extra bracing to support the riser forms. This set of forms also has a short sidewall form. The sidewall will be poured along with the steps.

Figure 15-14
Riser form is nailed to layout form

Figure 15-15
Extra bracing is added to support riser forms

Open Steps

The forms for an open concrete stairway are somewhat more difficult. You need to build a wooden platform, usually of ¾-inch sheathing, to provide support for the bottom slab of the stairs. The platform should be the length of the stairway, with the width extending out about 12 to 14 inches beyond each side of the stairs to provide a support for stringer bracing blocks (see Figure 15-16). Brace and support the back of the platform panel with 4 x 4 posts, as illustrated in the figure. The posts should rest on wedges so they'll be easy to adjust and to simplify their removal when the concrete sets. Place 2 x 4 cleats every 16 inches on the 4 x 4 supports.

Lay out the side stringers in the same way you would the supporting carriage for a flight of wooden stairs. Mark the treads and risers off on 2 x 12 wood planks and cut the stringers out. Save the cut-out pieces — you can nail them to a piece of 2 x 4 or 2 x 6 to make an additional stringer, if needed.

Figure 15-17 shows another method of building forms for steps. If you have a long span, wide stairs, or the stairs will be subject to heavy service, you can add additional bracing. Use a hanging stringer down the center of the risers. This prevents the center of the risers from being pushed out. You can use heavy 2 x 6 or 2 x 8 boards for the soffit.

Let's look at building the forms for open steps in more detail, starting with the platform, as shown in Figure 15-18.

1. Lay out line D for the bottom of the platform. This is the bottom line of the stair stringer that you cut out for the pattern.
2. Lay out line E, which is the top of the inclined member F, shown in Figures 15-18 and 15-19. From line E, you can obtain the length and bevels of F.
3. Cut two pieces of stock for the inclined F members, and lay them in place on the full-size layout to see if they fit.

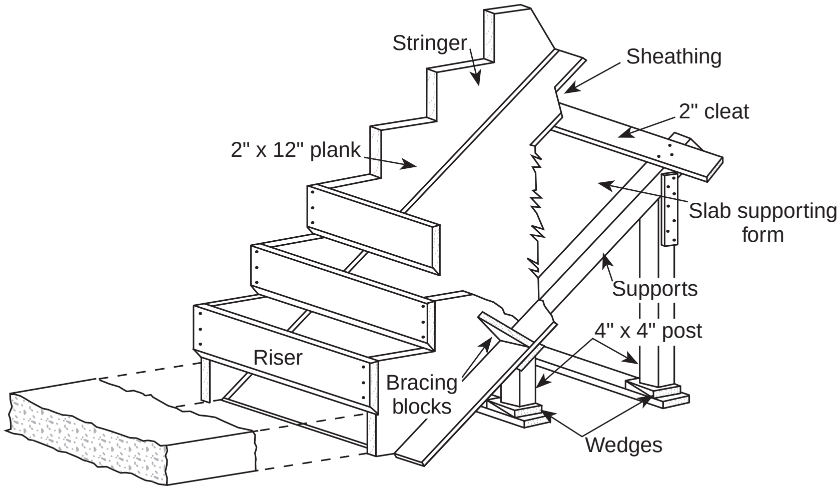


Figure 15-16
Forms for open concrete steps

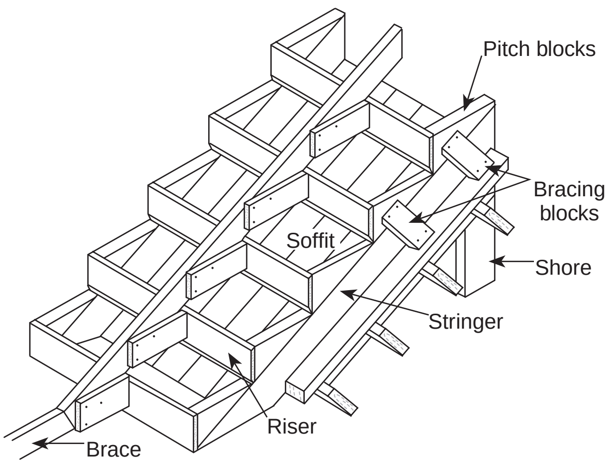


Figure 15-17
Forms for heavy-duty steps

4. Determine the length and bevel of the posts at G (Figures 15-18 and 15-19), and cut both of these.
5. Nail pieces F and G together and reinforce them with cleats (H), as shown in Figure 15-19.
6. Place the assembled support horses squarely against the wall where the form will be located.
7. Nail the cross joists (see Figure 15-20) to the inclined tops of the horse (Figure 15-18 E) with as few nails as you need to hold them in place. Space the cross joists 16 inches on center. They should project about 14 inches on each side of the supports.
8. Using either heavy tongue-and-groove sheathing boards or ¾-inch plywood sheathing, nail the platform in place, forming the bottom of the stair support (Figure 15-21). If using tongue-and-groove sheathing boards, lay the sheathing from the sides in to the center and put in the filler piece last. Shorter pieces can be used to advantage, as shown in the figure.

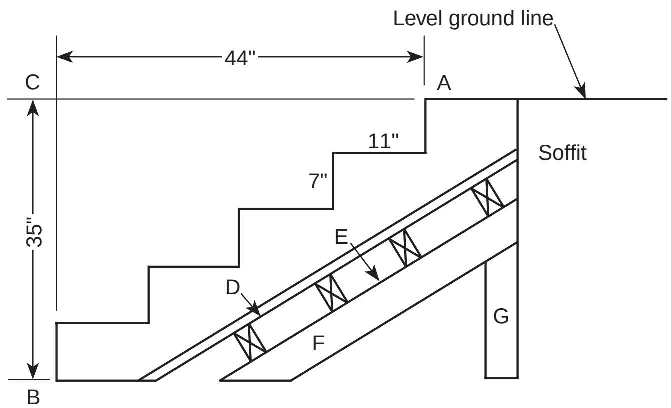


Figure 15-18
Layout of form for open stairs

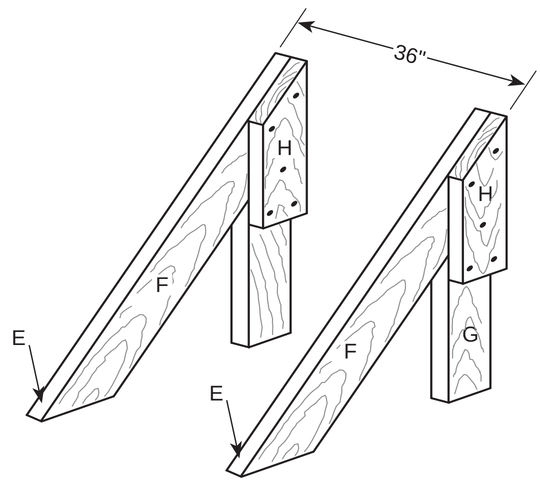


Figure 15-19
Supporting horses

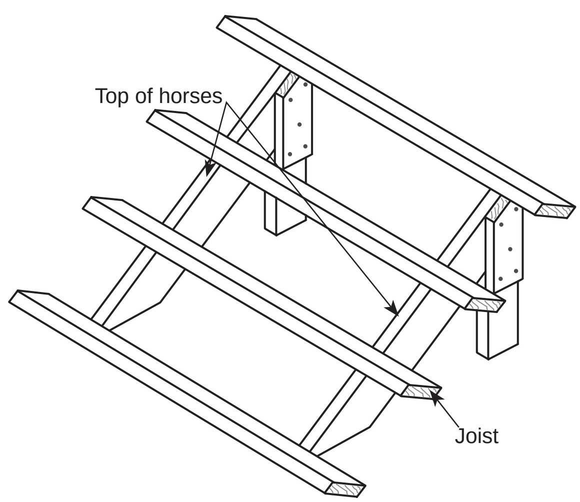


Figure 15-20
Cross joist nailed on horses

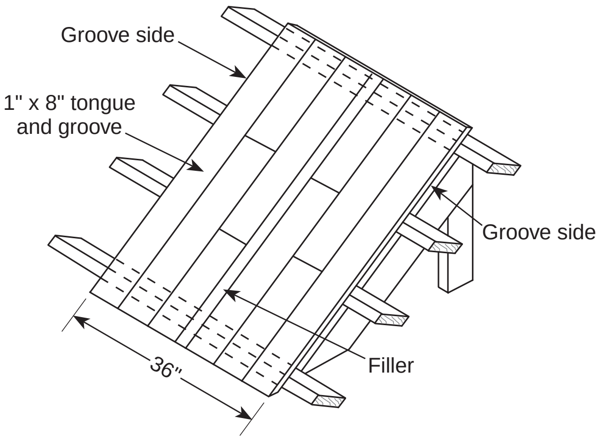


Figure 15-21
Sheathing nailed in place

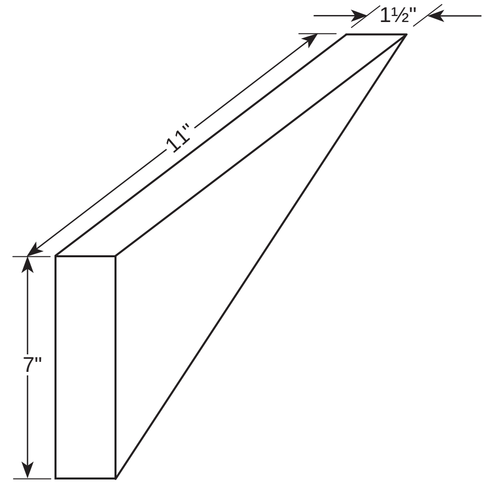


Figure 15-22
Pitch board

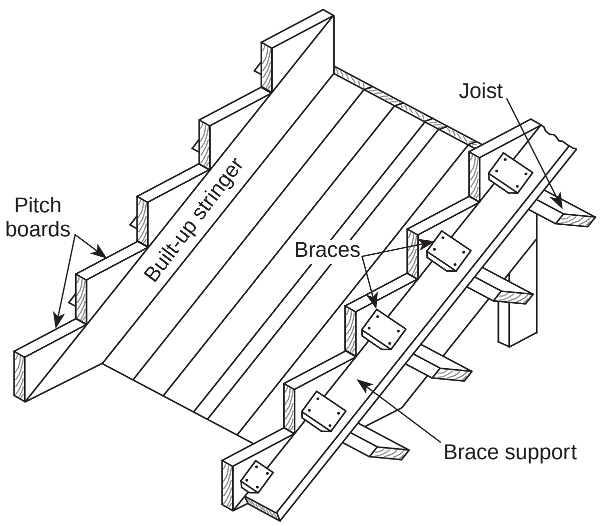


Figure 15-23
Stringers in place

9. Lay out and cut the pitch boards. See Figure 15-22 and refer back to Figure 15-5 for laying out pitch boards.
10. Nail the pitch boards to the 2 x 12 planks to form built-up stringers, and place them on each side of the form, as shown in Figure 15-23.
11. Nail 2 x 8 brace supports on the outside of each stringer. *Don't* drive the nails home.
12. Plumb the stair stringers and then fasten the brace supports into place. Add braces behind the peak of each pitch board to reinforce the built-up stringer (Figure 15-23).
13. An alternative method is to transfer the riser and tread layout onto plywood. Then cut out the layout and nail it to the 2 x 12 to create a form like the one in Figure 15-24.

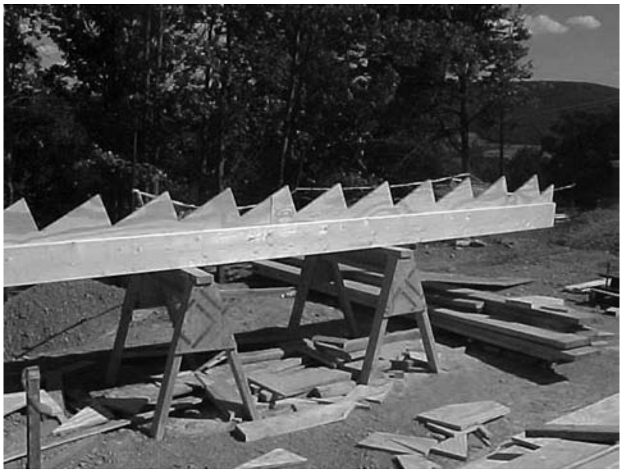


Figure 15-24
Nail the tread and riser layout to the form lumber

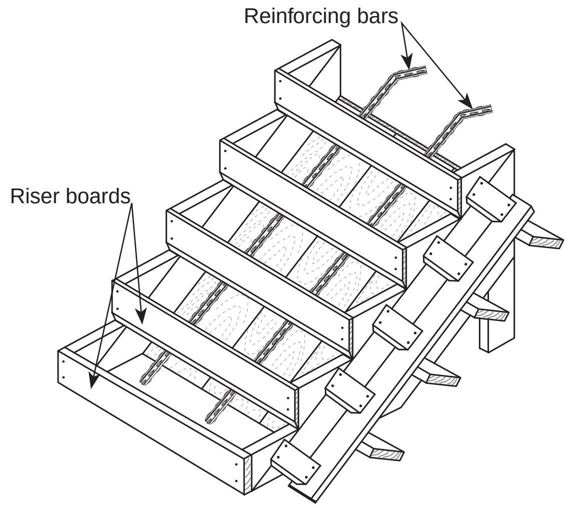


Figure 15-25
Finished form for open steps

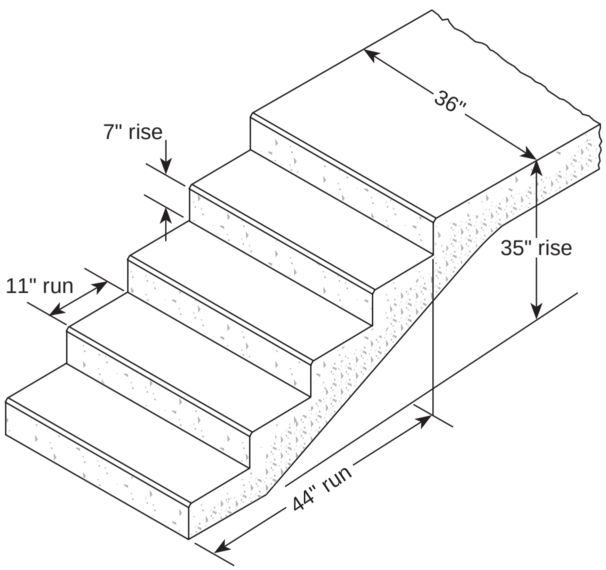


Figure 5-26
Completed open concrete steps

14. Cut the riser boards to length and width, and bevel the bottom edges. You don't need to bevel the bottom riser board.

15. Nail the risers to the stringers, as shown in Figure 15-25.

16. Check the tops of the riser boards and the tread line of the pitch boards to make sure they're all level. Recheck all members of the forms to be sure they haven't moved, or won't move from the pressure of the concrete.

17. Place reinforcing rods 1 inch from the surface of the sheathing.

Figure 15-26 shows the completed open concrete stairs. The rise of each step is 7 inches and the treads are 11 inches. The total rise is 35 inches and the total run is 44 inches.

Reinforcement for Concrete Steps				
			Reinforcement	
Number of steps	**Clear span**	**Slab thickness**	**Diameter**	**Spacing rods**
4	2'-2"	4"	¼"	10"
5	3'-0"	4"	¼"	10"
6	3'-10"	4"	¼"	7"
7	4'-8"	5"	¼"	7"
8	5'-6"	5"	¼"	5"
9	6'-4"	6"	¼"	5"
10	7'-2"	6"	⅜"	5"
11	8'-0"	6"	⅜"	6"

Figure 15-27
Concrete step reinforcement

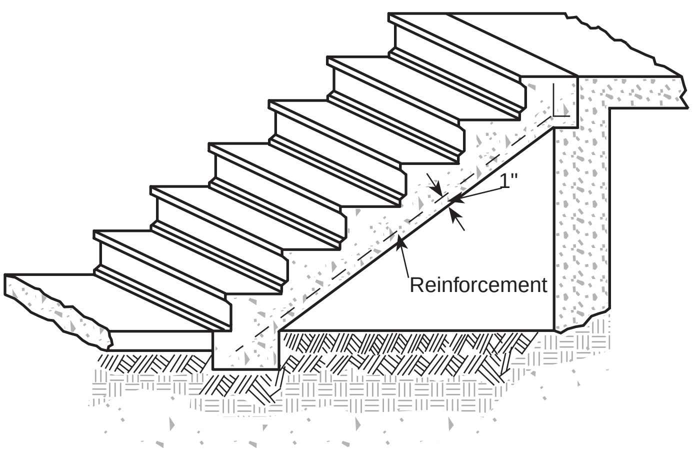


Figure 15-28
Section of steps showing reinforcing rods

Reinforcement for Concrete Steps

Place reinforcing rods 1 inch above the surface of the form supporting the slab, as mentioned earlier. Run the rods lengthwise up the platform. The table in Figure 15-27 gives recommended spacing of reinforcement for concrete steps. You can see the location of the rebar in the finished steps in Figure 15-28.

Remove the side forms and riser forms about 24 hours after the concrete has been poured so the troweled finishing coat of cement will bond with the faces of the treads, risers and side walls. Leave the supporting forms, the platform and the shoring, intact for about three weeks.

16
SMALL PROJECTS

It's important to plan ahead if you're going to prepare small batches of concrete for repairs or small projects. You should have all the tools you need for the project on hand and ready for use. If you wait until after the concrete is mixed to get your tools together, you may find the concrete "getting away from you." Then, when the concrete begins to hydrate (set up), you'll have a hard time finishing it off.

Planning

Before you head out to pick up the materials, you need to consider their weight. Let's say you want to make 1 cubic yard of concrete — that's a typical 5-bag mix. The ratio would be 1:2:3 (cement/sand/gravel).

Our mix will use the following (not including mixing water):

470 pounds of cement (5 bags)
940 pounds of dry sand
1,410 pounds of stone (½ #1 and ½ #2 stone)
2,820 pounds total weight

With a total weight of 2,820 pounds, you'll either need to make one trip with a large truck or several trip-loads with a small truck. Keep all the ingredients separate when transporting them, so it'll be easier to make up the correct proportions when you're ready to prepare your mix.

Proper mixes (depending on type of job)					
	Proportions (to 1 sack of cement)		Water per sack of cement, when sand is:		
Type of work	**Sand (CF)**	**Gravel (CF)**	**Wet (gal)**	**Moist (gal)**	**Dry (gal)**
Thin work, 2" to 4" thick	2	2	3½	3¾	4½
Waterproof and wear-resistant, 4" to 8" thick	2	3	3¾	4½	5½
General purpose, reinforced and waterproof, 8" to 12" thick	2½	3½	4½	5	6½
Mass concrete with moderate strength, not waterproof	3	5	5	6	7

Figure 16-1
Concrete mixtures for various kinds of work

Once you get the material to the worksite, place the bags of cement on a raised, dry surface so they won't be in contact with any moisture on the ground. Cover the bags until you're ready to use them. The sand and gravel should be placed on tarps and covered to protect them from contamination by dirt or moisture. Keep in mind that sand absorbs ground moisture easily, which can greatly increase its moisture content and weight. Covering the sand and gravel also prevents them from losing moisture through evaporation.

Unless you have some kind of moisture meter, you may have trouble determining the moisture content of the sand and gravel. Sand is the most questionable element when determining the amount of water to add. Here's a way to test the moisture in sand. When you pick up a handful of dry sand, it usually slips through your fist if you try to squeeze it. Moist sand sticks together — you might even be able to form it into a ball. You can form wet sand into a ball and usually squeeze beads of water out of it. The table in Figure 16-1 shows mixes for various types of concrete work and the amount of water to add to the different mixes.

Measuring Materials by Volume

You can also determine your mix proportions by volume using containers of equal size and volume. Old 5-gallon sheetrock cement pails are excellent for this purpose. They're lightweight plastic, have handles, are rustproof, and have lids to protect the contents. Be sure to clean out any gypsum residue. Soak them in water and scrape out any old material. Or, you can buy new 5-gallon pails at a building supply store.

Assume you want to prepare a 1:2:3 mix:

1. Measure 1 pail of portland cement

2. Measure 2 pails of dry sand
3. Measure 3 pails of gravel
4. Start with about ½ pail of water

Be sure you measure the water accurately. It's a *very* important part of the concrete mix. The water content affects the quality of the concrete during both the mixing and curing stages. Use too much water when you're mixing concrete, and you'll get weak concrete. Concrete made with 6 gallons of water per bag of cement is 40 percent stronger than concrete made with 8 gallons of water per bag. But if you use *too little* water, the concrete will be difficult to handle. Only the correct amount of water will provide a good, strong, workable concrete mix.

It's also important that you only use clean water. Be sure the water contains no oil, organic materials, strong acids or alkaline compounds. Never use seawater or brackish (saturated with salt) water. There are alkaline salts in both. Be *very* careful here. Even a small amount of salts in the mixing water can ruin a good concrete job. The general rule is: "If you won't drink it, it's not good for concrete."

Material Proportions

You can also purchase prepared mixes. Different concrete mixes are designed for different uses. When you buy a prepackaged mix, make sure you check the three-digit number printed on the bag. It provides very important information about the mix proportions. These numbers tell you the amounts of cement and gravel in the mix. A 1:2:3 mix contains one part cement, two parts sand and three parts gravel.

Mixing Small Concrete Batches

The best way to mix small batches of concrete is with a portable concrete mixer. Mixers come in ⅓- to ½-bag capacities, ½- to 1-bag capacities, and 1- to 1½-bag capacities. Mixers are quite expensive to buy ($1,500 to $4,000), so unless you'll be using one frequently, it's probably better to rent one — or better yet, borrow one from a friend. Figure 16-2 shows a typical portable mixer.

Figure 16-2
Portable concrete mixer

Figure 16-3
Small concrete mixer

You can get smaller model mixers, like the one in Figure 16-3. It has a 4-cubic-foot drum and will mix 2 cubic feet of concrete. This one operates with a 115-volt electric motor, is on wheels, and breaks down into three pieces for transporting or storage. The small mixer in Figure 16-4 also has the added advantage of being on wheels, making it easier to bring the concrete to the pour location. It also operates on 115-volt electric power, and will make 1½ cubic feet of concrete. Use two 80-pound bags of concrete mix and 1½ gallons of water. An 80-pound bag of concrete mix contains 0.6 cubic feet. These small mixers are much less expensive than the larger, sturdier models — about half the cost.

The drum on a concrete mixer turns around and the paddles inside the drum remain stationary. A mortar mixer, like the mortar miser mixer in Figure 16-5, operates just the opposite. The drum is stationary, and the paddles turn around inside the drum. Never mix concrete in a mortar mixer. The coarse aggregate (gravel) can get wedged between the paddles and the drum. That's not only messy to clean, but can create quite a costly repair. And — it won't adequately mix your concrete.

Portable concrete mixers are powered by both gas and electric engines. However, only the small electric mixers can be run on normal 115-volt household electricity. The larger portable electric mixers need 115/230-volt power.

Figure 16-4
Small concrete mixer with wheels

When you rent or borrow a mixer, make sure it's clean before you take it home to use. And always clean it out completely after you use it. If you allow concrete to harden inside the drum or on the outside of the mixer, it's very difficult to remove.

Using the Mixer

Concrete must be thoroughly mixed. To be sure your batch is properly mixed, let the mixer run at least three minutes after you've added the last ingredient. Here are some suggestions to follow when using a portable concrete mixer.

Figure 16-5
Masonry cement mixer

1. Turn the mixer on. *Don't put any ingredients in before turning the mixer on.*
2. Put about 25 percent of the mixing water in first to prevent the mix from clinging to the side of the mixer.
3. Add the dry ingredients one at a time, and add some water after each ingredient is mixed in.
4. When all the ingredients are added, let the mixer run for *at least* another three minutes.
5. After you've dumped the mix into a wheelbarrow or pan, put water into the mixer and let it continue to run to start cleaning out the mixer. If you're going to mix more batches, pour out the cleaning water before you begin to add in the measured amount of water for the new batch.

[Blank Page]

17

ESTIMATING CONCRETE QUANTITIES

Concrete isn't difficult to estimate because most concrete shapes are regular and they're usually clearly shown on the plans. You measure, estimate, and price concrete work in cubic feet or cubic yards — in other words, by volume. Small jobs are generally calculated in cubic feet while larger jobs are more often calculated in cubic yards. You'll need to know the height, width and thickness of the pour to determine its volume. All the measurements should be in whole numbers or decimals so you can easily calculate your quantities.

Footings and Walls

The best method to take off concrete for walls and footings is to add up all the lengths of the same cross section and make one volume calculation for each section. In other words, if you're building walls that are 12, 18, 22 and 24 feet long and all the footings are 1 foot 6 inches by 8 inches, calculate all your footings together. First convert all the inches to decimals of a foot. 1 foot 6 inches becomes 1.5 feet, and 8 inches is 0.67 foot. Add your lengths together (12 + 18 + 22 + 24 = 76), and then calculate the volume. Volume = 1.5 × 0.67 × 76 = 76.38 cubic feet.

When taking off footings and walls, be careful not to count the corners twice as you measure the lengths. For example, in Figure 17-1 you would calculate your take off like this:

$$[2 \times 36 \text{ ft.}] + [2 \times (24 \text{ ft.} - 2 \text{ ft.})] = 72 \text{ ft.} + 44 \text{ ft.} = 116 \text{ feet}$$

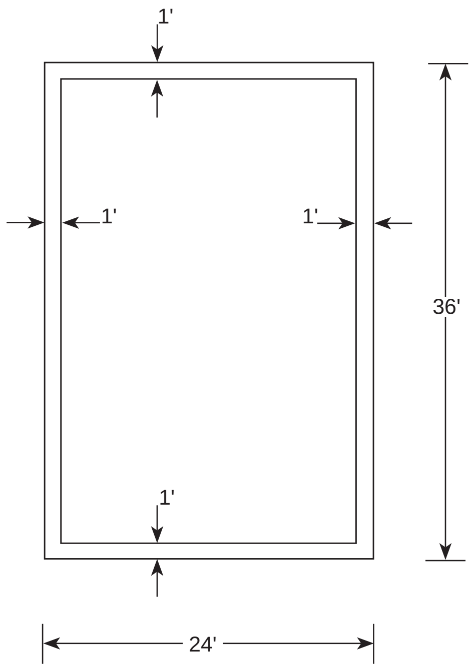


Figure 17-1
Measuring for footing calculations

Volume of Concrete in Footings per Foot of Length		
Width (ft.)	**Depth (ft.)**	**Volume per foot of length (cu. ft./ft.)**
1'-0"	6"	0.50
1'-2"	6"	0.585
1'-4"	6"	0.665
1'-6"	6"	0.75
1'-0"	8"	0.67
1'-2"	8"	0.784
1'-4"	8"	0.889
1'-6"	8"	1.00
1'-0"	10"	0.833
1'-2"	10"	0.972
1'-4"	10"	1.11
1'-6"	10"	1.25
1'-8"	10"	1.39
1'-10"	10"	1.53
2'-0"	10"	1.67
1'-2"	1'-0"	1.17
1'-4"	1'-0"	1.33
1'-6"	1'-0"	1.50
1'-8"	1'-0"	1.67
1'-10"	1'-0"	1.83
2'-0"	1'-0"	2.00

Figure 17-2
Calculating concrete footing volume per foot

You have to subtract 2 feet from the 24-foot width because you've already included this part of the wall when you measured the 36-foot length.

You can use tables like the one in Figure 17-2 to simplify your calculations. This one gives you the volume of concrete needed for various footing cross sections per foot of length. Walls are often taken off by the square foot of surface. That gives you one calculation that can serve for both the concrete take off and the formwork. Figure 17-3 gives the cubic feet of concrete required for 100 square feet of wall.

Flatwork and Slabs

Take off sidewalks and slab work by figuring the total surface area and then multiplying that by the required thickness. When the sections are simple and the dimensions are written on the plans, you can use basic geometrical formulas to calculate the area. However, if the sections are

Cubic Feet of Concrete per 100 Square Feet of Wall	
Wall thickness (in.)	**Concrete (cu. ft./100 sq. ft.)**
4	33.3
5	41.7
6	50.0
7	58.3
8	66.7
9	75.0
10	83.3
11	91.7
12	100.0

Figure 17-3
Calculating cubic feet of concrete for walls

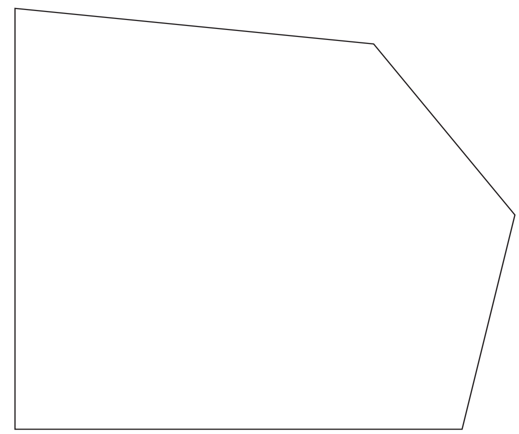


Figure 17-4
Irregular slab area

irregular, you may have to divide them up into simpler forms before you can calculate the area. Do this by drawing straight lines through the sections on the plans. You can then scale the plan dimensions off for the smaller sections, calculate the individual areas, and then add the totals together. Before you use this method, be sure that your plans are drawn to scale.

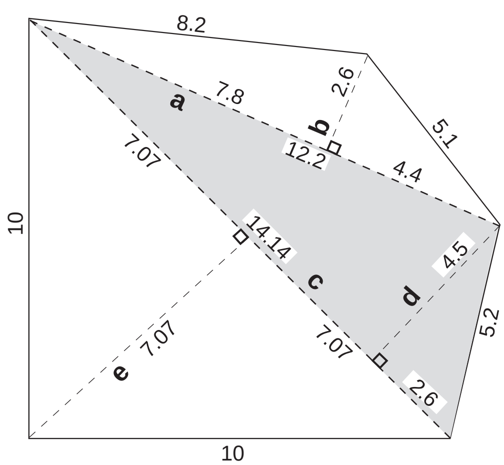


Figure 17-5
Divide complex areas into simpler shapes

Let's look at an example. Figure 17-4 shows an irregular slab area. In Figure 17-5 you can see how you'd divide up this type of slab into three triangles. You can then calculate the area of each triangle and add the areas together to get a total for the entire slab.

The formula for the area of a triangle is: A=½bh. Here's the formula for your calculation:

$$\begin{aligned} \mathbf{A} &= \tfrac{1}{2}(ab) + \tfrac{1}{2}(cd) + \tfrac{1}{2}(ce) \\ &= \tfrac{1}{2}(12.2 \times 2.6) + \tfrac{1}{2}(14.14 \times 4.5) + \tfrac{1}{2}(14.14 \times 7.07) \\ &= \tfrac{1}{2}(31.72) + \tfrac{1}{2}(63.63) + \tfrac{1}{2}(99.97) \\ &= 15.86 + 31.82 + 49.99 \end{aligned}$$

$$\mathbf{A = 97.67 \text{ square feet}}$$

Once you've determined the total area of the slab in square feet, multiply that by the depth of the slab in decimals of a foot. Your answer will be the volume (in cubic feet, or *cf*) of concrete needed to pour the slab.

Conversion Chart		
Inches	to	Feet
1	=	0.083
2	=	0.167
3	=	0.250
4	=	0.333
5	=	0.417
6	=	0.500
7	=	0.583
8	=	0.6667
9	=	0.750
10	=	0.833
11	=	0.917
12	=	1.000

Figure 17-6
Converting inches to decimals of a foot

Slabs — Cubic Measure per 100 Square Feet		
	Per 100 square foot slab	
Thickness	Cubic feet of concrete	Cubic yards of concrete
2"	16.7	0.62
3"	25.0	0.93
4"	33.3	1.24
5"	41.7	1.55
6"	50.0	1.85

Figure 17-7
Cubic feet and cubic yards of concrete required per inch of thickness

Let's say you want the irregular slab in Figure 17-5 to be 4 inches thick. First convert 4 inches to decimals of a foot. Using the chart in Figure 17-6, you see 4 inches is equal to 0.333 foot. Now multiply to get the volume:

$$\text{Volume} = 97.67 \text{ sq. ft.} \times 0.333 \text{ ft.} = 32.52 \text{ cf}$$

If you want to convert cf to cubic yards (*cy*), just divide by 27. There are 27 cf in a cy. Figure 17-7 gives you the conversion for cf and cy of concrete per 100 square feet of area for several slab thicknesses.

Basic Geometry Formulas

Use the following formulas to calculate area and volume for concrete pours in various shapes. The tables show examples of how to apply the formulas for each shape represented.

Rectangle

Area: A = (bh)
Volume: Area × thickness in feet
Cubic yards = Cubic feet ÷ 27

Figure 17-8 shows examples of calculations for finding the cubic yards of concrete required for a rectangular slab like the one in Figure 17-9.

Applying the formula:

$$\begin{aligned} A &= 12 \times 10 \\ &= 120 \text{ sq. ft.} \end{aligned}$$

Volume for a 4-in.-thick pour

$$\begin{aligned} \text{Vol.} &= 120 \text{ sq. ft.} \times 0.333 \text{ ft.} \\ &= 39.96 \text{ cf} \end{aligned}$$

$$\begin{aligned} \text{Vol. in cubic yards} &= 39.96 \text{ cf} \div 27 \\ &= 1.48 \text{ cy} \end{aligned}$$

Concrete Required for Rectangular Slab					
Measurements in feet			**Concrete required in cubic yards**		
b	**h**	**A**	**4" thick**	**6" thick**	**8" thick**
12	**10**	**120**	**1.48**	2.22	2.96
36	22	792	9.77	14.67	19.57
42	20	840	10.36	15.56	20.75

Figure 17-8
Cubic yards of concrete required for a rectangular slab

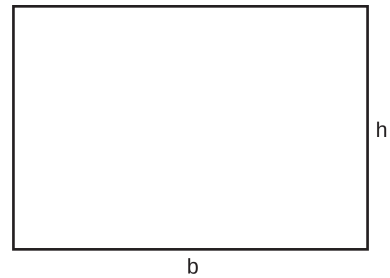


Figure 17-9
Rectangle

Parallelogram

Area: A = (bh)
Volume: Area × thickness in feet
Cubic yards = Cubic feet ÷ 27

Figure 17-10 shows examples of calculations for finding the cubic yards of concrete required for an irregular-shaped slab like the parallelogram in Figure 17-11.

Applying the formula:

$$A = 22.4 \times 18.9$$
$$= 423.4 \text{ sq. ft.}$$

Volume for an 8-in.-thick pour

$$\text{Vol.} = 423.4 \text{ sq. ft.} \times 0.667 \text{ ft.}$$
$$= 282.4 \text{ cf}$$
$$\text{Vol. in cubic yards} = 282.4 \text{ cf} \div 27$$
$$= 10.46 \text{ cy}$$

Concrete Required for Irregular Slab					
Measurements in feet			**Concrete required in cubic yards**		
b	**h**	**A**	**4" thick**	**6" thick**	**8" thick**
12	8	96	1.19	1.78	2.37
22.4	**18.9**	**423.4**	5.23	7.84	**10.46**
30	12	360	4.44	6.67	8.89

Figure 17-10
Cubic yards of concrete required for an irregular slab

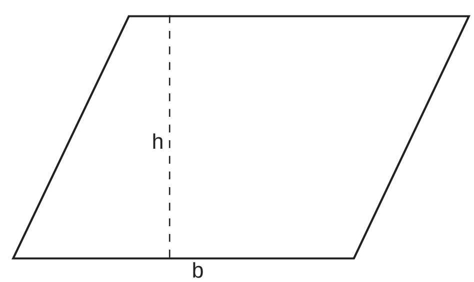


Figure 17-11
Parallelogram

Trapezoid

Area: A = (b1 + b2) × h ÷ 2
Volume: Area x thickness in feet
Cubic yards = Cubic feet ÷ 27

Figure 17-12 shows examples of calculations for finding the cubic yards of concrete required for an irregular-shaped slab like the trapezoid in Figure 17-13.

Applying the formula:

$$\begin{aligned} A &= (8.6 + 12.8) \times 10 \div 2 \\ &= 21.4 \times 10 \div 2 \\ &= 214 \div 2 \\ &= 107 \text{ square feet} \end{aligned}$$

Volume for a 4-in.-thick pour

$$\begin{aligned} \text{Vol.} &= 107 \text{ sq. ft.} \times .333 \text{ ft.} \\ &= 35.6 \text{ cf} \end{aligned}$$

$$\begin{aligned} \text{Vol. in cubic yards} &= 35.6 \text{ cf} \div 27 \\ &= 1.32 \text{ cy} \end{aligned}$$

Concrete Required for Irregular Slab						
Measurements in feet				Concrete required in cubic yards		
b1	b2	h	A	4" thick	6" thick	8" thick
8.6	**12.8**	**10**	**107.00**	**1.32**	1.98	2.64
10	15	8	100.00	1.23	1.85	2.47
10	15	10	125.00	1.54	2.31	3.09

Figure 17-12
Cubic yards of concrete required for an irregular slab

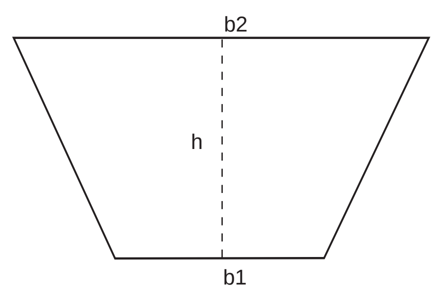


Figure 17-13
Trapezoid

Triangle

Area: A = ½bh
Volume: Area × thickness in feet
Cubic yards = Cubic feet ÷ 27

Figure 17-14 shows examples of calculations for finding the cubic yards of concrete required for a triangular slab like the one in Figure 17-15.

Applying the formula:

$$\begin{aligned} A &= 25 \times 15 \div 2 \\ &= 375 \div 2 \\ &= 187.5 \text{ square feet} \end{aligned}$$

Volume for an 8-in.-thick pour

$$\begin{aligned} \text{Vol.} &= 187.5 \text{ sq. ft.} \times 0.667 \text{ ft.} \\ &= 125 \text{ cf} \end{aligned}$$

$$\begin{aligned} \text{Vol. in cubic yards} &= 125 \text{ cf} \div 27 \\ &= 4.63 \text{ cy} \end{aligned}$$

Concrete Required for Triangular Slab

Measurements in feet			Concrete required in cubic yards		
b	**h**	**A**	**4" thick**	**6" thick**	**8" thick**
3	6	9	0.11	0.17	0.22
12.4	22.6	140.1	1.73	2.59	3.46
25	**15**	**187.5**	2.31	3.47	**4.63**
28.7	19	272.7	3.37	5.05	6.73

Figure 17-14
Cubic yards of concrete required for a triangular slab

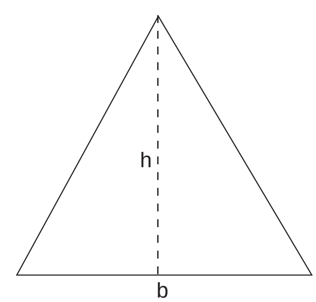


Figure 17-15
Triangle

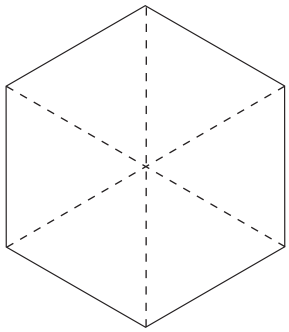


Figure 17-16
Polygon

Polygons

To find the area of any polygon (pentagon, hexagon, etc.), divide it into triangles as shown in Figure 17-16, calculate the area for each triangle, and then add them up.

Circle

Area: $A = \pi r^2$

Area: $A = (\pi d^2) \div 4$ *or* $d^2 \times 0.7854$

Volume: Area × thickness in feet

Cubic yards = Cubic feet ÷ 27

Figure 17-17 shows examples of calculations for finding the cubic yards of concrete required for a circular slab like the one in Figure 17-18.

Applying the formula using the radius:

$$\begin{aligned} A &= 3.1416\ (\text{pi}) \times 5^2 \\ &= 3.1416 \times 25 \\ &= 78.54 \text{ square feet} \end{aligned}$$

Volume for a 6-in.-thick pour

$$\begin{aligned} \text{Vol.} &= 78.54 \text{ sq. ft.} \times 0.5 \text{ ft.} \\ &= 39.27 \text{ cf} \end{aligned}$$

$$\begin{aligned} \text{Vol. in cubic yards} &= 39.27 \text{ cf} \div 27 \\ &= 1.45 \text{ cy} \end{aligned}$$

Using the diameter:

$$\begin{aligned} A &= (3.1416 \times 4^2) \div 4 \\ &= (3.1416 \times 16) \div 4 \\ &= 50.27 \div 4 \\ &= 12.57 \text{ sq. ft.} \end{aligned}$$

Volume for a 6-in.-thick pour

$$\begin{aligned} \text{Vol.} &= 12.57 \text{ sq. ft.} \times 0.5 \text{ ft.} \\ &= 6.29 \text{ cf} \end{aligned}$$

$$\begin{aligned} \text{Vol. in cubic yards} &= 6.29 \text{ cf} \div 27 \\ &= 0.23 \text{ cy} \end{aligned}$$

Concrete Required for Circular Slab					
Measurements in feet			Concrete required in cubic yards		
r	d	A	4" thick	6" thick	8" thick
5		**78.54**	0.97	**1.45**	1.94
8.7		237.8	2.94	4.40	5.87
	4	**12.57**	0.16	**0.23**	0.31
	11	95.03	1.17	1.76	2.35
	23	415.5	5.13	7.69	10.26

Figure 17-17
Cubic yards of concrete required for an circular slab

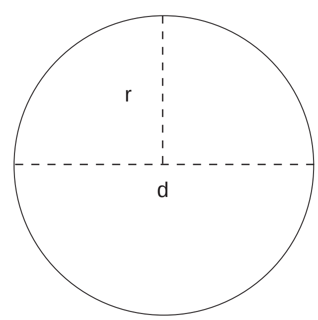


Figure 17-18
Circle

Concrete Required for Elliptical Slab					
Measurements in feet			Concrete required in cubic yards		
r1	r2	A	4" thick	6" thick	8" thick
5	8	125.7	1.55	2.33	3.10
6.6	12	237.8	3.07	4.61	6.14
7	**9**	**197.9**	**2.44**	3.67	4.89

Figure 17-19
Cubic yards of concrete required for an elliptical slab

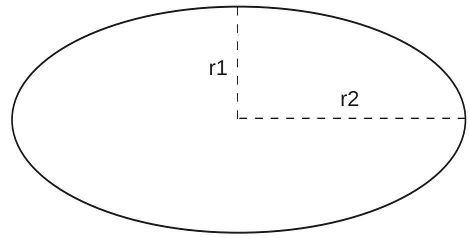


Figure 17-20
Ellipse

Ellipse

Area: $A = \pi r^1 \times r^2$
Volume: Area × thickness in feet
Cubic yards = Cubic feet ÷ 27

Figure 17-19 shows examples of calculations for finding the cubic yards of concrete required for an elliptical slab like the one in Figure 17-20.

Applying the formula:

$$A = 3.1416 \times 7 \times 9$$
$$= 197.92 \text{ square feet}$$

Volume for a 4-in.-thick pour

$$\text{Vol.} = 197.92 \text{ sq. ft.} \times 0.333 \text{ ft.}$$
$$= 65.9 \text{ cf}$$
$$\text{Vol. in cubic yards} = 65.9 \text{ cf} \div 27$$
$$= 2.44 \text{ cy}$$

Circular Ring

To find the area of a circular ring, add the diameters of the two circles, and multiply that by the difference of the diameters of the two circles, and multiply that product by 0.7854.

Area of circular ring = [(Circle A d + Circle B d) ×
(Circle A d – Circle B d)] × 0.7854
Volume: Area × thickness in feet
Cubic yards = Cubic feet ÷ 27

Concrete Required for Circular Ring					
Measurements in feet			Concrete required in cubic yards		
Circle A diameter	Circle B diameter	Area of ring	4" thick	6" thick	8" thick
10	**8**	**28.27**	0.35	0.52	**0.70**
15	12	63.62	0.78	1.18	1.57
20	15	137.45	1.70	2.55	7.63

Figure 17-21
Cubic yards of concrete required for a circular ring

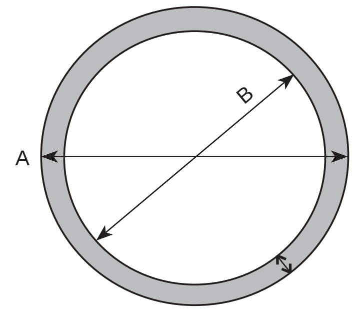


Figure 17-22
Circular ring

Figure 17-21 shows examples of calculations for finding the cubic yards of concrete required for a circular ring like the one in Figure 17-22.

Applying the formula:

$$\text{Area of a circular ring} = [(\text{Circle A diameter} + \text{Circle B diameter}) \times (\text{Circle A diameter} - \text{Circle B diameter})] \times 0.7854$$

$$\begin{aligned}\text{Area of a circular ring} &= [(10 + 8) \times (10 - 8)] \times 0.7854 \\ &= (18 \times 2) \times 0.7854 \\ &= 36 \times 0.7854 \\ &= 28.27 \text{ sq. ft}\end{aligned}$$

Volume for an 8-in.-thick pour

$$\begin{aligned}\text{Vol.} &= 28.27 \text{ sq. ft.} \times 0.667 \text{ ft.} \\ &= 18.86 \text{ cf}\end{aligned}$$

$$\begin{aligned}\text{Vol. in cubic yards} &= 18.86 \text{ cf} \div 27 \\ &= 0.70 \text{ cy}\end{aligned}$$

Other Useful Formulas

The following formula information is useful in calculating area and volume.

Circle

- Pi (π) = 3.1416
- Circumference of a circle = π (3.1416) × diameter
- Radius of a circle = ½ diameter
- Diameter of a circle = 2 × radius
- Diameter of a circle = circumference × π (3.1416)

- Diameter of circle that shall contain the area of a given square = side of square × 1.1284
- Doubling the diameter of a circle increases the area four times; tripling the diameter increases the area nine times

Square

- Area of a square = side^2
- Diagonal of a square = side × 1.4142
- Side of a square = diagonal × 0.7071
- Side of square that shall equal area of circle = diameter × 0.8862
- Side of square that shall equal area of circle = circumference × 0.2821

Rectangle

- Diagonal of a rectangle = square root of the width^2 + length^2

Cube

- Area of the surface of a cube = side^2 × 6
- Volume of a cube = side^3
- Diagonal of a cube = side × 1.732

Cylinder

- Surface of cylinder or prism = area of both ends + length × circumference
- Area of curved surface (cylinder) = diameter × length × 3.1416
- Volume of cylinder = diameter^2 × length^2 × 0.7854

Sphere

- Surface of sphere = diameter × circumference
- Solidity of sphere = surface × $\frac{1}{6}$ diameter
- Solidity of sphere = diameter^3 × 0.5236
- Solidity of sphere = radius^3 × 4.1888
- Solidity of sphere = circumference^3 × 0.016887
- Diameter of sphere = cube root of solidity × 1.2407
- Diameter of sphere = square root of surface × 0.56419

- Circumference of sphere = square root of surface × 1.772454
- Circumference of sphere = cube root of solidity × 3.8978

Pyramid or Cone

- Surface of pyramid or cone = circumference of base × ½ of the slant height + the area of base

Estimating Aids

There are a couple of shortcuts that you can use to speed up your estimating process. Conversion tables are always helpful, and a concrete calculator can help you estimate the concrete volume you need for a variety of projects in just seconds. Most concrete suppliers have quick calculators for concrete on their website for you to use, but a masonry contractor really needs a calculator that he can carry with him.

Concrete Calculators

Hand-held calculators, like the ConcreteCalc Pro, allow you to give quick, accurate estimates of the concrete volume you need while you're in the field. You can estimate concrete placement for slabs and flatwork, as well as concrete fills for a block wall or a column. These calculators offer special features for estimating area, volume and weight per volume, calculations for circular layouts and stair layouts, and they even have the ability to quickly determine the number of truckloads of concrete you'll need based on load size. They work in both standard and metric and also function as regular math calculators. A concrete calculator is a valuable tool for concrete, masonry and paving work.

Estimating Books and Programs

Estimating books and computer programs are also valuable aids. The *National Concrete & Masonry Estimator* by Dan Atcheson is an excellent resource. It has manhours, labor and material costs for all types of concrete and masonry work. The book comes with *National Estimator*, an easy-to-use estimating program on CD-ROM that you can install on your computer. You can download a trial version of the program at www.Craftsman-book.com. Or, you'll find an order form for *National Concrete & Masonry Estimator,* as well as other books published by Craftsman Book Co., in the back of this book.

Number of Square Feet from 1 Cubic Yard of Concrete							
Thickness in inches	**No. sq. ft.**	**Thickness in inches**	**No. sq. ft.**	**Thickness in inches**	**No. sq. ft.**	**Thickness in inches**	**No. sq. ft.**
1	324	4	81	7	46	10	32
1¼	259	4¼	76	7¼	44	10¼	31
1½	216	4½	72	7½	43	10½	31
1¾	185	4¾	68	7¾	42	10¾	30
2	162	5	65	8	40	11	29½
2¼	144	5¼	62	8¼	39	11¼	29
2½	130	5½	59	8½	38	11½	28
2¾	118	5¾	56	8¾	37	11¾	27½
3	108	6	54	9	36	12	27
3¼	100	6¼	52	9¼	35	12¼	26½
3½	93	6½	50	9½	34	12½	26
3¾	86	6¾	48	9¾	33	12¾	25½

Figure 17-23
Coverage per cubic yard of concrete

Concrete Conversion Tables

Figures 17-23 through 17-25 are useful conversion tables, especially for small concrete pours where smaller quantities of concrete are needed. Figure 17-23 shows the number of square feet and thickness in inches that 1 cubic yard of concrete can cover. You can use this information to estimate any concrete pour by the cubic yard. Figure 17-24 converts gallons of water and bags of cement to pounds for calculating weight. Figure 17-25 provides conversion formulas for Fahrenheit to Celsius temperatures (and the reverse) and a list of equivalent temperatures. The last table, Figure 17-26, gives you mix ratios for the base and finish course for concrete walls, floors, sidewalks and slabs of various thicknesses.

Each of these aids will help you make accurate bids, reduce your waste, and improve your design capabilities and estimating efficiency.

Conversion Chart — Gallons of Water & Bags of Cement to Pounds			
Water		Cement	
U.S. Gallons	Pounds	Bags	Pounds
1	8.35		
2	16.69	0.25	23.5
3	25.04	0.50	47
4	33.38	0.75	70.5
5	41.73		
		1.00	94
6	50.07	1.25	117.5
7	58.42	1.50	141
8	66.76	1.75	164.5
9	75.11		
10	83.45	2.00	188
		2.25	211.5
11	91.80	2.50	235
12	100.14	2.75	258.5
13	108.49		
14	116.83	3.00	282
15	125.18	3.25	305.5
		3.50	329
16	133.52	3.75	352.5
17	141.87		
18	150.21	4.00	376
19	158.56	4.25	399.5
20	166.90	4.50	423
		4.75	446.5
21	175.25		
22	183.59	5.00	470
23	191.94	5.25	493.5
24	200.28	5.50	517
25	208.63	5.75	540.5
26	216.97	6.00	564

Figure 17-24
Conversion factors for concrete mixes

Conversion Chart — Fahrenheit to Celsius	
Temperature	
°F	°C
0	–17.8
5	–15.0
10	–12.2
15	–9.4
20	–6.7
25	–3.9
30	–1.1
32	0
35	1.7
40	4.4
45	7.2
50	10.0
55	12.8
60	15.6
65	18.3
70	21.2
75	23.9
80	26.7
85	29.4
90	32.2
95	35.0
100	37.8
105	40.6
110	43.3
115	46.1
120	48.9
125	51.7
°F = 1.8 × °C + 32	
°C = (°F – 32) ÷ 1.8	

Figure 17-25
Fahrenheit to Celsius temperature conversion

Materials for 100 sf of Walls, Floors, Sidewalks, or any Slabs															
Concrete Base															
	1:1¾:2¾			1:2:3			1:2:3½			1:2½:4			1:3:5		
Slab Thickness (inches)	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.
2½	5.7	0.36	0.62	5.2	0.40	0.59	4.8	0.37	0.64	4.2	0.40	0.63	3.4	0.39	0.65
3	6.8	0.43	0.74	6.3	0.48	0.71	5.8	0.44	0.76	5.0	0.48	0.75	4.1	0.47	0.78
3½	8.0	0.51	0.86	7.3	0.56	0.83	6.8	0.52	0.90	5.8	0.56	0.88	4.8	0.55	0.92
4	9.1	0.58	0.99	8.4	0.64	0.95	7.7	0.59	1.02	6.6	0.64	1.01	5.5	0.63	1.05
4½	10.3	0.65	1.11	9.4	0.72	1.06	8.7	0.66	1.15	7.5	0.72	1.13	6.1	0.70	1.17
5	11.4	0.73	1.23	10.5	0.80	1.19	9.7	0.74	1.28	8.3	0.80	1.26	6.8	0.79	1.31
5½	12.6	0.80	1.36	11.6	0.88	1.31	10.7	0.82	1.41	9.2	0.88	1.39	7.5	0.87	1.45
6	13.7	0.87	1.48	12.6	0.96	1.42	11.6	0.89	1.54	10.0	0.96	1.52	8.2	0.94	1.57

Wearing or Finish Course														
	1:1½		1:2		1:1:1			1:1:1½			1:1:2			
Thickness (in inches)	Cement Sacks	Sand Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.	Cement Sacks	Sand Cu. Yd.	Stone Cu. Yd.
½	2.4	0.13	2.0	0.15	2.1	0.08	0.08	1.8	0.07	0.10	1.6	0.06	0.12
¾	3.6	0.19	2.9	0.22	3.1	0.11	0.11	2.7	0.10	0.15	2.4	0.09	0.18
1	4.8	0.26	3.9	0.29	4.2	0.15	0.15	3.7	0.14	0.20	3.2	0.12	0.24
1¼	6.0	0.33	4.9	0.36	5.2	0.19	0.19	4.6	0.17	0.25	4.1	0.15	0.30
1½	7.2	0.40	5.9	0.43	6.3	0.23	0.23	5.5	0.20	0.30	4.9	0.18	0.36
1¾	8.4	0.46	6.9	0.50	7.3	0.27	0.27	6.4	0.24	0.36	5.7	0.21	0.42
2	9.6	0.53	7.9	0.58	8.3	0.31	0.31	7.3	0.27	0.41	6.5	0.25	0.50

Figure 17-26
Concrete base and finish course mixes

[Blank Page]

18

OSHA

The Occupational Safety and Health Administration (OSHA) was established in 1970 as part of the U.S. Department of Labor. Its goal is to keep workers safe and healthy — and it has succeeded. Workplace fatalities have been reduced by 62 percent and injuries and illness by 40 percent, in spite of the fact that employment has nearly doubled in that time period. It's clearly a program that works, and its standards should be enforced and followed in every workplace and on every jobsite.

As part of their enforcement program, OSHA is increasingly making surprise visits to jobsites, and issuing citations where they find violations. They can even shut down your job. It's in everybody's interest to have OSHA's guidelines on hand, and to familiarize yourself with them.

OSHA's standard for concrete and masonry construction is in Subpart Q, Concrete and Masonry Construction, Title 29 of the Code of Federal Regulations (CFR). Part 1926.700 through 706 provides the compliance standards required of construction employers to protect their workers from accidents and injuries that may result from:

- The premature removal of formwork
- The failure to correctly brace masonry walls
- The failure to support precast panels
- The inadvertent operation of equipment
- The failure to guard against injury from falls on reinforcing steel

Subpart Q prescribes performance-oriented requirements designed to help protect all construction workers from the hazards associated with concrete and masonry construction operations at construction, demolition, alteration, or repair work sites. Other relevant provisions located in both the general industry and construction standards (29 CFR Parts 1910 and 1926) also apply to these operations.

Changes to the Standard

OSHA's concrete and masonry standard includes the following important changes:

- It expands and toughens protection against masonry wall collapses by requiring bracing and a limited access zone prior to and during the construction of a wall.
- It permits employers to use several recently-developed methods of testing concrete instead of the single method employed over the last several years.
- It sets and clarifies requirements for both cast-in-place concrete and precast concrete during construction.

Components of the New Standard

Subpart Q of the standard is divided into the following major groups:

- Scope, application, and definitions (29 CFR 1926.700)
- General requirements (29 CFR 1926.701)
- Equipment and tools (29 CFR 1926.702)
- Cast-in-place concrete (20 CFR 1926.703)
- Precast concrete (29 CFR 1926.704)
- Lift-slab construction (29 CFR 1926.705)
- Masonry construction (29 CFR 1926.706)

We'll give a brief analysis of most of these topics in this chapter. The complete text of Parts 1926.700 through 705 is reproduced at the end of this chapter.

Figure 18-1
Safety caps cover reinforcing steel bars

General Requirements of the Standard

The General Requirements section of Subpart Q (29 CFR, Part 1926.701) concerns all masonry and concrete contractors. Everyone working in the trade should be familiar with the provisions in this section. Here's an overview of the information:

Construction Loads — Employers can't place construction loads on a concrete structure or portion of a concrete structure unless a person who is qualified in structural design determines that the structure or portion of the structure is capable of supporting the intended loads.

Reinforcing Steel — To eliminate possible impalement hazards, cover all protruding reinforcing steel onto which employees could fall with safety guards. Figure 18-1 shows safety caps on steel reinforcement bars.

Post-Tensioning Operations — Employees (except those essential to the post-tensioning operation) aren't permitted behind the jack during tensioning operations. There must be signs and barriers in place to limit employee access to the post-tensioning area during tensioning operations.

Concrete Buckets — Employees aren't allowed to ride in concrete buckets.

Working Under Loads — Employees can't be working under concrete buckets while the buckets are being elevated or lowered into position.

When at all practical, route elevated concrete buckets so that no employees — or the fewest employees possible — are exposed to the hazards associated with falling concrete buckets.

Personal Protective Equipment — Never allow employees to use a pneumatic hose to apply a cement, sand, and water mixture unless they're wearing protective head and face equipment.

Equipment and Tools

You can find detailed information on requirements for equipment and tools in Subpart Q (29 CFR, Part 1926.702) under the following headings:

- Bulk cement storage
- Concrete mixers
- Power concrete trowels
- Concrete buggies
- Concrete pumping systems
- Concrete buckets
- Tremies
- Bullfloats
- Masonry saws
- Lockout/tagout procedures

Requirements for Cast-In-Place Concrete

The exact wording and requirements for the following information from Subpart Q (29 CFR, Part 1926.703) is reproduced at the end of this chapter.

General Requirements for Formwork

Design, fabricate, erect, support, brace, and maintain formwork so that it'll be capable of supporting, without failure, all vertical and lateral loads that might be applied to it. As the Appendix to the standard indicates, formwork that's designed, fabricated, erected, supported, braced, and maintained in conformance with Sections 6 and 7 of the American National Standard for Construction and Demolition Operations — Concrete and Masonry Work (ANSI) A10.9-1983, will also meet this requirement.

Drawings or Plans

Have all drawings and plans available at the jobsite, including revisions for the jack layout, formwork (including shoring equipment), working decks, and scaffolds.

Shoring and Reshoring

Inspect all shoring equipment (including equipment used in reshoring operations) prior to its erection to determine that the equipment meets the requirements specified in the formwork drawings.

Never use damaged equipment for shoring. Once you've erected shoring equipment, it must be inspected just prior to, during, and immediately after placing the concrete. Reinforce shoring equipment that's damaged or weakened immediately.

Ensure sills for shoring are sound, rigid, and capable of carrying their maximum intended load. Secure all base plates, shore heads, extension devices and adjustment screws. Make sure they're in firm contact with the foundation and the form, when necessary.

Eccentric loads on shore heads are prohibited, unless the members are designed for this type of loading. There are additional shoring requirements for using single-post shores one on top of another (tiered). In that instance the shores must be:

- Designed by a qualified designer, and once erected, inspected by an engineer qualified in structural design
- Vertically aligned
- Spliced to prevent misalignment
- Adequately braced in two mutually perpendicular directions at the splice level, with each tier diagonally braced in the same two directions

Don't adjust single-post shores to raise the formwork after placing the concrete.

When the concrete must support loads in excess of its capacity, erect reshoring as you remove the original forms and shores.

Vertical Slip Forms

The steel rods or pipes that the jacks climb on or which lift the forms must be:

1. specifically designed for that purpose, and
2. adequately braced where they're not encased in concrete.

The forms must be designed to prevent excessive distortion of the structure during the jacking operation. Position the jacks and vertical supports so that the loads don't exceed the rated capacity of the jacks.

Make sure the jacks or other lifting devices have mechanical dogs or other automatic holding devices to support the slip forms in case the power supply or lifting mechanisms fail. Never exceed the predetermined safe lift rate.

"Don't remove forms and shores (except those used for slabs on grade and slip forms) until the employer determines that the concrete has gained sufficient strength to support its weight and superimposed loads."

Maintain the form structure within all the design tolerances specified for plumb during the jacking operation. Provide vertical slip forms with scaffolds or work platforms where employees will be working or where they may need to pass one another while on the forms.

Reinforcing Steel

To prevent overturning or collapse, adequately support reinforcing steel for walls, piers, columns, and similar vertical structures.

Employers must take measures to prevent unrolled wire mesh from recoiling. These measures may include, but aren't limited to, securing each end of the roll or turning the rolls over.

Removal of Formwork

Don't remove forms and shores (except those used for slabs on grade and slip forms) until the employer determines that the concrete has gained sufficient strength to support its weight and superimposed loads. That determination must be based on compliance with one of the following:

1. The plans and specifications stipulate conditions for removal of forms and shores, and those conditions have been followed.
2. The concrete has been properly tested with an appropriate American Society for Testing and Materials (ASTM) standard test method designed to indicate concrete compressive strength, and the test results indicate that the concrete has gained sufficient strength to support its weight and superimposed loads.

If you've reshored, don't remove it until the concrete being supported has attained adequate strength to support its weight and all the loads placed upon it.

Precast Concrete

Make sure precast concrete wall units, structural framing, and tilt-up wall panels are adequately supported to prevent overturning or collapse until you've completed the permanent connections.

Lifting inserts that are embedded or otherwise attached to tilt-up wall panels must be capable of supporting at least two times the maximum intended load applied or transmitted to them; lifting inserts for other precast members must be capable of supporting four times the load. Lifting hardware should be capable of supporting at least five times the maximum intended load applied or transmitted to the lifting hardware.

Only permit essential employees under precast concrete that's being lifted or tilted into position.

Lift-Slab Operations

Lift-slab operations must be designed and planned by a registered professional engineer with experience in lift-slab construction. The contractor must receive detailed instructions and sketches showing the prescribed method of erection in order to properly implement the design plans. These must include provisions for ensuring the lateral stability of the building/structure during construction.

Jacking equipment should be marked with the manufacturer's rated capacity and be capable of supporting at least 2½ times the load that will be lifted during the jacking operations. Never overload the equipment. For the purpose of this provision, jacking equipment includes any loadbearing component that's used to carry out the lifting operations. This includes, but isn't limited to, the following equipment: threaded rods, lifting attachments, lifting nuts, hook-up collars, T-caps, shearheads, columns, and footings.

Jack/lifting units must be designed and installed so that they can't lift or continue to lift when loaded in excess of their rated capacity. They must have a safety device that'll allow the jack/lifting units to support the load at any position in the event they malfunction or they're unable to continue lifting.

Permit only employees essential to the jacking operation in the building or structure while a jacking operation is taking place, unless the building or structure has been reinforced sufficiently to ensure its integrity during erection. The phrase “reinforced sufficiently to ensure its integrity” as used in this paragraph means that a registered professional engineer, independent of the engineer who designed and planned the lifting operation, has determined from the plans that if there’s a loss of support at any jack location, that loss will be confined to that location and the structure as a whole will remain stable.

Under no circumstances should any employee who isn’t essential to the jacking operation be permitted immediately beneath a slab that’s being lifted.

Masonry Construction

Whenever a masonry wall is being constructed, the contractor must establish a limited access zone prior to the start of construction. The limited access zone should conform to the following:

- be equal to the height of the wall to be constructed plus 4 feet (1.2 meters), and run the entire length of the wall;
- be on the side of the wall that won’t have scaffolding;
- entry restricted to just those employees actively engaged in constructing the wall;
- kept in place until the wall is adequately supported to prevent overturning and collapse, unless the height of the wall is more than 8 feet (2.4 meters) and it’s unsupported, in which case it must be braced. The bracing must remain in place until the permanent supporting elements of the structure are in place.

What Other Help Can OSHA Provide?

In addition to establishing safety standards, OSHA also provides guidelines for training and education programs to help employers and their employees develop good workplace health and safety practices. These voluntary provisions are covered in the Safety and Health Program Management Guidelines (Federal Register 54(18):3908-3916, January 26, 1989).

There are provisions for free on-site consultations for employers who want help establishing a safer work environment. OSHA also provides an emergency call line for employees who need to report a life-threatening work situation. Let's take a closer look at some of the benefits provided by this program.

Safety and Health Program Management Guidelines

Effective management of worker safety and health protection is clearly a factor in reducing the extent and severity of work-related injuries and illnesses — and their related costs.

The guidelines, which apply to all places of employment covered by OSHA, identify four general elements that are critical to the development of a successful safety and health management program:

1. management commitment and employee involvement
2. work site analysis
3. hazard prevention and control
4. safety and health training

There are specific actions recommended under each of those four topics to help employers achieve an effective safety and health program. You can get a single free copy of the guidelines from the Department of Labor by sending a self-addressed mailing label with your request to:

U.S. Department of Labor
OSHA / OICA Publications
P.O. Box 37535
Washington, DC 20013-7535
Telephone: (202) 693-1888
Fax: (202) 693-2498
www.osha.gov

Free On-site Consultation

Employers who want help in establishing and maintaining a safe and healthful workplace can request assistance. An on-site consultation is provided by OSHA at no cost to the employer. The consultation service, primarily developed for smaller employers with hazardous operations, is delivered by state government agencies or universities employing professional safety consultants and health consultants. They provide a comprehensive appraisal of all work practices and environmental hazards in the workplace and all aspects of the employer's present job safety and health programs.

The service is confidential and operates as a program separate from OSHA's official inspection efforts. There are no penalties proposed or citations issued for any safety or health problems identified by the consultant.

For more information concerning consultation assistance, go to Consultation Services on the OSHA website. There is an office listing by state with contact information.

Voluntary Protection Program (VPP)

OSHA has set up the Voluntary Protection Program for employers who successfully incorporate comprehensive safety and health programs into their total management system. Approval into VPP is OSHA's official recognition of the employers' and employees' outstanding efforts to achieve a high standard of occupational safety and health. The three VPP Awards, Star, Merit and Demonstration, are designed to recognize outstanding achievements by companies in these areas. Participating companies help motivate other companies to follow their example and institute similar policies. The program is a cooperative effort between management, labor and OSHA.

The Voluntary Protection Program (VPP) and on-site consultation service, when coupled with an effective enforcement program, expand the worker's protection to help meet the goals of the Act. For more information on the VPP and how to apply, contact your local OSHA area or regional office or visit the OSHA website at www.osha.gov.

Training and Education

OSHA area offices offer a variety of information services, such as publications, audiovisual aids, technical advice, and guest speakers for special engagements. The OSHA Training Institute in Des Plaines, Illinois, provides basic and advanced courses in safety and health for federal and state compliance officers, state consultants, federal agency personnel, and private sector employers, employees, and their representatives. In recent years, the number of requests for training from the private sector as well as federal agencies has grown, and OSHA has met this demand by using outside educational institutions to conduct OSHA Training Institute courses. To find the closest training program in your area, check online at www.osha.gov and click on Training.

OSHA also provides funds to nonprofit organizations, through grants, to conduct workplace training and education in subjects where OSHA believes there's a lack of training. Grants are awarded annually and grant recipients are expected to contribute 20 percent of the total grant cost.

For more information on grants, training, and education, contact:

OSHA Training Institute
Office of Training and Education
1555 Times Drive
Des Plaines, IL 60018
Telephone: (847) 297-4810
www.osha.gov

For further information on any OSHA program, contact your nearest OSHA area or regional office.

Electronic Information

You can find information and materials regarding OSHA standards, interpretations, directives, technical advisors, compliance assistance, and more, on the Internet at http://www.osha.gov. There are materials available for purchase, as well as free downloadable articles and publications in PDF format.

A wide variety of OSHA materials, including standards, interpretations, directives, and more, can be purchased on CD-ROM from the U.S. Government Printing Office. To order these materials, write or telephone:

Superintendent of Documents
U.S. Government Printing Office
P.O. Box 371954
Pittsburgh, PA 15250-7954
(202) 512-1800
Fax: (202) 512-2250
www.gpo.gov

Specify OSHA Regulations, Documents, and Technical Information on CD-ROM (ORDT).

Emergencies

If you have workplace safety- and health-related questions, you can call OSHA at 1-800-321-OSHA (6742). Call the same number to report:

- accidents
- unsafe working conditions
- safety & health violations
- life-threatening situations

Your complaints or concerns will go immediately to the nearest OSHA area or state office for help.

State Programs

The Occupational Safety and Health Act of 1970 encourages states to develop and operate their own job safety and health plans. States administering occupational safety and health programs through plans approved under Section 18(b) of the Act must adopt standards and enforce requirements that are "at least as effective" as federal requirements. There are currently 26 State Plan states (including Puerto Rico and the Virgin Islands): 22 cover the private and public sector (state and local governments) and three cover the public sector only. For more information on state plans, or to see the list of states with approved plans, go to the OSHA website at www.osha.gov.

For further information on any OSHA program, contact your nearest OSHA area or regional office, or the national office at:

U.S. Department of Labor
Occupational Safety and Health Administration (OSHA)
200 Constitution Avenue, N.W.
Washington, D.C. 20210
www.dol.gov

OSHA Sections 1926.700 – 1926.705

The following pages are the OSHA sections that apply to the concrete construction industry. We've reprinted this material with permission from the United States Occupational Safety and Health Administration provisions, U.S. Department of Labor.

§1926.700 Concrete and Masonry Construction

(a) *Scope and application*. This subpart sets forth requirements to protect all construction employees from the hazards associated with concrete and masonry construction operations performed in workplaces covered under 29 CFR Part 1926. In addition to the requirements in Subpart Q, other relevant provisions in Parts 1910 and 1926 apply to concrete and masonry construction operations.

(b) *Definitions applicable to this subpart*. In addition to the definitions set forth in 1926.32, the following definitions apply to this subpart:

(1) "Bullfloat" means a tool used to spread out and smooth concrete.

(2) "Formwork" means the total system of support for freshly placed or partially cured concrete, including the mold or sheeting (form) that is in contact with the concrete as well as all supporting members including shores, reshores, hardware, braces, and related hardware.

(3) "Lift slab" means a method of concrete construction in which floor and roof slabs are cast on or at ground level and, using jacks, lifted into position.

(4) "Limited access zone" means an area alongside a masonry wall, which is under construction, and which is clearly demarcated to limit access by employees.

(5) "Precast concrete" means concrete members (such as walls, panels, slabs, columns, and beams), which have been formed, cast and cured prior to final placement in a structure.

(6) "Reshoring" means the construction operation in which the shoring equipment (also called reshores or reshoring equipment) is placed as the original forms and shores are removed, in order to support partially cured concrete and construction loads.

(7) "Shore" means a supporting member that resists a compressive force imposed by a load.

(8) "Vertical slip forms" means forms which are jacked vertically during the placement of concrete.

(9) "Jacking operation" means the task of lifting a slab, or group of slabs, vertically from one location to another (e.g. from the casting location to a temporary [parked] location, or to its final location in the structure) during the construction of a building/structure where the lift-slab process is being used.

§1926.701 General Requirements

(a) *Construction loads*. No construction loads shall be placed on a concrete structure or portion of a concrete structure unless the employer determines, based on information received from a person who is qualified in structural design, that the structure or portion of the structure is capable of supporting the loads.

(b) *Reinforcing steel.* All protruding reinforcing steel, onto and into which employees could fall, shall be guarded to eliminate the hazard of impalement.

(c) *Post-tensioning operations.*

(1) No employee (except those essential to the post-tensioning operations) shall be permitted to be behind the jack during tensioning operations.

(2) Signs and barriers shall be erected to limit employee access to the post-tensioning area during tensioning operations.

(d) *Riding concrete buckets*. No employee shall be permitted to ride concrete buckets.

(e) *Working under loads*.

(1) No employee shall be permitted to work under concrete buckets while buckets are being elevated or lowered into position.

(2) To the extent practical, elevated concrete buckets shall be routed so that no employee or the fewest number of employees, are exposed to the hazards associated with falling concrete buckets.

(f) *Personal protective equipment*. No employee shall be permitted to apply a cement, sand, and water mixture through a pneumatic hose unless the employee is wearing protective head and face equipment.

§1926.702 Requirements for Equipment and Tools

(a) *Bulk cement storage*.

(1) Bulk storage bins, containers and silos shall be equipped with the following:

(i) Conical or tapered bottoms; and

(ii) Mechanical or pneumatic means of starting the flow of material.

(2) No employee shall be permitted to enter storage facilities unless the ejection system has been shut down, locked out, and tagged to indicate that the ejection system is not to be operated.

(b) *Concrete mixers*. Concrete mixers with one cubic yard ($0.76m^3$) or larger loading skips shall be equipped with the following:

(1) A mechanical device to clear the skip of materials; and

(2) Guardrails installed on each side of the slip.

(c) *Power concrete trowels*. Powered and rotating type concrete troweling machines that are manually guided shall be equipped with a control switch that will automatically shut off the power whenever the hands of the operator are removed from the equipment handles.

(d) *Concrete buggies*. Concrete buggy handles shall not extend beyond the wheels on either side of the buggy.

(e) *Concrete pumping systems*.

(1) Concrete pumping systems using discharge pipes shall be provided with pipe supports designed for 100 percent overload.

(2) Compressed air hoses used on concrete pumping systems shall be provided with positive fail-safe joint connectors to prevent separation of sections when pressurized.

(f) *Concrete buckets*.

(1) Concrete buckets equipped with hydraulic or pneumatic gates shall have positive safety latches or similar safety devices installed to prevent premature or accidental dumping.

(2) Concrete buckets shall be designed to prevent concrete from hanging up on top and the sides.

(g) *Tremies*. Sections of tremies and similar concrete conveyances shall be secured with wire rope (or equivalent materials) in addition to the regular couplings or connections.

(h) *Bullfloats*. Bullfloat handles used where they might contact energized electrical conductors shall be constructed of nonconductive material or insulated with a nonconductive sheath whose electrical and mechanical characteristics provide the equivalent protection of a handle constructed of nonconductive material.

(i) *Masonry saws*.

(1) Masonry saws shall be guarded with a semicircular enclosure over the blade.

(2) A method for retaining blade fragments shall be incorporated in the design of the semicircular enclosure.

(j) *Lockout/Tagout procedures*.

(1) No employee shall be permitted to perform maintenance or repair activity on equipment (such as compressors, mixers, screens or pumps used for concrete and masonry construction activities) where the inadvertent operation of the equipment could occur and cause injury, unless all potentially hazardous energy sources have been locked out and tagged.

(2) Tags shall read Do Not Start or similar language to indicate that the equipment is not to be operated.

§1926.703 Requirements for Cast-In-Place Concrete

(a) *General requirements for formwork*.

(1) Formwork shall be designed, fabricated, erected, supported, braced and maintained so that it will be capable of supporting without failure all vertical and lateral loads that may reasonably be anticipated to be applied to the formwork. Formwork which is designed, fabricated, erected, supported, braced and maintained in conformance with the Appendix to this section will be deemed to meet the requirements of this paragraph.

(2) Drawings or plans, including all revisions, for the jack layout, formwork (including shoring equipment), working decks, and scaffolds, shall be available at the jobsite.

(b) *Shoring and reshoring*.

(1) All shoring equipment (including equipment used in reshoring operations) shall be inspected prior to erection to determine that the equipment meets the requirements specified in the formwork drawings.

(2) Shoring equipment found to be damaged such that its strength is reduced to less than that required by 1926.703(a)(1) shall not be used for shoring.

(3) Erected shoring equipment shall be inspected immediately prior to, during, and immediately after concrete placement.

(4) Shoring equipment that is found to be damaged or weakened after erection, such that its strength is reduced to less than that required by 1926.703(a)(1), shall be immediately reinforced.

(5) The sills for shoring shall be sound, rigid, and capable of carrying the maximum intended load.

(6) All base plates, shore beads, extension devices, and adjustment screws shall be in firm contact, and secured when necessary, with the foundation and the form.

(7) Eccentric loads on shore beads and similar members shall be prohibited unless these members have been designed for such loading.

(8) Whenever single post shores are used one on top of another (tiered), the employer shall comply with the following specific requirements in addition to the general requirements for formwork:

(i) The design of the shoring shall be prepared by a qualified designer and the erected shoring shall be inspected by an engineer qualified in structural design.

(ii) The single post shores shall be vertically aligned.

(iii) The single post shores shall be spliced to prevent misalignment.

(iv) The single post shores shall be adequately braced in two mutually perpendicular directions at the splice level. Each tier shall also be diagonally braced in the same two directions.

(9) Adjustment of single post shores to raise formwork shall not be made after the placement of concrete.

(10) Reshoring shall be erected, as the original forms and shores are removed, whenever the concrete is required to support loads in excess of its capacity.

(c) *Vertical slip forms*.

(1) The steel rods or pipes on which jacks climb or by which the forms are lifted shall be:

(i) specifically designed for that purpose; and

(ii) adequately braced where not encased in concrete.

(2) Forms shall be designed to prevent excessive distortion of the structure during the jacking operation.

(3) All vertical slip forms shall be provided with scaffolds or work platforms where employees are required to work or pass.

(4) Jacks and vertical supports shall be positioned in such a manner that the loads do not exceed the rated capacity of the jacks.

(5) The jacks or other lifting devices shall be provided with mechanical dogs or other automatic holding devices to support the slip forms whenever failure of the power supply or lifting mechanism occurs.

(6) The form structure shall be maintained within all design tolerances specified for plumbness during the jacking operation.

(7) The predetermined safe rate of lift shall not be exceeded.

(d) *Reinforcing steel*.

(1) Reinforcing steel for walls, piers, columns, and similar vertical structures shall be adequately supported to prevent overturning and to prevent collapse.

(2) Employers shall take measures to prevent unrolled wire mesh from recoiling. Such measures may include, but are not limited to, securing each end of the roll or turning over the roll.

(e) *Removal of formwork*.

(1) Forms and shores (except those used for slabs on grade and slip forms) shall not be removed until the employer determines that the concrete has gained sufficient strength to support its weight and superimposed loads. Such determination shall be based on compliance with one of the following:

(i) The plans and specifications stipulate conditions for removal of forms and shores, and such conditions have been followed, or

(ii) The concrete has been properly tested with an appropriate ASTM standard test method designed to indicate the concrete compressive strength, and the test results indicate that the concrete has gained sufficient strength to support its weight and superimposed loads.

(2) Reshoring shall not be removed until the concrete being supported has attained adequate strength to support its weight and all loads in place upon it.

§1926.703 APP General Requirements for Formwork

This appendix serves as a nonmandatory guideline to assist employers in complying with the formwork requirements in 1926.703(a)(1). Formwork which has been designed, fabricated, erected, braced, supported and maintained in accordance with Sections 6 and 7 of the American National Standard for Construction and Demolition Operations Concrete and Masonry Work, ANSI A10.9-1983, shall be deemed to be in compliance with the provision of 1926.703(a)(1).

§1926.704 Requirements for Precast Concrete

(a) Precast concrete wall units, structural framing, and tilt-up wall panels shall be adequately supported to prevent overturning and to prevent collapse until permanent conditions are completed.

(b) Lifting inserts which are embedded or otherwise attached to tilt-up precast concrete members shall be capable of supporting at least two times the maximum intended load applied or transmitted to them.

(c) Lifting inserts which are embedded or otherwise attached to precast concrete members, other than the tilt-up members, shall be capable of supporting at least four times the maximum intended load applied or transmitted to them.

(d) Lifting hardware shall be capable of supporting at least five times the maximum intended load applied or transmitted to the lifting hardware.

(e) No employee shall be permitted under precast concrete members being lifted or tilted into position except those employees required for the erection of those members.

§1926.705 Requirements for Lift-Slab Operations

(a) Lift-slab operations shall be designed and planned by a professional engineer who has experience in lift-slab construction. Such plans and designs shall be implemented by the employer and shall include detailed instructions and sketches indicating the prescribed method of erection. These plans and designs shall also include provisions for ensuring lateral stability of the building/structure during construction.

(b) Jack/lifting units shall be marked to indicate their rated capacity as established by the manufacturer.

(c) Jack/lifting units shall not be loaded beyond their rated capacity as established by the manufacturer.

(d) Jack/lifting equipment shall be capable of supporting at least two and one-half times the load being lifted during jacking operations and the equipment shall not be overloaded. For the purpose of this provision, jacking equipment includes any load-bearing component which is used to carry out the lifting operation(s). Such equipment includes, but is not limited to, the following: threaded rods, lifting attachments, lifting nuts, hook-up collars, T-caps, shearheads, columns, and footings.

(e) Jack/lifting units shall be designed and installed so that they will neither lift nor continue to lift when they are loaded in excess of their rated capacity.

(f) Jack/lifting units shall have a safety device installed which will cause the jack/lifting units to support the load in any position in the event any jack/lifting unit malfunctions or loses its lifting ability.

(g) Jacking operations shall be synchronized in such a manner to ensure even and uniform lifting of the slab. During lifting, all points at which the slab is supported shall be kept within ½ inch of that needed to maintain the slab in a level position.

(h) If leveling is automatically controlled, a device shall be installed that will stop the operation when the ½-inch tolerance set forth in paragraph (g) of this section is exceeded or where there is a malfunction in the jacking (lifting) system.

(i) If leveling is maintained by manual controls, such controls shall be located in a central location and attended by a competent person while lifting is in progress. In addition to meeting the definition in 1926.32(f), the competent person must be experienced in the lifting operation and with the lifting equipment being used.

(j) The maximum number of manually controlled jack/lifting units on one slab shall be limited to a number that will permit the operator to maintain the slab level within specified tolerances of paragraph (g) of this section, but in no case shall that number exceed 14.

(k)

(1) No employee, except those essential to the jacking operation, shall be permitted in the building/structure while any jacking operation is taking place unless the building/

structure has been reinforced sufficiently to ensure its integrity during erection. The phrase “reinforced sufficiently to ensure its integrity” used in this paragraph means that a registered professional engineer, independent of the engineer who designed and planned the lifting operation, has determined from the plans that if there is a loss of support at any jack location, that loss will be confined to that location and the structure as a whole will remain stable.

(2) Under no circumstances, shall any employee who is not essential to the jacking operation be permitted immediately beneath a slab while it is being lifted.

(3) For the purpose of paragraph (k) of this section, a jacking operation begins when a slab or a group of slabs is lifted and ends when such slabs are secured (with either temporary connections or permanent connections).

(4) Employers who comply with Appendix A to 1926.705 shall be considered to be in compliance with the provisions of paragraphs (k)(1) through (k)(3) of this section.

(l) When making temporary connections to support slabs, wedges shall be secured by tack welding, or an equivalent method of securing the wedges to prevent them from falling out of position. Lifting rods may not be released until the wedges at that column have been secured.

(m) All welding on temporary and permanent connections shall be performed by a certified welder familiar with the welding requirements specified in the plans and specifications for the lift-slab operation.

(n) Load transfer from jack/lifting units to building columns shall not be executed until the welds on the column shear plates (weld block) are cooled to air temperature.

(o) Jack/lifting units shall be positively secured to building columns so that they do not become dislodged or dislocated.

(p) Equipment shall be designed and installed so that the lifting rods cannot slip out of position or the employer shall institute other measures, such as the use of locking or blocking devices, which will provide positive connection between the lifting rods and attachments and will prevent components from disengaging during lifting operations.

§ 1926.705 APP Lift-Slab Operations

In paragraph 1926.705(k), OSHA requires employees to be removed from the building/structure during jacking operations unless an independent registered professional engineer, other than the engineer who designed and planned the lifting operation, has determined that the building/structure has been sufficiently reinforced to ensure the integrity of the building/structure. One method to comply with this provision is for the employer to ensure that continuous bottom steel is provided in every slab and in both directions through every wall or column head area. (Column head area means the distance between lines that are one and one-half times the thickness of the slab or drop panel. These lines are located outside opposite faces of the outer edge of the shearhead sections — See Figure 18-2). The amount of bottom steel shall be established by assuming loss of support at a given lifting jack and then determining the steel necessary to carry, by catenary action over the span between surrounding supports, the slab service dead load plus any service dead and live loads likely to be acting on the slab during jacking. In addition, the surrounding supports must be capable of resisting any additional load transferred to them as a result of the loss of support at the lifting jack.

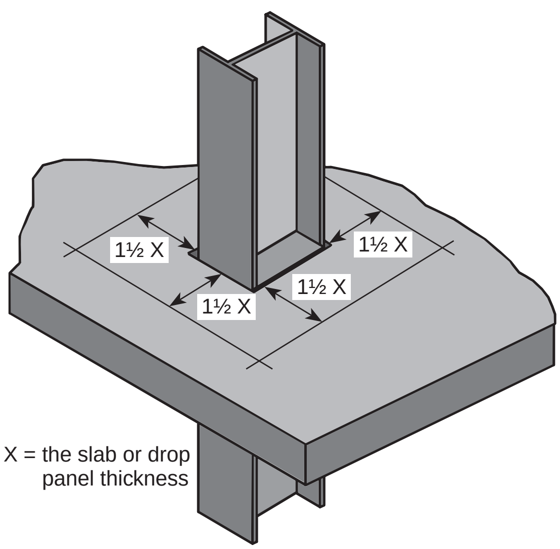


Figure 18-2
Ensure that there's continuous steel in both directions through every wall or column head

GLOSSARY

Absorbent: Capable of taking in water or moisture.

Abutment: A supporting wall carrying the end of a bridge or span and sustaining the pressure of the earth next to it.

Accelerator: A substance which, when added to concrete or grout, increases the rate of hydration of the hydraulic cement, shortens the setting time, or increases the rate of hardening, strength development, or both.

Admixtures: Materials added to a concrete mix to change the chemical reaction.

Aggregate: Inert particles, such as sand, gravel or rock, that are mixed with portland cement and water to form concrete.

Air-entrained concrete: Concrete containing an admixture that produces microscopic air bubbles in the concrete. Used to improve the workability and freeze resistance of concrete.

American Concrete Institute (ACI): A technical and educational society dedicated to improving design, construction, manufacture, and maintenance of concrete structures.

American Society of Testing Materials (ASTM): A professional association that develops standards and specifications for materials of all types.

Anchor: A piece of material, usually metal, used to attach building parts.

Anchor bolt: A bolt embedded in the top of a foundation wall or floor to secure the sill plate.

Arch: A curved compressive structural member spanning openings or recesses; may also be built flat.

Architectural concrete: Specially finished or formed concrete that's exposed to public view, and is so identified on the plan drawings.

Architectural finish: The surface treatment applied to architectural concrete.

Arris: The external edge formed by the meeting of two surfaces, whether plane or curved.

Auger: A mechanical device with screw-like fins mounted on a shaft that's used to mix materials that are in a loose or fluid state.

Balanced: Made symmetrical and in the correct position.

Barrier curb: A curb designed to stop traffic movement; usually 6 inches high or more.

Base: A layer of compactible granular fill placed directly above the subgrade and below the slab.

Batch: A quantity of concrete mixed at one time.

Batterboards: Pairs of horizontal boards nailed to the corner posts to indicate the desired elevations at an excavation, and to outline the building foundation.

Battered foundation: Foundation wall consisting of a vertical outside surface and an inclined inside surface that provides a wider base surface at the bottom of the wall.

Bay: A division or compartment of a wall, arcade, roof or other part of a structure. The space from pillar to pillar in a cathedral is a bay.

Beam: A piece of wood, metal or masonry that's supported at either end by walls, columns, or posts and is used to bear the weight over an opening.

Bearing capacity: The maximum pressure that soil or another material can withstand without failure or a great amount of settlement.

Belled caisson: A concrete caisson flared at its bottom to provide a greater bearing area.

Belt course: A narrow, continuous horizontal course of masonry that projects out slightly from a surface, such as a windowsill. Also, a continuous horizontal division in a wall plane.

Bench mark: A known point of reference for grades and elevations on a construction site.

Bleeding: A condition in freshly-placed concrete in which excess water rises to the surface.

Blistering: The irregular rising of a thin layer of mortar paste at the surface of a slab, appearing during or soon after the completion of the concrete finishing operation.

Blowup: A defect in concrete when the concrete on one or both sides of a joint or a crack buckles upward.

Bollard: A guard attached to a corner, freestanding post, or pole to protect the structure from machinery.

Bond: 1) The adhesion between different masonry and concrete units, usually produced by the addition of grout or chemicals. 2) Lapping masonry over other masonry with metal ties.

Bond beam: A reinforced concrete beam designed to strengthen a wall and reduce the chance of cracking.

Bonded floor slab: A floor composed of a base coat of concrete with a high strength mineral or metallic aggregate applied as a topping.

Bonding agent: A substance applied to an existing concrete surface to help the new mixture adhere to the surface.

Bored caisson: Caisson that's constructed by placing a metal casing into a hole bored into the earth and filled with concrete after it's in position.

Box out: A form that's used to create an opening or pocket in concrete. Box outs can be built of wood or Styrofoam.

Broom finish: The non-slip finish created by moving a wide broom across concrete that has almost set.

Buckling: A defect in concrete when the concrete on one or both sides of a joint or a crack buckles upward. Also called a *blowup*.

Builder's level: A telescope-like instrument used to establish elevation points and measure horizontal angles over long distances for leveling and grading operations.

Building Code: A set of laws or regulations governing the materials and workmanship used in the construction of buildings.

Bulkhead buck: Frame placed inside a form to provide an opening for a door or window after the concrete is set.

Bulkheads: Forms used with isolation or control joints to mark the end of a day's placing activity.

Bull float: A wide tool with a long handle that's used to smooth the surface of concrete after it's been screeded off.

Caisson: A cast-in-place pile formed by drilling a hole, removing the earth, inserting reinforcement, and filling the hole with concrete.

Calcium chloride: A solid crystalline added to a concrete mix to accelerate the set time.

Capital: The flared section at the top of a concrete column that supports the floor or roof slab above.

Cast-in-place concrete: Concrete placed in forms at the location where it will remain as a part of the structure.

Catch basin: An area excavated, and often filled with gravel, that receives surface water runoff.

Cavation: Pitting in concrete caused by water flowing at an extremely high rate of speed.

Cellular concrete: Concrete to which a foaming agent is added, to create a mix with high air content and low density.

Chamfers: Beveled corners and edges that are formed in concrete by placing triangular strips in the corner of the form.

Chase: A continuous recess built into a wall to receive pipes, ducts, etc.

Checking: A network of very fine cracks forming irregular patterns in a concrete surface. See also *Crazing*.

Chert: Porous whitish-colored, flint-like quartz in the pozzolan class.

Chute: Trough-like device used to move concrete from a high point to a lower point.

Coarse aggregate: Crushed stone retained on a U.S. Standard #4 (4.75 mm) sieve.

Code (building): A set of laws or regulations governing the materials and workmanship in the construction of buildings.

Cold joint: Joint occurring where fresh concrete is placed adjacent to previously-placed concrete that has already set.

Column: Vertical member supporting beams, girders and/or floor slabs.

Compression test: Test conducted on a specimen of concrete to determine its compressive strength.

Compressive strength: Maximum resistance of a concrete specimen to vertical loads.

Concrete surface profile (CSP): A measure of the degree of roughness suitable for the application of overlays, ranging from CSP 1, nearly flat, to CSP 9, very rough.

Consistency: Degree of plasticity of concrete and its ability to flow when it's placed.

Consolidation: The process of working fresh concrete so that a closer arrangement of particles is created and the number of voids decreased or eliminated.

Construction joint: A cold joint between two adjacent placements of concrete.

Control joint: A shallow groove in the surface of concrete designed to control and confine cracking in the concrete resulting from expansion and contraction.

Course: Horizontal layer of concrete. Several courses make up a lift.

Cover: The distance between the reinforcement and the surface of the concrete.

Crazing: A network of very fine cracks forming irregular patterns in a concrete surface. See also *Checking*.

Creep: Deformation of a concrete member due to sustained loads.

Curing: The process of maintaining the proper moisture content and temperature in concrete during the first few days after pouring to allow its desired properties to develop; concrete hardening due to hydration.

Dampproofing: One or more coatings of a compound that's impervious to water.

Dead load: Total weight of the superstructure of a building, including all construction materials.

Deck form: Form upon which concrete for a floor or roof slab is placed.

Decking: Sheathing material used for a deck form.

Delamination: A separation along a plane parallel to the surface, or the separation of a slab in a plane parallel to the upper surface caused by the corrosion of rebar or freeze/thaw action affecting two or more layers of the concrete.

Design reference panel: A panel constructed as a sample of the materials, skills, and finishing techniques to be used on the project.

Dome pan: Metal or plastic square form used in a two-way concrete joist system.

Doubling up walls: Trade term used when putting up inside wall forms.

Dowel: Deformed or plain round steel bar extending into adjoining portions of separately-placed concrete structures.

Dusting: The development of a light powdery material on the surface of hardened concrete.

Early strength: Concrete strength during the first three weeks after placement.

Earth-formed footing: A footing formed by a trench dug into firm stable soil.

Edge form: A low wall form positioned around the perimeter of the placement area to contain concrete. Form commonly used in flatwork.

Efflorescence: A deposit of salts (usually white) on the surface of concrete, emerging from the interior of the concrete.

Elephant trunk: A flexible tube extending from the bottom of a hopper or concrete pumping pipe.

Elevation: A grade level established to indicate vertical distance above or below a reference point.

Entrance platform: A low stoop or porch located at an entrance to a building.

Entrained air: The system of microscopic bubbles intentionally incorporated into a concrete mixture.

Expansion anchor: A metal expandable unit inserted into a drilled hole that grips by expansion.

Expansion joint: Separation between parts of a concrete structure that's used in locations where expansion and contraction forces are anticipated. The cause of contraction or expansion is usually changes in temperature.

Fiber reinforced concrete: A concrete mixture that uses glass, metal, or plastic fibers to strengthen the concrete mix.

Fill: Soil or other material brought in from another location and deposited at the building site to raise the grade level.

Fine grained soil: Soil composed of fine particles, such as silt or clay.

Firewall: Any wall designed to resist the spread of fire that subdivides a building and extends continuously from the foundation through the roof.

Flashing: A thin impervious material placed in masonry and through air spaces to prevent water penetration, and/or provide water drainage.

Flat slab floor: Concrete floor slab system supported by columns and reinforced in two or more directions without beams or girders.

Flatwork: Construction of floor slabs, patios, sidewalks and other flat concrete surfaces.

Float: A flat broad-based wood or metal hand tool.

Floating concrete: Leveling a fresh concrete surface with a float. Also, creating sufficient water and paste needed for troweling the concrete. Floating is done immediately after a concrete surface has been consolidated and struck off.

Floating foundation: A thick reinforced slab placed monolithically, with walls and/or footings that distribute the load over a large area.

Flushed: Filled up to the surface.

Fogging: A concrete curing procedure, similar to spraying, that uses a fine mist of water to increase hydration.

Footing: The base of a foundation pier, column or wall, that's usually wider than the upper part of the foundation or wall, and which is designed to spread the weight of the structure over a larger area.

Form anchor: A device embedded in concrete to be used at a later date to anchor formwork.

Form hanger: A metal device, used to support the formwork, which is suspended from a structural form such as steel or precast concrete beams and girders.

Form liners: Rigid or elastic wood or plastic material placed against the inside of a form wall to produce a textured or patterned finish, or that's used to absorb moisture.

Form tie: A device that's used to separate and tie opposite form walls.

Form work: the total system of support for freshly-placed or partially-cured concrete, including the mold or sheeting (form) that's in contact with the concrete, as well as all supporting members, including shores, reshores, hardware, braces and other related hardware.

Foundation wall: The portion of a load-bearing wall that's below the level of the adjoining grade, or below the first floor beams or joists.

Front setback: The distance from the front of a structure to the front of the property line.

Frost line: The depth to which soil freezes in a particular area.

Full basement foundation: A foundation that provides living space or storage area below the structure.

Gang form: Prefabricated panels joined together to make a much larger unit for convenience in erecting, stripping, and reusing.

Gap graded concrete: A mixture of cement, sand, coarse aggregate and water. No intermediate or fine aggregate is included.

Georgia buggy: Manual or motor-driven cart used to move small amounts of concrete from a mixer to the placement point.

Girder: A large horizontal member that supports a bending load over a span.

Grade: The existing or proposed ground level at a building site.

Grade beam: A reinforced concrete beam, placed at grade level, used as a main support between the piers or column footings on which it rests.

Green concrete: Concrete that has set up, but not hardened to the point where it can't be damaged.

Ground beam: A concrete beam that's placed at ground level to tie walls or column footings together.

Groundwater: Water beneath the surface that's at the level of the water table.

Grout: A thin, fluid mortar made of a mixture of portland cement, fine aggregate, lime and water, used for finishing joints and filling voids in masonry walls.

Heave: An upward force in the ground due to frost and the expansion of frozen soil.

High early strength concrete: A concrete mix using Type III portland cement that sets more quickly and hardens faster in cold weather than a standard mix.

High lift grouting: The technique of grouting the voids in a masonry wall in lifts of up to 12 feet.

Honeycomb: A concrete pour that isn't totally consolidated by some means before it sets, leaving voids that result in a weakened concrete structure.

Hopper: A funnel-shaped device or box that's used in placing concrete, usually with a flexible hose attachment. See also *Elephant trunk*.

Hub: A stake used to indicate a corner of a property.

Hydration: The chemical reaction between water and cement that hardens the concrete mix.

Insert: An anchoring device placed in precast concrete that provides a means to lift the precast section and move or deliver it to the desired location.

Internal disconnecting tie: A form tie consisting of two external sections that screw into an internally-threaded bolt that remains in place after the forms are stripped. These ties eliminate the need for spreader cones and reduce the size of the holes remaining to be filled in the concrete surface.

Introdos: The inside curve of an arch.

Isolation joint: The separation between adjoining parts of a concrete structure that allows for movement between the parts. The joint, usually filled with caulking material, is designed to prevent cracking or buckling when ground settling, earthquakes or wind cause a degree of horizontal or vertical movement, or when temperature changes cause the structure to expand and contract.

J-bolt: An anchor bolt, embedded into concrete at the time of placement, to allow for the attachment of a sill plate or some other structural member. The threaded end of the j-bolt projects from the concrete.

Jacking operation: Lifting a slab (or group of slabs) vertically from one location to another during a lift-slab operation. For example, lifting a slab from the casting location to a temporary location or to its final location in the structure.

Jamb: The inside framing members of an opening for a window or door.

Joint: The opening between two concrete surfaces, usually filled with some other material.

Kerf: A cut or groove made by a saw blade, such as the cut made in the cross board of a batterboard to hold the string line in position.

Keyway: A groove formed into a concrete pour used to interlock another concrete structure poured at a later time, such as interlocking a wall to a footing in order to create a mechanical bond between the old and new pour.

Kicker: 1) A wood block used to brace a form. 2) Concrete placed at bend in an underground pipe system to support the joint.

Laitance: An accumulation of fine white dusty particles on the surface of fresh concrete. Laitance occurs when the concrete has not been worked properly during finishing, or when there's too much water in the mix. The water brings the particles to the surface and they remain after the water evaporates.

Lally column: A steel pipe column that rests on a concrete pier and is used to support a beam above it.

Lateral pressure: Horizontal pressure, such as the force of soil against the side of a foundation.

Ledger: The horizontal support member fastened to a wall, on which joists or other permanent or temporary structural members rest. Also called a ledger board.

Leveling rod: A rod, marked with graduated measurements, used with a transit or builder's level to determine elevations.

Lift: Layers of concrete placed in a wall and separated by horizontal construction joints.

Lift slab: A method of concrete construction in which floor and roof slabs are cast on or at ground level and, using jacks, are lifted into position.

Lightweight concrete: A concrete mix that uses lightweight aggregates, such as vermiculite, perlite, scoria, expanded shale, slate, slag, or cinders, to reduce the weight of the mix.

Limited access zone: An area, alongside a masonry wall under construction, which is clearly demarcated to limit access by employees.

Line of sight: The imaginary straight line extending from a transit to the object being sighted.

Lintel: A horizontal structural member that supports the load over a door, window or other opening.

Live load: The load on a structure that's movable and temporary, such as people, furniture, equipment and snow. Live loads are not part of the building structure.

Mat foundation: A spread foundation consisting of a solid slab of heavily reinforced concrete.

Minimum bending radius: The bending capacity of a piece of wood, such as plywood used in curved formwork.

Mix: The proportion of aggregates, cement, water or other components to make up a mixture of concrete, mortar, or other compound.

Monolithic concrete slab: Concrete slab cast with no joints other than construction joints; often a floor slab and wall cast as part of the same pour.

Mortar: A mixture of portland cement, lime and sand used to fill voids in masonry units, bond them together and add support.

Mudsill: A wood member, attached to the top of a foundation, to which the joists can be attached.

Occupational Safety and Health Administration (OSHA): The federal agency that establishes safety regulations for the construction industry; a division of the U.S. Department of Labor.

Panel: 1) A piece of construction material, such as wood or precast masonry, made to form part of a surface. 2) A form section, usually made from plywood and stiffeners, used to support a concrete pour.

Parapet: A wall or barrier on the edge of an elevated structure for the purpose of protection or ornamentation.

Pier: An isolated column of concrete, usually designed as a vertical structural support.

Pier footing: A concrete base for a column.

Pilaster: A wall section that projects out from the wall, on either or both sides, which serves as a vertical column and, or, a beam.

Pile: A long slender column, usually of steel, wood or reinforced concrete, driven into the ground until it reaches a solid surface, or is adequately held by friction; used to support the weight of a structure built on an unsound or unstable surface.

Placement: The term used to describe the pouring of concrete.

Plasticity: The property of a fresh cement paste, concrete or mortar mixture that determines its workability and shaping qualities.

Plasticizer: A water-reducing agent that provides concrete with increased workability with less mix water.

Plinth: 1) The square block at the base of a column or pedestal. 2) The base course of a stone wall or rough stonework; the bottom course of a continuous stone foundation; the base course.

Plumb: True vertical; to be, or cause to be, vertically aligned.

Polyethylene film: A thin sheet of plastic used as a vapor barrier.

Ponding: 1) Covering fresh concrete with water as part of the curing process. 2) The unwanted accumulation of water on a surface, usually due to poor drainage.

Popout: A shallow conical depression in a concrete surface caused by a piece of concrete that has broken away, usually because of foreign materials in the mix or unsound aggregates.

Plyform: A special plywood used to make forms for concrete.

Power screed: An engine-driven screed used for striking off concrete.

Pozzolan: A fine particle substance that chemically reacts with calcium hydroxide to produce a strong, slow-hardening cement mixture.

Precast concrete: Concrete members, such as walls, panels, slabs, columns and beams, that have been formed, cast and cured in one location prior to their final placement in a structure at another, final location.

Prefabricated forms: Forms that are constructed from prebuilt sections.

Prestressed concrete: Concrete that's poured around steel cables that are put under tension or stress during the pour. The steel cables are the concrete reinforcement and help the finished masonry structure resist stress.

Raft foundation: A continuous, heavily-reinforced slab of concrete placed monolithically with walls and/or columns over soil with poor bearing capacity.

Raggle: A groove in a joint or special unit designed to hold or guide a panel or to receive roofing or flashing. Also called a reglet.

Ready-mixed concrete: Concrete that's manufactured at a batch plant and delivered by truck to a site.

Rebar: Steel reinforcing bar.

Reshore: A temporary brace used to support a concrete member, such as a beam or girder, that's only partially cured. Reshores are placed as the original forms and shores are removed in order to support the concrete member until it's fully cured.

Relief: The projection of parts of a structure so that they stand out against a plane or flat surface.

Recess: A depth of some inches in the thickness of the wall, such a niche, etc.

Return: Any surface turned back from the face of the principal surface.

Retarder: An admixture that delays the setting and hardening of the concrete.

Rise: The total height of a flight of stairs.

Riser: The vertical portion of a stair that's perpendicular to the ground or floor. The riser fits between the back of the lower tread and the front of the tread immediately above it.

Ribbon: A narrow strip of wood used in formwork.

Rodded concrete: Concrete layers that have been integrated by working a tamping rod up and down through the layers.

Rock pocket: A porous void in hardened concrete that consists primarily of coarse aggregates and open voids with little or no mortar.

Rock salt texture: A pitted surface made by scattering rock salt over the surface of fresh concrete and, after the concrete hardens, washing off the salt.

Run: The total length of a flight of stairs from bottom to top; the run is always greater than the rise.

Rustications: Having beveled or rebated edges, producing deeply sunk, deliberately-conspicuous joints; producing or causing a rustic look.

Sand streaking: A concrete defect found in vertical surfaces that's caused by excessive bleedwater rising to the surface immediately after placing the concrete.

Scab: A small piece of wood used to fasten two formwork members together to secure a joint.

Scaffold shoring: Tubular steel frames that support beam and floor forms.

Scaling: The disintegration and flaking of surface cement on hardened concrete.

Screeding: The operation of leveling off the surface of concrete, performed by moving a straightedge across the top of the forms. Also called striking off.

Segregation: The tendency of coarse aggregates to separate from the cement paste and sand as the concrete is placed.

Separation: Due to improper placement and/or consolidation of the concrete, the coarse aggregates separate from the rest of the mix during the placement procedure.

She-bolt: A type of form tie and spreader bolt with end fastenings that are threaded into the end bolt, thus eliminating the need for cones on the ends of the tie.

Sheet piling: Interlocking metal piles, frequently used in deep excavations, designed to resist lateral pressure.

Shore: A temporary support for formwork and fresh concrete or for recently-built structures which haven't developed full design strength.

Shoring: A system of braces used to prevent the sliding or collapse of earth banks during excavation.

Shotcrete: A concrete mix that's transported through a hose and projected, under pneumatic pressure, through a nozzle at high velocity onto a form surface. Generally used on curved surfaces, such as swimming pools and domes, to produce a covering thicknesses of up to 4 inches.

Shrinkage crack: A crack caused by the too rapid evaporation of moisture. The moisture leaves the surface of the concrete at a faster rate than it bleeds out of the rest of the mix.

Shut-off: A vertical bulkhead placed at the end of a wall form to contain fresh concrete.

Sill plate: A wood plate fastened to the top of a foundation wall and used to anchor joists. See also *Mudsill*.

Silt: Granular material consisting of fine mineral particles, greater than 0.0002 inch and up to and including 0.003 inch in diameter.

Single wall form: A wall form system that incorporates one constructed wall form on one side with the other side composed of solid rock or an extremely hard surface.

Site cast: When concrete is precast in a form on the job site.

Sitework: Preliminary layout, clearing, excavation, and other work before the actual building construction can start.

Slab: A flat horizontal layer of concrete.

Slab-on-grade foundation: A concrete floor slab resting directly on a bed of gravel.

Sleeve: A metal or fiber cylinder set inside the form to allow a passageway for pipes or electrical lines.

Soil compaction: Compressing loose soil or gravel with a machine, such as a tamper or roller, before placing concrete.

Spading: Consolidation of fresh concrete with a narrow wood rod or spading tool.

Spall: A small section of concrete that comes off the surface because of the elements, such as freezing and thawing, a blow to the surface, or expansion within the concrete.

Span: The distance between two structural supports, such as two columns or piers.

Spandrel beam: A beam located in an outer wall of a building, usually used to support a floor or roof.

Splay: The sloped or beveled surface around an opening.

Spread footing: A footing that's wider than usual in order to spread support for the weight of a structure over a greater area.

Station: A reference point used in surveying. Usually a station is a mark along an alignment or grade every 100 feet.

Steel reinforcing bar: A deformed steel bar placed in concrete to increase its ability to withstand lateral pressure and to tie other concrete members to together. See also *Rebar*.

Stepped foundation: A foundation built on a sloping surface. It's usually built similar to regular steps, but with longer, wider tread surfaces.

Stepped pier: A series of piers, where each one is built up by placing one on top of the other to increase their depth. As the steps rise, the piers are placed in decreasing sizes.

Stoning: A hand-rub finishing process, using a carborundum stone, which raises a coat of mortar paste to fill bug holes, pitting, or light honeycomb.

Stratification: The separation of the concrete ingredients into separate horizontal layers, with the lighter ingredients rising to the top.

Strike-off board: A board (2 x 4 or 2 x 6 wood or aluminum) used to level off fresh concrete placed in forms.

Strike off: The operation of leveling off the surface of concrete, performed by moving a straightedge across the top of the forms. Also called *screeding*.

Strip: To remove all formwork from the new concrete.

Strongback: The vertical member attached to the walers to brace the outside of forms.

Story high: The level where the floor joists are installed.

Structural steel: Steel beams, girders, and columns used for building purposes, particularly for high-rise buildings.

Stud: A vertical wood board used to stiffen and support the forms.

Subbase: A layer of compacted granular fill directly above the subgrade and beneath the slab.

Subgrade: The compacted and excavated earth beneath a slab or subbase.

Superplasticizer: A water-reducing admixture capable of producing large water reduction or great flow-ability without causing undue set retardation.

Superstructure: The part of the building above the foundation.

Tapered pier: A pier form with tapered sides.

Template: Wood used to layout and hold anchors in formwork.

Textured plywood: Form sheathing producing a special surface effect.

Tilt-up construction: The method of pouring concrete walls in a form on the ground, then tilting them up into place with a crane when they're set.

Transit level: A surveying instrument used to establish level grades over long distances.

Tremie: A pipe through which concrete may be deposited under water.

Tubular fiber form: Round column forms constructed of spirally-wound fiber plies.

Vapor barrier: Waterproof membranes placed under a slab or ground concrete to prevent surface water from moving up into the concrete.

Vertical slip forms: Forms that are jacked vertically during the placement of concrete.

Vibrator: A metal tube attached to a vibrating motor used to consolidate fresh concrete in the forms.

Voids: Air spaces in hardened concrete, which are the result of segregation and improper consolidation of the concrete during pouring.

Waler: Horizontal boards attached to the outside of forms to strengthen and stiffen the forms.

Waler rod: A form-tie assembly consisting of an inner rod, threaded at each end, into which two outside rods are screwed. The outside rods are tightened against the walers with large nut washers.

Water-cement ratio: The amount of water in relation to the amount of cement used in a concrete mix. The water-cement ratio is a major factor in the compressive strength of concrete.

Water-reducing admixture: A chemical added to concrete to increase the slump or maintain workability with a reduced amount of water.

Waterstop: Thin pieces of metal, rubber, or plastic inserted in a construction joint to prevent the passage of water through the joint.

Water table: 1) The point below grade where the soil is saturated with water. 2) a horizontal siding member that projects outward at the bottom of the siding to direct water running down the siding away from the foundation wall.

Wedge: A metal piece that's driven against a waler at the end of a form tie to hold the opposite form wall in place.

Welded wire fabric: Heavy steel wire in a 6-inch grid pattern, supplied in rolls or sheets for reinforcing concrete.

[Blank Page]

CONVERSION TABLES

Standard Units	
12 inches	1 foot
3 feet	1 yard
5,280 feet	1 mile
144 square inches	1 square foot
9 square feet	1 square yard
1,728 cubic inches	1 cubic foot
27 cubic feet	1 cubic yard
8 fluid ounces	1 cup
2 cups	1 pint
2 pints	1 quart
4 quarts	1 gallon
1 gallon	231 cubic inches
7.48 gallons	1 cubic foot
202 gallons	1 cubic yard

Length Measurement (Metric)	
10 millimeters	1 centimeter
10 centimeters	1 decimeter
10 decimeters	1 meter
10 meters	1 dekameter
10 dekameters	1 hectometer
10 hectometers	1 kilometer

Length — Metric to Standard	
1 centimeter	0.394 inches
1 decimeter	3.94 inches (0.328 foot)
1 meter	3.281 feet (1.093 yards)
1 kilometer	3,281 feet (0.621 or 5/8 mile)

Length — Standard to Metric	
1 inch	2.54 centimeters
1 foot	3.048 decimeters (0.3048 meters)
1 yard	0.9144 meters
1 mile	1.609 kilometers

Area — Metric to Standard	
1 square centimeter	0.1550 square inch
1 square meter	10.764 square feet
1 square meter	1.196 square yards
1 square kilometer	0.386 square mile

Area — Standard to Metric	
1 square inch	6.452 square centimeters
1 square foot	0.93 square meter
1 square yard	0.8361 square meter
1 square mile	2.59 square kilometers

Linear Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
inches	25.4	millimeters	millimeters	0.039	inches
feet	0.30	meters	meters	3.28	feet
yards	0.91	meters	meters	1.09	yards
miles	1.61	kilometers	kilometers	0.62	miles

Area Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.840	sq. meters	sq. meters	1.20	sq. yards
sq. miles	2.600	sq. kilometers	sq. kilometers	0.38	sq. miles

Volume Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
fluid ounces	29.6	milliliters	milliliters	0.03	fluid ounces
cups	0.24	liters	liters	4.23	cups
pints	0.47	liters	liters	2.10	pints
quarts	0.95	liters	liters	1.06	quarts
gallons	3.19	liters	liters	0.26	gallons
cubic inches	16.0	milliliters	milliliters	0.06	cubic inches
cubic feet	28.3	liters	liters	0.036	cubic feet
cubic feet	0.028	cubic meters	cubic meters	1.31	cubic feet
cubic yards	0.76	cubic meters	cubic meters	35.3	cubic yards

Mass per Volume Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
pounds per cubic foot	16.02	kilograms per cubic meter	kilograms per cubic meter	0.06	pounds per cubic foot
pounds per cubic yard	0.59	kilograms per cubic meter	kilograms per cubic meter	1.69	pounds per cubic yard
pounds per gallon	0.12	kilograms per liter	kilograms per liter	8.34	pounds per gallon

Volume per Mass and Volume per Volume Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
fluid ounces per cubic yard	38.68	milliliters per cubic meter	milliliters per cubic meter	0.026	fluid ounces per cubic yard
fluid ounces per 100 pounds	65.2	milliliters per 100 kilograms	milliliters per 100 kilograms	0.015	fluid ounces per 100 pounds
gallons per cubic yard	4.95	liters per cubic meter	liters per cubic meter	0.202	gallons per cubic yard

Mass Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
ounces	28.3	grams	grams	0.035	ounces
pounds	0.45	kilograms	kilograms	2.2	pounds
short tons	0.91	metric tons	metric tons	1.1	short tons

Mass per Area Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
pounds per square foot	4.88	kilograms per square meter	kilograms per square meter	0.205	pounds per square foot

Area per Volume Conversions

Approximate Conversions *To* Metric Measures			Approximate Conversions *From* Metric Measures		
When you know:	**Multiply by:**	**To find:**	**When you know:**	**Multiply by:**	**To find:**
square feet per gallon	0.025	square meters per liter	square meters per liter	40.75	square feet per gallon

INDEX

D

E

F

G

H

I

J

K

L

M

N

O

T

U

V

W

XYZ