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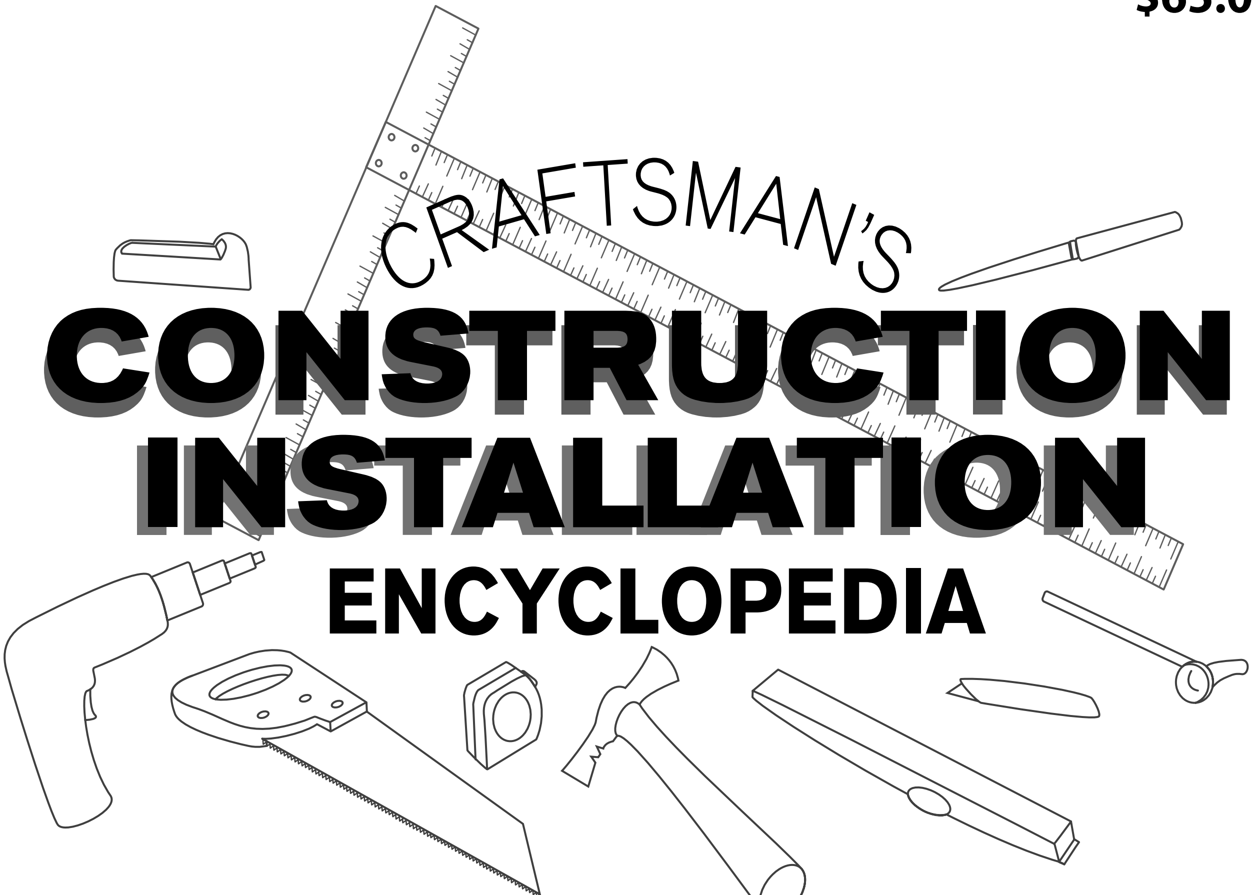
CRAFTSMAN'S CONSTRUCTION INSTALLATION ENCYCLOPEDIA



by

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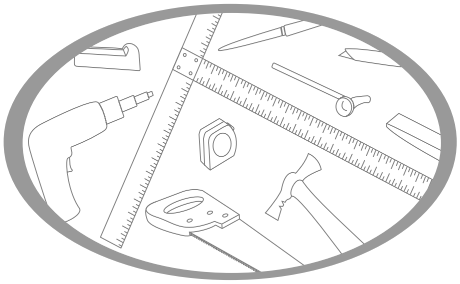

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Acoustical Tile

Acoustical material is designed to meet a variety of standard federal ratings. Manufacturers generally rate the Sound Transmission Class (STC) and the Noise Reduction Coefficient (NRC) of their products. (See *Acoustics*.) While increasing the thickness of the material will often increase the NRC or STC, the most important factors in these ratings are the surface finish and composition of the material. Acoustical products are also rated for their fire resistance, surface burning and light-reflection characteristics.

Acoustical Material

Acoustical material is made primarily from mineral, fiberglass, vinyl or wood. Presently, a new generation of acoustical material, called Orion, is being introduced to replace fiberglass. In the past, asbestos cement was common because it's noncombustible and resistant to high moisture conditions. However, it's rarely used anymore because of the concern for asbestos-related health problems. (See *Asbestos*.) Cellulose fiber, the oldest and cheapest acoustical material, is also seldom used anymore. It's not fire rated, and it doesn't hold up well when subjected to moisture.

Mineral Fiber

Mineral fiber is by far the most common acoustical material. It's made from mineral wool — blast-furnace slag that's been reheated and blown into wool or spun into filaments. The process produces a highly durable, fire-rated material. Then the surface is either fissured or perforated to absorb sound. Where appearance is important, the material has fissures (voids) in the surface. It's perforated (with regular holes) more often in industrial settings where maximum performance is more important than appearance. As a general rule of thumb, the rougher the texture, the better the material will absorb sound. When you paint mineral fiber material, it's extremely important to use a non-bridging paint. Otherwise, the paint may close the pores, destroying the material's acoustical qualities.

Because there are so many kinds of mineral fiber acoustical materials, they fall within a wide NRC range, from the 0.40s to the 0.80s. The STC range generally falls between 35 and 49.

Fiberglass

Glass fiber, or fiberglass, is made up of tiny glass rods less than $^1/_{20}$ the diameter of a human hair. These rods are pressed together, creating tiny voids between the fibers. These voids absorb the sound. Glass fiber tends to fall into a high NRC range, but it has a low STC. A backing such as foil can be used to improve the STC. A further disadvantage of glass fiber is that it doesn't come in a fire-rated form, more because it can't meet the weight standards (1 pound per square foot) than because the material is combustible. Fiberglass is more expensive than mineral fiber. Also, there's growing concern that fiberglass may be a health hazard, so its use is decreasing.

Vinyl

Vinyl-covered gypsum is occasionally used in food processing areas or garages because it's easy to clean. The smooth surface of the vinyl keeps it from absorbing sound, so the product has a low or unrated NRC. But the STC range is very good.

Wood Fiber

Wood fiber, or fiberboard, is a lightweight backing that comes in 4 × 8-foot sheets, $^1/_2$ inch thick. Fiberboard is often used instead of gypsum board if acoustic performance is a consideration. Fiberboard with an acoustical coating has a good NRC rating. You can't use it for ceilings in commercial applications, but you can use it for walls.

Orion

Orion is a unique acoustical material. The material, an oatmeal-like substance, is dumped into 8-foot wide pans and shaken and shifted until it settles into flat sheets. Rollers squeeze out the excess water. The material is kiln dried for 8 to 10 hours and then cut to size. Orion is presently more expensive than other common acoustical materials, but its high NRC (up to 1.00) makes it an attractive option.

Acoustical Characteristics

Fire Resistance

Fire resistance measures how well a structure keeps fire from spreading from one part of a building to another, while maintaining structural integrity. In the past, material was classed A, B, C, or D. Currently, material is either Class A (nonfire-rated), or fire rated into 1, 2, or 3 hour classes. Fire-rated material has ceramic in it to slow its burning. Class A material may be used only in residential construction.

Fire-resistance ratings are frequently misunderstood by architects and builders alike. They often assume that by using 1-hour panels, they have a 1-hour ceiling. But classifications are established for an entire *system* and not just one component in the design. For instance, while 3-hour material will be slower-burning than 1-hour material, it will still burn through in less than 3 hours. The larger design of which it's a part, however, will theoretically keep a fire from spreading for 3 hours. The fire-resistance capabilities of a system are tested according to Underwriters Laboratories' specifications. If, during a fire test, a panel stays in its grid from 60-119 minutes, it's considered 1-hour rated. From 120-179 minutes, it's 2 hour. And from 180-223 minutes, it's considered 3 hour.

Surface Burning Characteristics

Surface burning characteristics are measured by observing how quickly flames spread and how much smoke develops. These factors are then expressed in a single number. The number is relative to how red oak burns (100) and inorganic reinforced cement board burns (0). Acoustical material commonly falls into the 0-25 range.

Light Reflection

Material is classified into light reflection (LR) grades, with 1.0 reflecting the most light. A grade of LR 1 means 75 to 100 percent of the light is reflected back; LR 2 is 70 to 74 percent reflection; LR 3 is 65 to 69 percent; LR 4 is 60 to 64 percent. Under 60 percent is ungraded. The vast majority of acoustical material falls into the first two grades, with LR 1 being the most common.

In addition to these federal ratings, you have to consider other characteristics for acoustical material. You'll weigh the ease of installation and maintenance, resistance to moisture, insulating properties, and cost as well.

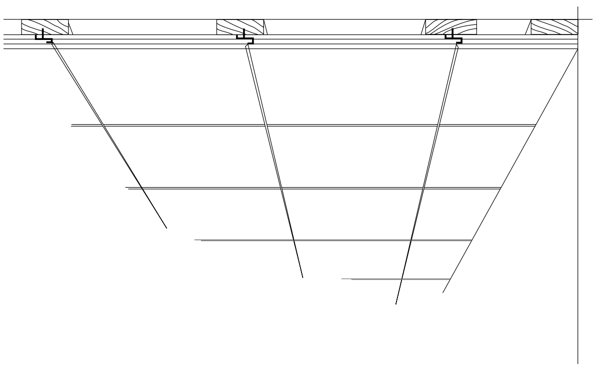


Figure 1
Ceiling tile on furring strips

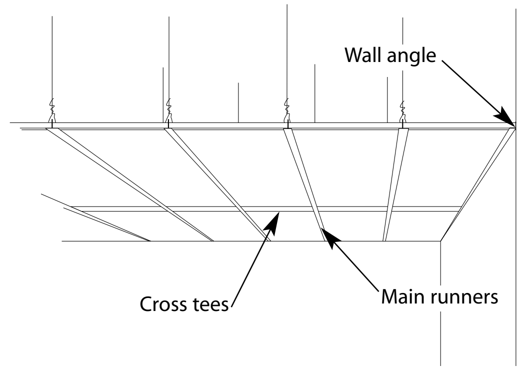


Figure 2
Suspended ceiling panels

Installing Acoustical Ceiling Tiles

There are two common ways to install acoustical ceiling tiles: directly to a smooth backing or attached to furring strips (Figure 1), or suspended in a metal grid (Figure 2). For either method, schedule ahead so the materials are delivered at least 24 hours before installation. Store them in the location they'll be used. That way, any shrinking or swelling due to temperature or humidity will happen *before* you install it.

Although it's not particularly difficult to hang a suspended ceiling, you can hire a drywall sub if you don't want to do it yourself.

Layout

Your finished ceiling will look better if the border tiles are the same width and none of them are less than half a tile wide. For instance, if you're using 12-inch tiles, you wouldn't want to have a row of full tiles on one end and a row of 4-inch tiles on the opposite end. For better balance, plan a row of 8-inch tiles on each end (12" + 4" ÷ 2 = 8"). To make sure this happens, you'll need to do a little simple preplanning. First measure the length and width of the room. Then snap a chalk line the length, width, and both diagonals of the room to find the center point. Finally, use Figure 3 to position the ceiling tile.

Cut the tile, face up, with a utility knife and a straightedge. Or score the face with a utility knife, and then follow with a handsaw or power saw with the face side still up.

Installing Ceiling Tiles

Tools and Materials

- *Utility knife*
- *Level or straightedge*
- *Chalk line*
- *Talcum powder or corn starch (use on your hands before handling tile to keep from smudging it)*
- *Staple gun with 9/16 inch staples or*
- *Hammer and 4d nails or*
- *Tile adhesive, brush, and putty knife; mineral spirits*
- *Putty*
- *Goggles*
- *Dust mask*
- *Protective clothing*

Ceiling tiles come in a variety of sizes. The 12- × 12-inch square tiles are the most common, but 12- × 24-inch tiles are also frequently used. Figure 4 shows a tongue-and-groove ceiling tile.

If the ceiling is level and in good shape, you can glue the tiles directly to the surface. But first allow new concrete to cure at least six months and new plaster to cure at least a month. Don't glue tile directly to concrete unless you've insulated and vented properly and placed a vapor barrier to avoid temperature and humidity differences. (See *Insulation*.) Prime the surface of new concrete, and clean all dust from the surfaces where you'll apply adhesive.

If the ceiling is in poor shape, install 1 × 3 furring strips 12 inches on center at right angles to the ceiling joists. Work from the center of the room out, shimming the furring strips wherever needed to make a level surface.

Furring Strip Method

1. Snap a chalk line for each border. Make sure the chalk line is parallel to the center line, not the wall. Cut corner tile to size, cutting off the two tongue sides. Cut the tongue side off of all border tiles for the first horizontal and vertical rows, adjusting for any unevenness in the walls. See Figure 5.
2. Place the first tile in the corner, flange side out. Nail the flush sides of the tile at the corner and walls. Continue with the border tiles, nailing the side against the wall and stapling the flanges to the furring strips. Putty the nail holes when the tiles are all in place.

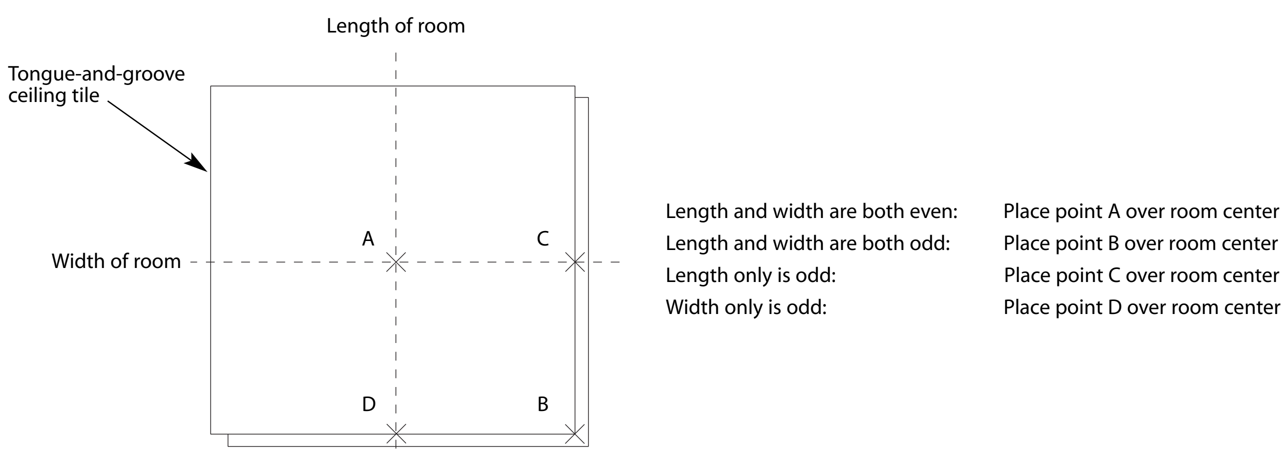


Figure 3
Positioning the ceiling tiles

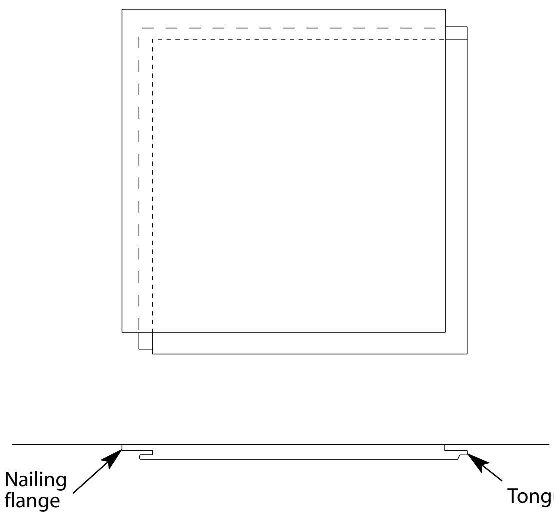


Figure 4
Ceiling tile

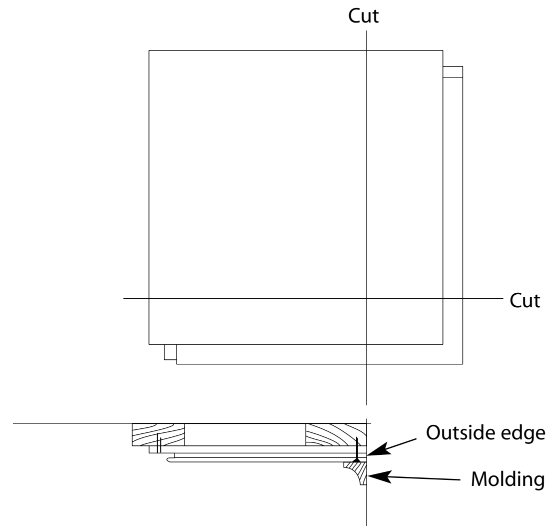


Figure 5
Corner/perimeter ceiling tile

3. Build out from the corner, slipping the tongue into the border tiles' grooves. Staple the flanges to the furring strips. For 12 × 12-inch tiles, use three staples to a side. Use five staples to a side for 12 × 24-inch tiles. Work across the room diagonally. See Figure 6.

Solid Backing Method

1. Follow steps just described for layout, cutting, and placement of tile.
2. Brush a light coat of glue on the back of the tile. Dab a walnut-size ball of glue on each corner about 2 inches in. (For 12 x 24-inch tiles, place eight balls of glue.) Press the tile firmly in place, sliding it into the adjacent tongue and groove, or kerf. Then clean up the adhesive with mineral spirits.
3. If the wall is solid drywall in good condition, you can staple the tiles directly to it in the pattern described.

Estimating Acoustical Ceiling Tiles

Estimate how many tiles you'll need by calculating the square footage of the ceiling (length times width). For 12- × 12-inch tiles, the square footage is the same as the number of tiles you need. If you're using 12- × 24-inch tiles, divide the square footage by 2.

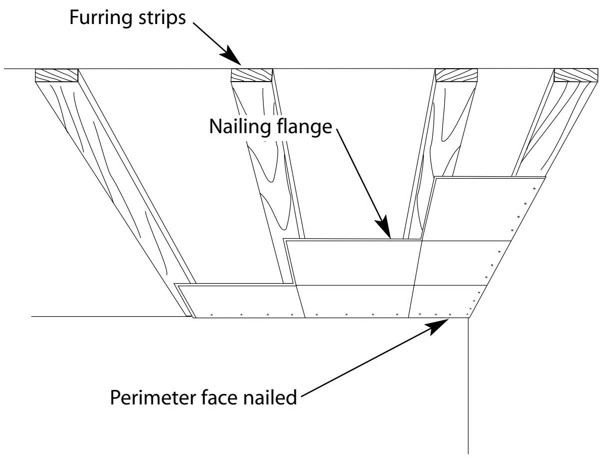


Figure 6
Installing ceiling tile on furring strips

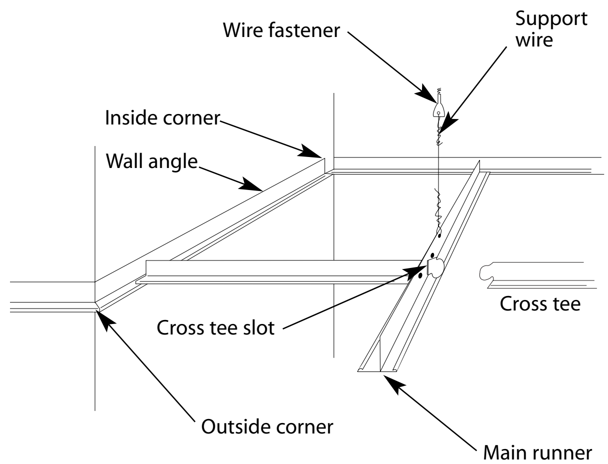


Figure 7
Suspended ceiling system

A two-person crew installing 12- × 12-inch tongue-and-groove ceiling tile with staples should be able to install about 58 tiles an hour. This will, of course, vary with the layout of the room. You can set more tiles per hour in a large open room, and substantially fewer per hour in small or cut-up rooms. If you use furring strips, a carpenter and a laborer should be able to install around 40 square feet of 1 × 2s at 12 inches on center per hour.

Repairing Ceiling Tiles

1. Use a utility knife to cut out damaged tile, scraping out stubborn pieces and adhesive with a putty knife. Clean out the grooves.
2. Cut a new tile to fit, removing its tongues and flanges. Glue or nail it in place.

Installing a Suspended Ceiling

When a ceiling needs to be lowered or you need easy access to wiring, ductwork and pipes, a suspended ceiling is a better choice than ceiling tile. The most common sizes used in suspended ceilings are 24 × 24 inches and 24 x 48 inches. The tiles are laid in a metal grid that's suspended from the ceiling. Allow at least 2 to 3 inches between the ceiling or joists and the new ceiling. It will be difficult to maneuver tiles into place if there's less space than that. Look at Figure 7.

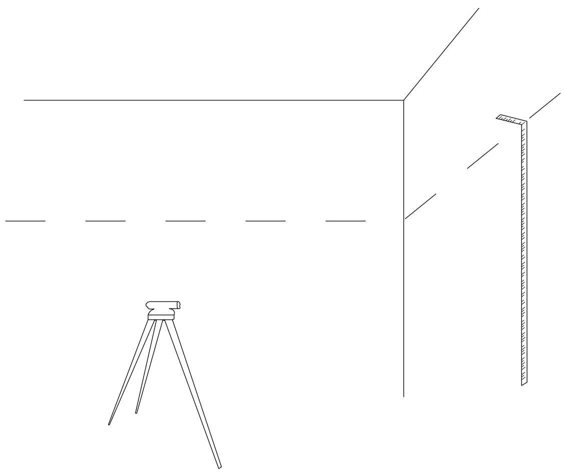


Figure 8
Shooting in a level line

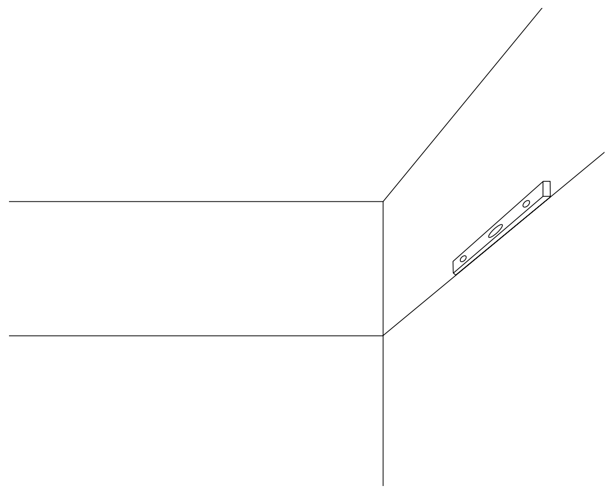


Figure 9
Placing wall molding with a builder's level

Don't hang light fixtures or other ceiling apparatus from the metal grid unless you're sure the system can support their weight. It's better to suspend the fixtures directly from the ceiling.

By far the most difficult part of hanging a suspended ceiling is getting it level. If the ceiling isn't perfectly flat, the tiles will rock or tip or appear out of line. Professional ceiling installers use laser levels to do the job right. For someone who only does an occasional ceiling, sighting in with a transit will work. If you don't have a transit, check repeatedly with your level and tape measure while hanging the wall angles and the main tees. See Figure 8. For small areas, you can get by with leveling with a builder's level (Figure 9).

Estimate the number of panels by finding the square footage of the ceiling, then dividing by 4 (for 2- × 2-foot panels) or 8 (for 2- × 4-foot panels). Or sketch the ceiling on paper and count the number of panels.

Installation Guidelines

1. Snap a chalk line around the room at the height where the new ceiling should go. Fasten the wall angle at this line. Cut your pieces carefully to make sure every end is fastened to a stud. Use nails, screws, or staples to attach the pieces to the studs. Use concrete nails to attach pieces to masonry. Miter outside corners; butt inside ones.

2. Snap a chalk line on the ceiling or ceiling joist to mark the center main tee. Hammer in 6d nails above the wall angles on both sides of the room where cross tees go. Tightly stretch the string across the room and tie it to the nails.

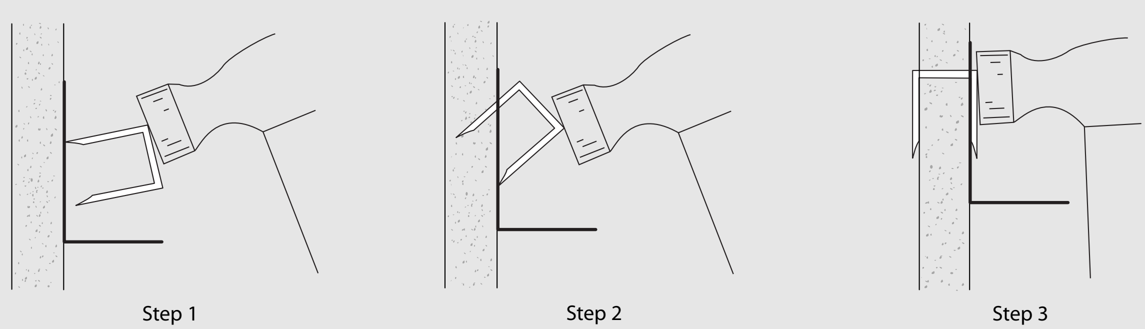
Materials and Equipment

- *Wall angle: L-shaped piece attached to the wall around the perimeter of the room; available in 10- or 12-foot lengths; nailed, screwed or stapled to the wall (see sidebar)*
- *Main tee: T-shaped piece for spanning the length of the room; placed at right angles to the joists; available in 8- or 12-foot sections; hung from the ceiling with screw eyes and wire*
- *Cross tee: T-shaped piece for spanning the width of the room, placed parallel with the joists; available in 2- or 4-foot sections; connects into the main tees by tabs and slots*
- *Splice plate: Straight piece with slots, used to connect main tees*
- *Screw eyes or hook and nail: Attached to the ceiling to hold wire; allow one for every 4 feet of main tee*
- *Wire: 18-gauge hanger wire for hanging the main tees; cut at least 4 inches longer than the distance between the old and new ceilings*
- *Tin snips: To cut steel tees and angles or*
- *Hacksaw: To cut aluminum*
- *Chalk line*
- *Transit and/or level*
- *Fasteners (staples, nails, or screws) with appropriate fastening equipment*
- *6d nails*
- *Hammer*
- *String*
- *Utility knife and/or saw (to cut panels)*

Attaching Wall Angle to Drywall

When backing isn't convenient, here's a slick way to attach the wall angle to drywall. But remember that it's only as strong as the drywall and the staple. You can't use this technique structurally, but it will work to attach a wall angle to support acoustic tile. Use a heavy gauge fence staple and follow these steps:

1. *With the metal angle molding in place, strike the staple, centering on only one of the points. For this technique to work, make sure only one of the points pierces the metal.*
2. *Strike the outer corner of the staple to continue to drive it sideways through the metal and the drywall. Carefully direct the force of the hammer on the staple, so you're driving only one point into the metal.*
3. *When the staple is tight, it will secure the metal anchor by pinching it to the drywall.*



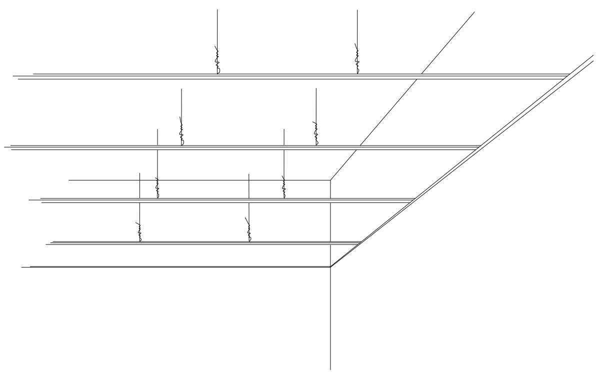


Figure 10
Hanging main runners

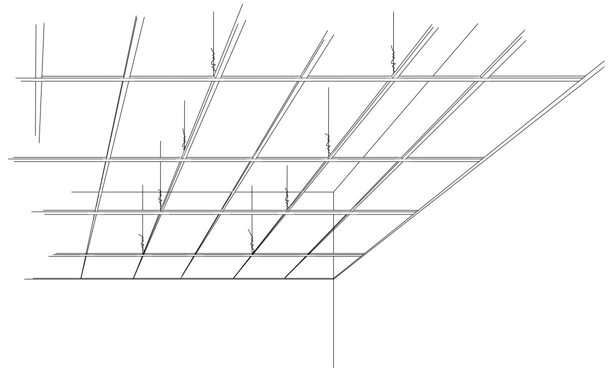


Figure 11
Main runners and cross tees in place

3. Cut suspension wires for the main tees. Attach screw eyes or hooks and nails to the ceiling joists at the chalk line every 4 feet where the cross tees will run. Slots in the main tee for the cross tees must line up with the cross strings.

4. Insert suspension wires through the screw eyes, twisting excess wire around itself. Insert the other end through the main tee and secure the loose wire by twisting it around itself. Make sure the tee is level. If the length of the room is more than 12 feet, splice two main tees together with a splice plate. Wire both sides of the splice. See Figure 10.

5. When main tees are in place, connect in the cross tees (Figure 11). Check again to make sure the entire system is level. Set in the panels by angling them up through the space, straightening the panel, and laying it in place.

Estimating a Suspended Ceiling

Estimate how many tiles you'll need by calculating the square footage of the ceiling (length times width). If you're using 12 × 24-inch tiles, divide the square footage by 2.

A two-person crew can usually install about 100 square feet of standard 2 × 4-foot grid with wires per hour. Be sure to allow additional time for cut-up or small rooms.

Placing the ceiling tile in the grid is a simple drop-in process except for borders, corners, lighting, columns and other nuisances. For a simple drop-in ceiling using an average price nonrated tile, the two-person crew should be able to install around 250 square feet, or 32 tiles per hour. Tile prices vary depending on cut, style, texture and fire rating.

Manhours

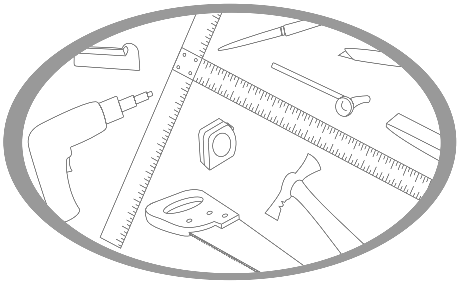
Manhours to Install Acoustical Ceiling, per SF		
Type	**Manhours**	**Suggested Crew**
Ceiling tiles, 12" × 12", glued or stapled	.035	1 carpenter
Suspended ceilings:		
Grid system, 2' × 2'	.017	1 carpenter
Grid system, 2' × 4'	.015	1 carpenter
Add for under 400 SF job	.007	1 carpenter
Ceiling tiles, deep textured, 3/4" reveal edge	.010	1 carpenter
Ceiling tiles, random pinhole or fissured, 5/8" square edge	.004	1 carpenter

For information on related topics, see:

Acoustics, page 21

Asbestos, page 31

Insulation, page 395



Acoustics

Acoustics is the science of sound – its spread, transmission, and effects. It's important for a contractor to understand acoustics because we live in such a noisy world. One objective of construction design is to control that noise, whether it's transmitted through walls, ceilings, or even across open space. If you build a spec house in an unusually noisy location, like an airport flight path or near a school with a sports stadium, you have to pay special attention to the acoustic materials you use. If you don't, selling it is going to be harder than building it. And if you build a room addition without adequate noise insulation, you can expect some very unhappy customers.

What Is Sound?

Sound is produced by vibrations that travel in waves at 1130 feet per second, or roughly one mile every five seconds. The frequency of the vibrations, measured cycles per second (Hz), determines the pitch of the sound. Humans can hear an enormous range of sound, from 16 Hz to 20,000 Hz. That's far wider than the piano's range of 30 Hz at the base end to 4,000 Hz at the soprano end. Sound intensity is measured in decibels (dB). At 0 dB, a person with normal hearing can barely hear the sound. At 130 dB, the noise is so loud it causes pain. A whisper would be in the 10 to 20 dB range, an average conversation at 50 to 60 dB, a train passing at 100 dB, and a jet plane closer to 130 dB.

Acoustical Ratings

Materials are acoustically rated in several ways. The most common is the Noise Reduction Coefficient (NRC) – the percentage of sound a material absorbs. An NRC rating of 0 means that the material will absorb no sound while a rating of 1.00 means the material absorbs 100 percent of the sound that strikes it. A material rated 0.75 absorbs 75 percent of the sound. Any material with a rating of 0.50 or greater is considered to have excellent sound-absorbing properties. Heavy drapes or thick carpet would fall above 0.50. Materials like brick, tile, glass and plaster are rated under 0.10.

Materials may also be given a Sound Transmission Class (STC) rating. This rates the effectiveness of a sound barrier, whether it's a door, partition or floor, in reducing the transmission of noise from one space to another. Figure 1 describes the range of ratings.

Building codes are primarily concerned with STC ratings, and then only for walls or floors that separate living units (apartments or townhouses) or guest rooms (hotel or dorm rooms). The Uniform Building Code requires a minimum STC rating of 50 for all separating walls and floor/ceiling assemblies. Any openings that may permit noise to filter in need to be treated to meet the rating.

In addition to NRC and STC ratings, floor/ceiling construction may have an Impact Noise Rating (INR). That's a measure of how much noise is transmitted from one level to the level below. The INR is shown on an impact noise curve. Above 0 is a plus value, below 0 is negative. The minimum floor construction should have a 0 rating; luxury apartments should have an INR of 10 or better. These standards are always measured in a sealed room, so the ratings are for the best circumstances without any variables.

Sound Absorption and Transmission

There are two aspects of sound to consider when you design or construct a building: sound *absorption* and sound *transmission*. You have to pay attention to both. A material that efficiently absorbs sound can also easily transmit it. Likewise, materials that prevent sound from being transmitted may reflect it, causing echoes or reverberations. Look at Figure 2.

Rating (dB)	Soundproofing quality	Speech comparison
25-30	Poor	Normal speech is understood easily through the wall
30-35	Fair	Loud speech is understood; normal speech is audible
35-40	Good	Loud speech audible but not understood; normal is inaudible
40-50	Very good	Loud speech is faintly audible
50+	Excellent	Very loud speech is inaudible

Figure 1
Sound Transmission Class (STC) ratings

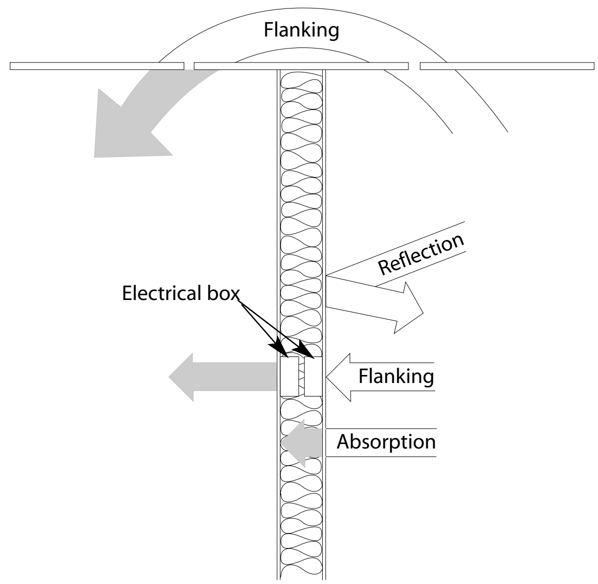


Figure 2
Sound absorption and transmission

The surfaces in a room determine how much sound is absorbed. The smoother the surface, the more sound is reflected back and not absorbed. For instance, a smoothly-plastered wall will reflect up to 98 percent of the sound that strikes it. Highly-textured surfaces will absorb considerably more sound. The amount of sound a surface will absorb depends on both the frequency of the sound *and* the size, depth, and number of pores in the material. Acoustics may also be controlled with construction methods such as angling walls and ceilings or leaving a dead air space between rooms. With ordinary construction materials and methods, it's difficult to absorb more than about 10 dB.

If you add a door or duct work or even electrical outlets back to back, additional noise will filter in. This is called *flanking*, and you can't afford to ignore it in the acoustical design. In commercial buildings where suspended ceilings are used, flanking can be a special problem because sound can travel by way of a common ceiling. To reduce flanking (in other words, reduce the sound transmission), you can build a vertical sound barrier between rooms in the plenum space. Or you can put an acoustic blanket, coating or film above the acoustical tile as long as it doesn't affect the fire resistance rating of the assembly. Any openings that permit flanking in ceilings and walls need to be treated to meet the required STC rating in multifamily housing.

You should also factor in background noise when you consider acoustic factors. Background noise tends to mask specific sounds. So although the decibel level is actually higher, sound transmission may be less of a problem because specific sounds aren't distinguishable.

For information on related topics, see:

Acoustical Tile, page 9

Insulation, page 395

Wall Framing, page 709

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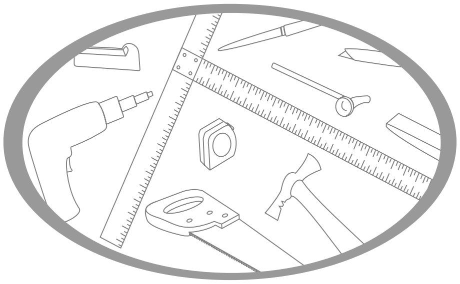


Adhesives

In basic terms, an adhesive is a liquid material used to bond two surfaces together. Depending on the adhesive, you may apply it to one or both of the parts to be bonded. That's a simple enough process.

But adhesives undergo complex physical and/or chemical changes that aren't totally understood. In the last 50 years, new chemically-synthesized adhesives have introduced changes that make it possible to bond materials that are very different in composition, thermal expansion, and thickness.

Beside bonding materials together, adhesives also add strength and stiffness to the materials. The stress is more uniformly transferred and distributed over the entire surface instead of just at the fasteners. As a result, the end product has greater strength than the sum of the parts. A glue-laminated beam is an excellent example of this. It's far stronger and can take far greater stress than a similar size solid wood beam.

Classes of Adhesives

Adhesives are generally classified three ways: elastomeric, thermoplastic or thermosetting.

Elastomers will stretch to twice their original size and still return to their original shape. By themselves, they aren't very strong, but they're often added to adhesives to give flexibility. Elastomers are used extensively in manufactured housing because they allow units to be transported without breaking apart.

Thermoplastics soften and harden as the temperature changes, like butter that's exposed to temperature variations. They generally adhere well to both plastics and metal. Don't use them for heavy load-bearing bonds because of their sensitivity to temperature.

Thermosetting adhesives set into a hard, rigid, and strong substance. Once set, they don't soften again. They might, however, be adversely affected by prolonged high heat — just like an already-baked cake would be ruined by further baking.

The adhesive formula depends on the specific needs for strength, durability, adhesion property, and the bond speed. Manufacturers add fillers, extenders, reinforcing agents, solvents and catalysts to the adhesive base.

- Fillers may control penetration and flow. They also add bulk and reduce the overall cost.
- Extenders are similar to fillers. They usually don't add adhesion capabilities, they just reduce the cost by increasing the volume of the adhesive.
- Reinforcing agents improve properties such as shrinkage and toughness.
- Solvents disperse or dissolve base materials, changing the viscosity (rate of flow) of the adhesive.
- Catalysts don't actually enter the chemical reaction; rather, they speed it up to create a faster set or cure time.

Manufacturers may also add other ingredients to meet specific needs, including preservatives to prolong the shelf life of the adhesive, wetting agents to help an adhesive to flow or penetrate better, antioxidants to inhibit oxidation and acid scavengers to remove or reduce impurities.

Types and Purposes of Adhesives

Although adhesives have been used for over 3,000 years, until the mid-1940s they were all derived from animal parts (like casein or blood) or plant products (like soybeans or rubber). The military needs of World War II prompted research and development in the field and gave rise to today's growing industry.

In construction, adhesives are used for everything from laminating plywood to hanging drywall. Each task requires different kinds of adhesives and processes. Remember, no connection is stronger than its weakest component. That's why knowing and using the correct adhesive for the job is as important as engineering a foundation to support the rest of the structure.

In choosing the right adhesive, it's important to assess the specific needs of the project. You may or may not need exceptional strength, temperature tolerance, resilience, long life expectancy or resistance to moisture, humidity or light. But you always need to consider the cost and ease of application.

On some jobs, you'll choose adhesives for their reaction to temperatures in the application and setting processes. Here are some of the common ones used in construction:

- Cold-setting adhesives set at temperatures below 87 degrees Fahrenheit. Contact adhesives form an instant bond upon contact between two treated surfaces.
- Heat-activated adhesives come as a dry adhesive film that becomes fluid and active with the application of heat. *Hot-melt* adhesives are applied hot and harden into a bond when cool. *Hot-setting* adhesives set at temperatures over 212 degrees Fahrenheit. *Intermediate-setting* adhesives set at a temperature from 87 to 211 degrees Fahrenheit.

There are thousands of adhesive formulas and brands, many for highly-specialized jobs. The chart in Figure 1 covers some of the most common types of adhesives.

Adhesive Dangers

Adhesives may contain toxic chemicals, or the chemical process of adhesion may produce toxic chemicals. Prolonged exposure to these adhesives in a closed area may cause health problems. Be sure to read the label and follow the guidelines for ventilation both during application and curing.

Some adhesives also have a low flashpoint. As long as an area is well-ventilated, fire danger is low. However, a lit cigarette could still cause a fire. Follow the manufacturer's warning labels to be safe. Ask your retailer for detailed information, then post this information at the job site.

Choosing the Right Adhesive

Choosing the right adhesive for the job is the most important factor in creating a successful bond. But surface preparation is also important. You greatly reduce the chances for a durable bond if you don't take time to correctly prepare the surface. Clean, smooth surfaces are essential. Wiping the surfaces with a clean cloth may be all that's necessary, although they may need sanding, chemical cleaning or treating, abrading or degreasing. Always follow the specific manufacturer's instructions.

Gluing Wood

Wood is actually the most complex bonding surface. Not only do species vary in their oil and moisture content and general chemistry, but their surface textures may be very different. These elements will even vary from tree to tree within a species. A single tree will vary in

Adhesive	Common brand names	Description	Typical uses	Application	Characteristics	Solvent
Acrylic	Duro Depend II; Devcon Plastic Welder	2 parts, liquid and powder, mix just before using	Wood, metal glass	Apply with brush, putty knife, or wood stick; sets in 5 minutes; cures overnight	Fast, strong bond; waterproof; rigid	Acetone
Aliaphatic resin (AR)	Elmer's Carpenter's; Duro Professional; Titebond	Yellow carpenter's glue; a ready-to-use liquid	Wood bonding and repair	Small jobs: squeeze from bottle, clamp. Large jobs: apply with brush, clamp. Sets in 1 hour, cures overnight; may be sanded or scraped	Rigid, water soluble, dries clear	Warm water
Animal glues	Franklin Liquid Hide Glue (liquid form); dry form marketed under store brands	Made from animal hides and bones; comes in dry (flake) or liquid form	Repairing items originally glued with hide glue	Dry form soaked and melted in water, then heated; applied hot to wood joints. Liquid form applied from bottle or with brush. Sets quickly	Water soluble	Warm water
Casein glue	National Casein Co. No. 4420	Milk-base glue; comes in powder that's mixed with water	Good for oily woods, Southern pine, sitka spruce, Douglas fir	Mix with water, apply with a brush or roller; sets in 6-8 hours	Doesn't withstand moisture	Warm water
Contact cement	Ashland Chemicals Contact Cement; Weldwood Contact Cement	Liquid cement with a neoprene base	Veneers, laminates	Apply with brush or roller to the 2 separate surfaces and allow to dry to tacky state; press together	When surfaces come into contact with each other, make instant and permanent bond	Acetone
Cyanoacrylate (super glue)	Krazy Glue; Duro Quick Gel	Ready-to-use liquid	Plastics, metals, vinyl, rubber, ceramics, wood	Apply sparingly direct from tube; sets in seconds; cures in 30 minutes to 12 hours	Highly irritating to skin; water resistant; rigid to semirigid; fast, strong bond	Acetone
Epoxy resin	Miracle Fast-Set Epoxy; Devcon 2-ton Epoxy	Epoxy resins cover a wide range; often a 2-part adhesive with equal parts of white liquid epoxy resin and a dark liquid catalyst	Metal, wood, glass, plastics, ceramics; good for bonding two dissimilar materials	Brush, flow roller, or extrusion; setting time varies from 5 minutes to overnight, depending on type	Dries to extremely rigid and strong bond; waterproof	Acetone
Mastic	Franklin Construction Adhesive; Webtex 200 Acoustical Adhesive, PL400	Comes in tubes or canisters	Installing plywood panels, flooring, ceiling, wall, and floor tiles	Use adhesive gun for tubes; wood paddle from canisters; press surfaces together before a skin forms on mastic	Thick, waterproof adhesive; can bridge gaps between rough or poorly-fitting surfaces; tolerates wide range of temperatures and moisture conditions	Mineral Spirits

Figure 1
Types and characteristics of common adhesives

Adhesive	Common brand names	Description	Typical uses	Application	Characteristics	Solvent
Plastic cement	Testors	Comes in tube; best known for model building	Used for minor repairs of plastics	Apply sparingly directly from tube onto 1 surface; sets in seconds; cures in 2 hours	Fast setting	Acetone
Polyvinyl chloride (PVC)	Do-It-Best; Plastmo	Ready-to-use liquid	China, marble, glass, wood, plastic	May require primer; apply directly from tube or use wood paddle and twist slightly; setting time depends on type	Waterproof, rigid	Acetone
Polyvinyl resin emulsion (PVA)	Elmer's Glue-All; Franklin's Home, Shop, Craft	Common white glue; comes in plastic bottle	Paper, wood, ceramics	Small jobs, squeeze directly from tube; large jobs, use brush; clamp. Set in 8 hours; cures in 24	Water soluble; heat sensitive; will soften if exposed to heat for long periods	Soap, warm water
Resorcinal-formaldehyde resin (RF)	Elmer's Waterproof Glue; Weldwood Waterproof Glue	2-part glue with liquid resin and a powdered hardener or catalyst	Wood; especially good for boat building and outdoor furniture	Apply with brush or roller; clean excess before it sets as it can't be removed when hard	Sets in 6-10 hours; has a hard dark joint; highly resistant to moisture	Cool water before hardening
Rubber cement	Black Magic (black); Brite Magic (white)	Rubber-based cement; comes ready to use	For temporary bonding on metal, glass, plastics	Small jobs, straight from the tube; large jobs, use spatula, putty knife, or trowel	Since it doesn't contain water, useful for bonding paper	Turpentine
Urea-formaldehyde resin (UF)	Welwood Plastic Resin Glue	Powder or liquid form; powdered catalyst added to liquid; powder is mixed with water	Wood joints that are subject to moisture	Apply with brush, roller, or spatula; sets in 4-6 hours, less at higher setting temperatures; cures in 24 hours	Leaves hard brown joint	Warm soapy water before hardening

A 70° Fahrenheit room temperature is assumed for setting and curing. Although many adhesives will set and cure at higher or lower temperatures, the times will vary and the bonds may be affected. Follow the manufacturer's directions.

Figure 1 (continued)
Types and characteristics of common adhesives

its porosity, density and dimensional stability, depending on whether it's cut radially, tangentially or transversely. And the milling process can cause chemical variations.

Wood bonds best when it's dry, clean, and free of irregularities. The optimum moisture content is below 10 percent. If the moisture content is too high, the adhesive will thin, and the joint will be weak and might raise or bulge.

It's easiest to edge glue a different wood surface, and most difficult to glue the end grain because that surface is the roughest. When gluing edges together, follow these three steps.

1. Place the wood so the grain of all the pieces runs in the same direction. This will make sanding the finished product easier. Try to match the design in the wood for the nicest effect.
2. Alternate the direction of the growth rings in order to avoid cupping later on.
3. Use pieces no more than 4 to 6 inches wide for best results.

Gluing Metal

Even though metal is a more predictable bonding surface, it still requires adequate preparation. Chemical cleaning, washing, drying and possibly even priming may all be necessary for a successful bond. Metal bonds fail most often because the metal is stronger than the adhesive.

Gluing Plastics

Plastics are generally easy to bond because it's easy to control the moisture and porosity. Their biggest drawback is that it can be difficult to evenly wet the surface with the adhesive. You may have to use a solvent wipe, sandpaper or other abrasive material, and then another solvent wipe.

For information on related topics, see:

Carpet, page 107

Ceramic Tile, page 125

Countertops, page 209

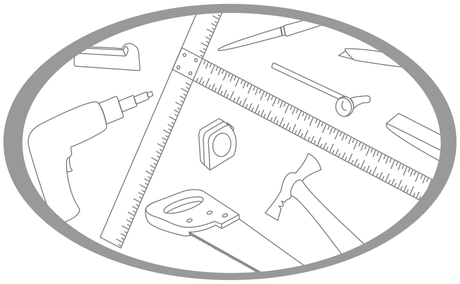
Flooring, page 359

Resilient Flooring, page 503

Trim, page 673

Wallpaper, page 737

Wood Flooring, page 759



Asbestos

Asbestos is a mineral fiber that's mined and processed from metamorphic rocks. The term actually refers to a variety of soft, thread-like, inorganic fibers. The two most common kinds of asbestos used are chrysotile and amphibole. But because there are many varieties, asbestos is more accurately identified by its characteristics. It's prized for its tensile strength and flexibility, as well as its resistance to high temperatures and acids. In addition, it doesn't conduct electricity.

For obvious reasons, all these qualities made asbestos extremely useful in construction materials. And from the mid-1940s to the 1980s, asbestos was used in countless ways: in pipes, insulation, shingles, siding, paint, fuse boxes, and even spackling compound. In fact, asbestos is part of so many products that it's difficult to identify which products contain it.

However, since the early 1970s, asbestos has come under heavy fire because of the potential health hazards associated with it, and its use has declined steeply. The danger associated with asbestos is the airborne particles, which are believed to cause various lung diseases, including cancer. Because of this potential hazard, regulatory agencies have required removal of asbestos in many public buildings, particularly schools. The cost of this is enormous.

Recent research suggests that not all of the fears are warranted. Two factors underscore this. First, studies indicate that the biggest risk with asbestos is with amphibole fibers, not chrysotile. Since 95 percent of the asbestos used in construction materials is chrysotile, the risks are probably not as great as authorities first thought.

Second, asbestos is a danger *only* when the particles are airborne. Fibers can be released during mining, processing and installation. But once the asbestos is in place, the fibers don't deteriorate spontaneously. Ironically, the very process of removing the asbestos can be more hazardous than leaving it in place because the fibers become airborne when disturbed.

The real risk is with exposed friable asbestos (asbestos that's easily crumbled or broken). Current regulations stress removal of exposed friable asbestos and monitoring the rest. For instance, roofing felt with asbestos is unlikely to be a problem because it's sealed and flexible. Pipe insulation, however, should be removed because it may be exposed and flaking.

The risk models to determine the safety of asbestos were based on statistics from people exposed to asbestos occupationally. The true risks for those exposed environmentally (day-to-day exposure in a building that has asbestos in it) are considerably lower. Let's put the danger from asbestos exposure in perspective. Statistically, 1 in 100,000 deaths may be caused by exposure to asbestos. That means a person is 10 times more likely to die from breathing the air in Los Angeles than he is from going to school in a building with asbestos.

Asbestos Abatement

In the construction industry, asbestos poses the greatest health risk to those who install it and those who remove it. Because the use of asbestos has declined dramatically since the 1970s, people in construction are most likely to be exposed to the risks when removing asbestos from existing buildings — or *asbestos abatement*.

If you have material with asbestos that needs to be removed, don't break, sand, sweep or vacuum the material. Wetting down the material in an effort to settle the fibers is only a temporary solution at best. When the material dries, the particles may still become airborne.

Clients expect their contractor to anticipate problems such as asbestos abatement. If you run into asbestos on a job and haven't included it in the bid, the cost to remove it will be yours. But there's a way to prevent that. Always include a clause in your contract that says asbestos abatement is not included in the price unless otherwise noted.

If you know you'll have to remove asbestos, include the cost in your proposal. To protect yourself, get a written estimate from an asbestos abatement contractor before submitting a final bid to the client. They have special equipment and a thorough knowledge of the process. Workers must take air samples, wear protective gear, and use respirators. The work area must be sealed and a change room provided for workers. Material containing asbestos must be disposed of properly. Some landfills won't take it at all, and some will take it only with special precautions (and an added fee). And some make a distinction between nondeteriorating and friable asbestos.

Local regulations vary concerning asbestos abatement, so the cost and difficulty of removal and disposal vary greatly as well. If you're uncertain if a substance is asbestos, ask a building inspector to inspect the site. Local building inspectors will also provide current regulations upon request.

For more information on related topics, see:

Radon and Other Pollutants, page 499

Resilient Flooring, page 503

Roofing, page 561

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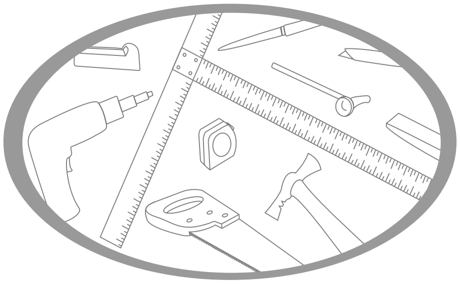


Asphalt Paving

Asphalt is a bituminous hydrocarbon, either solid or semisolid. It may be a natural asphalt, like lake or rock asphalt, or derived from petroleum refining. Asphalt has a viscous (sticky or glutinous) quality that cements materials. As it's heated, it gradually liquefies.

Many small contractors will go through a lifetime of building and remodeling without ever needing to know anything about Hot Mix Asphalt (HMA). So a contractor who has a job that requires HMA often has little experience to fall back on. Hot Mix Asphalt (also called *blacktop*, *asphalt base*, *open-graded friction course* or *sand asphalt*) has specialized terms, design requirements, and scheduling and estimating problems that are uniquely its own.

For a paving job of any size, you'll want to get bids from several asphalt contractors. While we can't teach you how to pave a parking lot in this limited space, we'll try to give you enough information to evaluate the bids you receive.

Asphalt Pavement

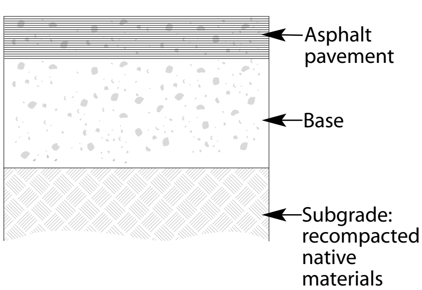


Figure 1
Asphalt pavement

Pavement is built in layers: the subgrade, base, and pavement (Figure 1). The thickness of each layer is determined by an engineer based on the traffic load and native material bearing capacities. We'll look at them one at a time.

Subgrade

The bottom layer is the soil subgrade, which supports the base and pavement. It should be a material that will compact well. You may be able to use the existing soil for the subgrade. But if it's poor quality, such as organic soil, silt or clay, you'll have to undercut and remove it, then replace it with sand or gravel. This is especially true in climates where moisture or frost is a problem. Clay and silt will swell with moisture and heave with frost, causing damage to the surface layer. (See Figure 2 for a more detailed explanation of subgrade soils.) When you've treated or replaced the subgrade soil with better soil, it's called *improved subgrade* or, less commonly, as *subbase*.

The subgrade must be dry and graded as smoothly and carefully as the pavement itself. The shaping should be smooth, with no spots where water will pond and saturate the soil, even before the pavement is laid. Finally, it must be compacted and protected from additional moisture, with subdrain systems if necessary. Good drainage is vital for durability.

Roads with two or more lanes should be crowned with a cross-slope of 2.0 percent. Large open areas, such as parking lots, should be crowned with a minimum slope of 1.0 percent. In addition, the soils engineer should design a minimum fall of 0.5 percent in the flow line along the curb. Otherwise, water will sit (or *bird bath*) and cause long-term damage to the pavement.

In recent years, growing awareness of protecting water quality and controlling flooding has led to new Environmental Protection Agency (EPA) regulations. The EPA has set rules for a National Pollutant Discharge Elimination System (NPDES). The guidelines encourage the use of systems that increase infiltration into the soil or increase the time of collection, such as porous pavements. The soils engineer or architect is responsible for designing the infiltration system.

Most early pavement failures aren't caused by flaws in the pavement itself but in the supporting layers — so it's absolutely essential to make sure your asphalt contractor follows these steps. Any shortcuts will only cause severe problems in the long run. The subgrade is the most difficult and expensive level to repair or replace. That's not a job you want to take on, especially if you're doing it as warranty work.

Very Good	Clean sands and gravels, usually well-graded; no significant amount of particles finer than 0.02 mm. Particularly good for improved subgrade, or "select borrow," to replace poor soils; excellent permeability; not frost susceptible.
Good	Sands and gravels similar to *Very Good* but not as well-graded. Good for "select borrow"; has good permeability; not as resistant to severe freezing conditions.
Medium	Sandy and gravelly soils that contain significant amounts of silt and clay; weakened by freezing and by intruding moisture.
Poor	Silts and clays that are severely weakened by freezing and moisture. Distinguished from *Medium* class by greater amount of silt or clay; lime stabilization of clays very effective in reducing plasticity but may aggravate frost susceptibility; should be replaced in severe frost areas.
Very Poor	Organic soils and clays; unsuitable as pavement subgrade in all climates. Should be removed and replaced.

Figure 2

Quality of subgrade

Base

The next layer is the base, which may be bound or unbound granular material. A variety of aggregates are allowed, depending on the required design. Crushed rock, gravel, sand and slag are common types of aggregates. They're sorted according to gradation, maximum size, soundness, particle shape, resistance to abrasion, and geologic source.

In some cases, the subgrade or base requires a prime coat. Its purpose is to maintain the prepared surface before paving. A prime coat is effective at holding together unbound aggregate bases. It's also used to protect the work from rain if paving is delayed. Because it seals the surface, prime coat shouldn't be applied to a subgrade when it's wet. Also, highly cemented soils that harden as they dry out may soften if prime coat is applied.

Prime coat has several disadvantages: The additional coat increases the cost, the 24-hour curing period causes delays, and some prime coats release hydrocarbons into the air, adding to environmental problems.

Hot Mix Asphalt

The top layer is the Hot Mix Asphalt. This is a carefully-controlled mixture of aggregates, asphalt cement (a black, viscous petroleum product which holds the particles of HMA together), and sometimes special ingredients. They're proportioned according to a Job Mix Formula (JMF) which specifies the percentage and size of aggregates in the asphalt cement, usually expressed as a percent of the weight of mix. The mix is combined at an elevated temperature in a mixing facility and delivered in open-bed trucks.

A tack coat is used to improve bonding between HMA layers. It's applied immediately before paving, after the surface has been cleaned of dust, debris and oil spots. The tack coat has a short curing period, usually less than 30 minutes.

A pavement sealer may be applied to the surface after the asphalt has fully cured, usually several months. It forms an opaque layer over asphalt, increasing pavement life by slowing oxidation, frost, and de-icing damage. It also protects the asphalt from gasoline or oil drips.

Reclaimed Asphalt Pavement

Since the late 1970s, the industry has developed the technology to recycle and reuse asphalt. At present, Reclaimed Asphalt Pavement (RAP) is usually 10 percent or less of the total ingredients. In some areas, though, it has been used 50-50 with HMA without compromising quality or durability. In fact, some engineers report that RAP actually improves pavement performance. The benefits are twofold: The savings are substantial, and it relieves the increasingly serious problem of solid waste disposal.

Type of facility and vehicle types	Maximum trucks per month (1 lane)	Traffic class
Residential driveways, parking stalls, parking lots for autos and pick-up trucks	<1	Class I
Residential streets without regular truck traffic or city buses; traffic consisting of autos, home delivery trucks, trash pickup, occasional moving vans, etc.	60	Class II
Collector streets, shopping center delivery lanes; up to 10 single-unit or 3-axle semi-trailer trucks per day or equivalents; average gross weights should be less than legal limit	250	Class III
Heavy trucks; up to 75 fully loaded 5-axle semi-trailer trucks per day; equivalent trucks in this class may include loaded 3-axle and 4-axle dump trucks, gross weights over 40,000 lbs.	2,200	Class IV

Figure 3
Traffic load

Designing Asphalt Pavement

All pavement is designed to last a specified number of years before it needs major maintenance or rehabilitation. For instance, highways are generally designed for 20 years. A restaurant may have a shorter design period, a mall or hospital a longer one. In order to make sure the pavement does, in fact, last its entire design period, you've got to analyze traffic patterns and volume. Designers have a tendency to underestimate traffic loads, which tends to shorten the life of the pavement.

Designers use the term Equivalent Single Axle Loads (ESAL) to express the pavement distress caused by an axle load of a given magnitude. A standard load of 18,000 pounds is assigned a damage factor of 1. Heavier axle loads have ESAL factors greater than 1, lighter axles less than 1. This measurement allows the designer to calculate the cumulative effects of many different types of trucks. If the ESAL is unknown, the designer may estimate the traffic load by using information in Figure 3.

For example, large retail parking lots will require a sophisticated design to allow for more than one kind of traffic. Most of the traffic will be cars and pickups, or Class I traffic. However, light delivery trucks and heavy three-axle semis, which fall into Classes II and III, will also make deliveries. By restricting the route of the heavy trucks, it's possible to design the parking lot to carry the Class II and Class III traffic to a loading dock while the rest of the parking lot is Class I. This reduces the overall expense of the pavement.

Unfortunately, estimating traffic loads and patterns isn't always easy. Construction vehicles will probably still use the pavement. And a variety of delivery, garbage, and other trucks will also use pavement that otherwise might be considered Class I. State and county agencies can usually furnish traffic count maps showing nearby arterial roads and projections of future growth. Comparing estimates to true traffic patterns of existing businesses can also increase accuracy.

Once the traffic load is estimated, the design period chosen and the subgrade soil identified, the architect or soils engineer will determine the depth of HMA.

Design Choices

After analyzing the soil, drainage and climate, the engineer or architect can select any one of several layer systems:

1. Full-depth asphalt: If the subgrade is very good (not affected by freezing or moisture problems), they can place HMA right over the subgrade, without a base in between.
2. Full-depth with improved subgrade: If the subgrade is improved with very good material, the HMA may be built directly on the subgrade. If the subgrade isn't deep enough, use a thicker layer of HMA to compensate. But unless the project is small or the subgrade is very poor and aggregates are unavailable or expensive, it's generally more cost effective to build up the subgrade and use less HMA.
3. Asphalt pavement over a granular or a stabilized base: If quarry aggregates aren't available, they can use alternative bases, such as cement-stabilized and emulsified-asphalt stabilized soil.

Full-depth HMA pavement is the most common design choice. In a full-depth design, the full layer of HMA is laid over the prepared subgrade and base. One advantage of the full-depth design is that it allows the possibility of site paving. *Site paving* is placing a layer of HMA as early in the project as the grading and other operations will permit. That layer forms a work and storage platform, and reduces cleanup problems at the job site. It's also an excellent way to avoid the problems of weather delays and defects caused by paving in cool weather or on wet subgrade.

Another option is called *stage construction*. That means laying only a single layer of HMA. Years later, before structural distress appears, another layer is added. Stage construction works particularly well for commercial facilities where pavement sealers are applied to the parking area at regular intervals to renew its appearance.

There are a couple of advantages to stage construction. The cost is spread over a period of years, although it ends up costing as much in the long run. It also allows some readjustment in the design if traffic patterns don't quite match the predictions. The major drawbacks are twofold. It requires remobilization of equipment (the major part of expense on a small job). And of course, it's inconvenient because the parking lot must be cleared of all traffic during the repaving process. In addition, the parking lines must be repainted with each new layer, which adds to the cost.

Asphalt Repair

As asphalt ages, it may develop cracks, or even potholes if it's allowed to deteriorate. If problems aren't repaired quickly, they'll continue to worsen, particularly if left through the winter. When water that collects in the cracks freezes, the asphalt breaks down further and the cracks widen. While the general contractor isn't likely to take on a large paving job, you may be called on to do some repairs. Repairing and patching cracks and potholes in asphalt is fairly simple with a commercial crack sealant or a cold-mix asphalt.

Sealing Cracks

Crack sealant is a highly-rubberized asphalt emulsion that's been modified with plasticizers to give it more flexibility. It's highly resilient and performs well at a wide range of temperatures. You can buy it in caulking-gun tubes for small repairs and 1- and 5-gallon buckets for larger repairs. A 1-gallon container will cover approximately 150 linear feet of cracks that are 1/2 inch wide and 1/4 inch deep.

When applying crack sealant, the air temperature should be between 45 and 90 degrees Fahrenheit. In weather above 90 degrees, spread sand over the newly-applied materials to reduce the chance of tracking. And try to do the repairs when it's not likely to rain for at least 24 hours.

You'll need:

- Crack sealant
- Stiff brushes
- Water

1. Thoroughly clean the loose material from the cracks with a stiff brush. Then spray with high-pressure water and allow them to dry. Fill any holes and cracks larger than 1 inch deep to within 1/2 inch of the surface with sand.
2. Pour crack sealant into the cracks, allowing it to fill slightly above the surface level. As the material settles, pour more as needed.
3. Depending on the weather, the material should be ready for foot or vehicle traffic within 12 to 24 hours. Test first to make sure it's dry and won't track.

4. Immediately wash tools with warm water. If the sealant dries on the tools, use gasoline or paint thinner to remove it.

Filling Potholes

Cold-mix asphalt comes in 60-pound bags in a ready-to-use, loose granular state. If you can't easily break the material into smaller pieces, allow it to stand in a warm place for a few hours, or overnight, until it warms up.

You'll need:

- Cold-mix asphalt
- Crack sealant
- Gravel
- Sand
- Trowel or shovel
- 4 × 4 vehicle

1. Thoroughly clean the loose material from the pothole. Fill deep holes to within 4 inches of the surface with loose gravel. Tamp thoroughly. Lightly cover the gravel with a layer of crack sealant (emulsified asphalt).
2. Layer 1 inch of cold-mix asphalt in the hole and pack it firmly. Tamp thoroughly and prod it with a trowel or shovel to remove any trapped air. Repeat the layering process until the hole is about $^{1}/_{2}$ inch above the surrounding surface. Tamp firmly between each layer and after laying the last layer.
3. Sprinkle a layer of sand on the patch. Slowly drive back and forth across the patch until it's level with the rest of the pavement.

Sealing Asphalt Pavement

For improved durability, pavement should be protected with an asphalt sealer when it's new and then again every few years as needed. A sealer automatically fills hairline cracks and will protect the surface from moisture and oil or grease spots. It may prolong the life of the asphalt for several years. Sealer comes in 5-gallon buckets, which cover 500 to 600 square feet. Ideally, seal when the air temperature is at least 70 degrees Fahrenheit, the humidity less than 50 percent, and no rain is expected for 24 hours. Allow all new asphalt, including hole and crack repairs, to cure for 30 days before applying a sealant.

You'll need:

- Sealer
- Stiff broom
- Rubber squeegee or broom
- Water and detergent

1. Clean the surface, removing all loose dirt and foreign material. Scrub all grease and oil spots with detergent. Flush with clean water. Be sure to remove all standing water before you move on to the next step.
2. Stir the sealer. With the pavement still damp, apply a coat of sealer approximately 4 feet square. Use a rubber squeegee or broom to spread the sealer coat. Avoid a heavy or uneven coating, which may crack or track.
3. Some manufacturers recommend a second coat when the first coat is dry to the touch.
4. Allow to dry at least 24 hours before letting foot or vehicle traffic on it.
5. If the sealant is still wet, you can use warm water to clean the tools. If the sealant has dried, use a petroleum solvent.

Estimating Asphalt Repair Costs

One ton of asphalt covers 160 square feet at a depth of 1 inch. To determine how many tons of asphalt you need, multiply the square footage of the area to be paved times the depth in inches of the asphalt. Divide this number by 160:

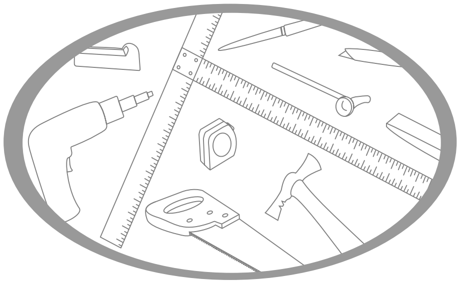
SF of area × Depth in inches ÷ 160 = Tons of asphalt.

Manhours

Asphalt Paving (minimum subcontractor job charge is $1800)		
Item	**Cost per SF**	**Crew**
Paving, including seal coat, residential walks and driveways		
2" asphalt	1.30	Subcontractor
3" asphalt	1.46	Subcontractor
4" asphalt	1.88	Subcontractor
Add for 4" base and fine grading	.79	Subcontractor
Add for 6" base and fine grading	.89	Subcontractor
Seal coat, applied with broom or squeegee	.21	Subcontractor

For information on related topics, see:

Concrete, page 141



Bathroom Fixtures

Fixture is the broad term used for all the items tied into a plumbing system, such as sinks, water closets, showers and bathtubs. Each inside fixture must have a water supply and a drain with a trap. You should also install a shut-off valve on the water supply line at the fixture so that you can repair or replace the fixture without shutting down the entire system.

Showers and Tubs

You can get showers and tubs as individual units or as combination units. You can also custom-build ceramic tile units into a wall enclosure, or install factory-produced built-in acrylic or fiberglass units, or freestanding metal or fiberglass units. Bathtubs are available in cast iron, steel, acrylic or fiberglass, with cast iron considered to be the most durable, and acrylics to be superior to gel-coated fiberglass. These generally-accepted opinions are reflected in the pricing structures for the units. Figure 1 shows standard heights for typical tubs and showers and their accessories.

Install shower and tub units during the rough-in phase before the drywall is hung, following manufacturer recommendations for supporting the units. Some tubs require a ledger strip for support on the wall side. Framers should install backerboards at the top of the shower or tub units to provide added support for the wallboard.

Connect $^1/_2$-inch copper or plastic supply lines directly to the water valve. Solder copper lines. Solder a threaded copper adapter to the valve on lines with threaded fittings. In almost all cases, supply lines are concealed in the finished wall. See Figure 2 for typical tub drain and trap placements.

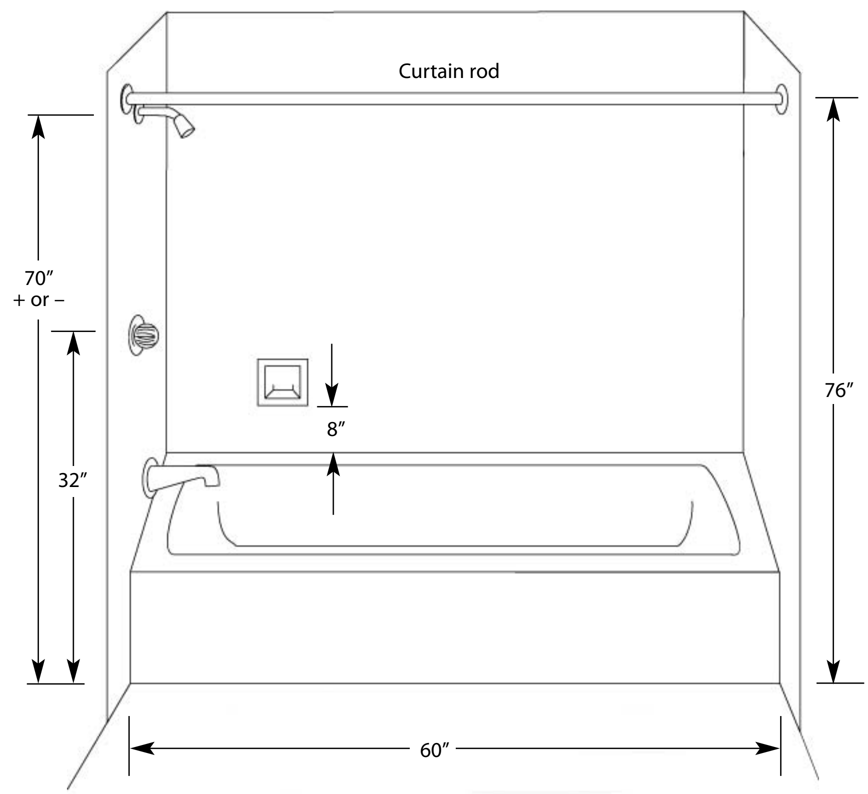


Figure 1

Standard dimensions and heights for tubs and showers

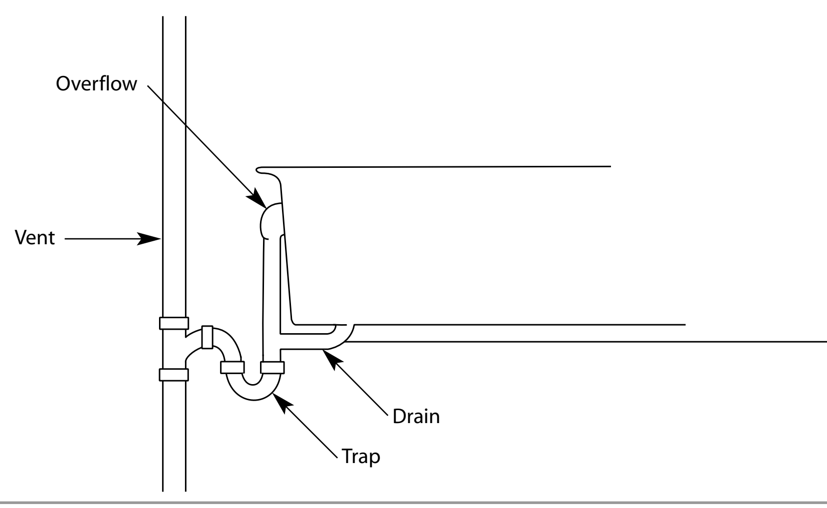


Figure 2

Tub drain and trap placements

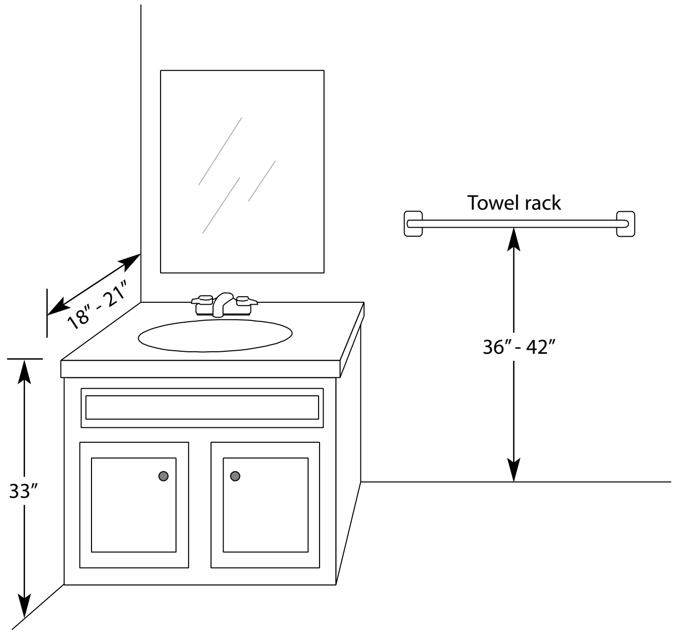


Figure 3
Standard heights for lavatories and accessories

Sinks and Lavatories

Most sinks and lavatories are made of cast iron, stainless steel, porcelain over steel and porcelain, with cast iron being the most expensive and durable. Bath lavs are also made of cultured marble. Figure 3 shows standard heights for bathroom lavatories and their accessories.

Sinks and lavatories come with a cutout template, often drawn onto the shipping carton, that you can use to trace the cutout onto the countertop. Countertop shops keep most manufacturers' standard templates on hand. By giving the shop the model of the sink or lavatory along with the centerline dimension, they can usually make the required cut for you. Make job site cutouts in plastic-laminate countertops by tracing the template, drilling a pilot hole, and cutting with a blade designed for plastics. A blade that's too coarse may pop pieces of laminate. Not only will you have to buy a new top, but you'll delay the project as well — so select your blade carefully.

Once you make the cutout in the countertop, set the sink with plumber's putty around the entire rim of the sink. Snug the sink down using the clips included with the package, and clean off the excess plumber's putty that squeezed out during positioning. (See Figure 4.) You need a good seal to prevent water from leaking under the sink and doing damage to the particleboard base under the countertop.

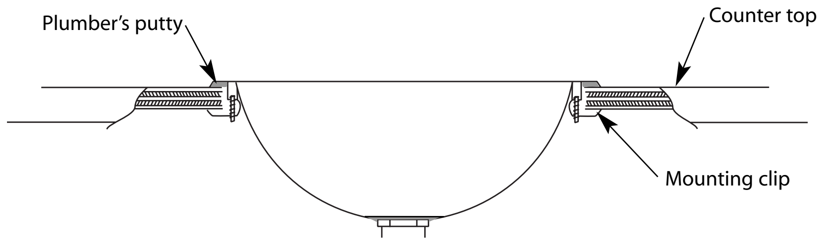


Figure 4
Set sink into countertop using mounting clips and plumber's putty

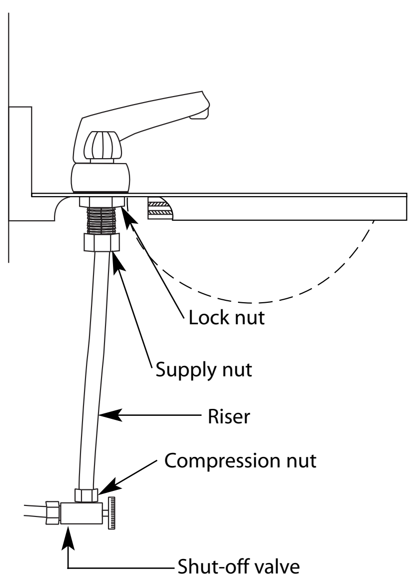


Figure 5
Faucet installation

Faucets

Bring the water supply lines to the lavatory or sink cabinet position during the rough plumbing installation and terminate them at a shut-off valve. Connect the faucet to the shutoff valve using a piece of $^3/_8$-inch tubing, called a *riser*. Use a compression fitting at the shutoff valve and riser. There's a special flared fitting matching the faucet that you pull tight with a nut slipped over the tubing to complete the connection. (See Figure 5.)

Installing a Faucet

1. Set the faucet in the sink or lavatory using the gaskets supplied by the manufacturer.
2. Connect the riser to the faucet by slipping the tightening coupling nut over the riser. The nut attaching to the faucet should work much like a compression fitting. Hand tighten and then finish tightening with a wrench. A turn and a half with the wrench should be all you need for a good connection.
3. Bend the riser as needed to neatly reach the shutoff valve, and cut to length so that the riser will project fully into the valve.
4. Place the compression nut on the riser, followed by the compression ring.
5. Hand tighten, following with one and a half turns with a wrench, or until snug. Do *not* overtighten.
6. Turn on the shutoff valve and check for leaks. If one of the fittings is leaking, tighten slowly with a wrench until the leak stops.

Water Closets

Water closets have two primary components: a water storage tank and a stool. The stool contains the trap, and like all traps retains a set amount of water. The stool is more sophisticated than just a trap, however. It's designed to make use of siphoning action to help pull wastes through the trap and into the sewer line. When the toilet is flushed, water empties from the tank into the bowl. The bowl fills to a point where water is forced through the trap, starting the siphon action. The waste and water are then pulled through the trap and into the drain until the tank is empty. When no more water is fed from the tank, the siphon breaks, and the trap is filled.

You install toilets during the finish trim-out phase of the construction process, after the vinyl or ceramic floors are installed but before carpet goes in. Figure 6 shows standard heights for water closets and their accessories. To install a toilet, follow the instructions from the manufacturer for assembling the stool, tank, and related components. These will include a flush valve for inside the tank, as well as a gasket and bolts for connecting the tank to the bowl. Place the gasket, called a wax ring, between the bowl and the closet flange. Connect the bowl to the closet flange using the bolts, appropriately called closet bolts, as shown in Figure 7. The wax ring molds to the bowl and flange, creating a tight seal.

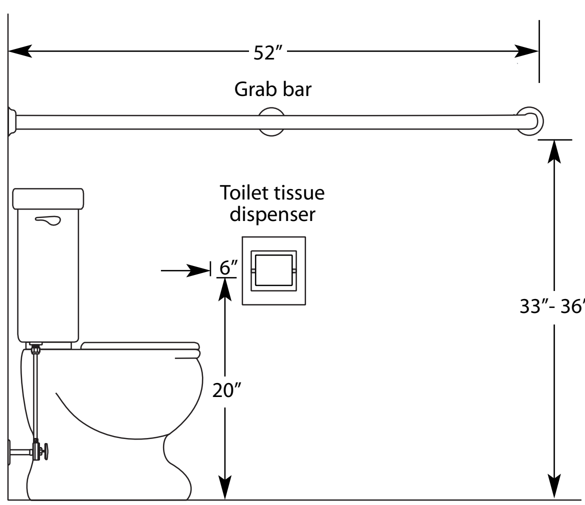


Figure 6
Standard heights and measurements for water closet accessories

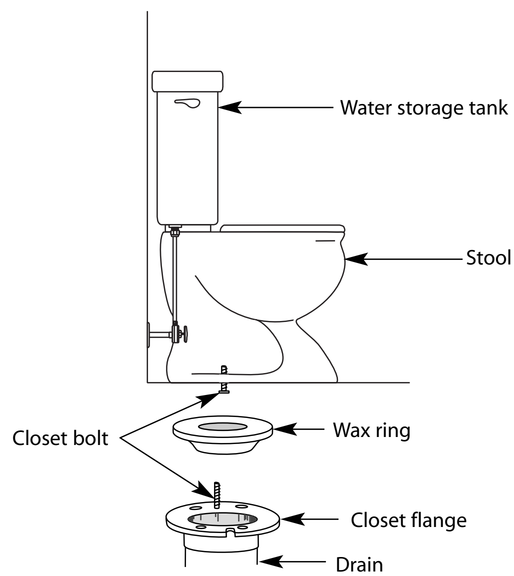


Figure 7
Attaching the toilet to the closet flange

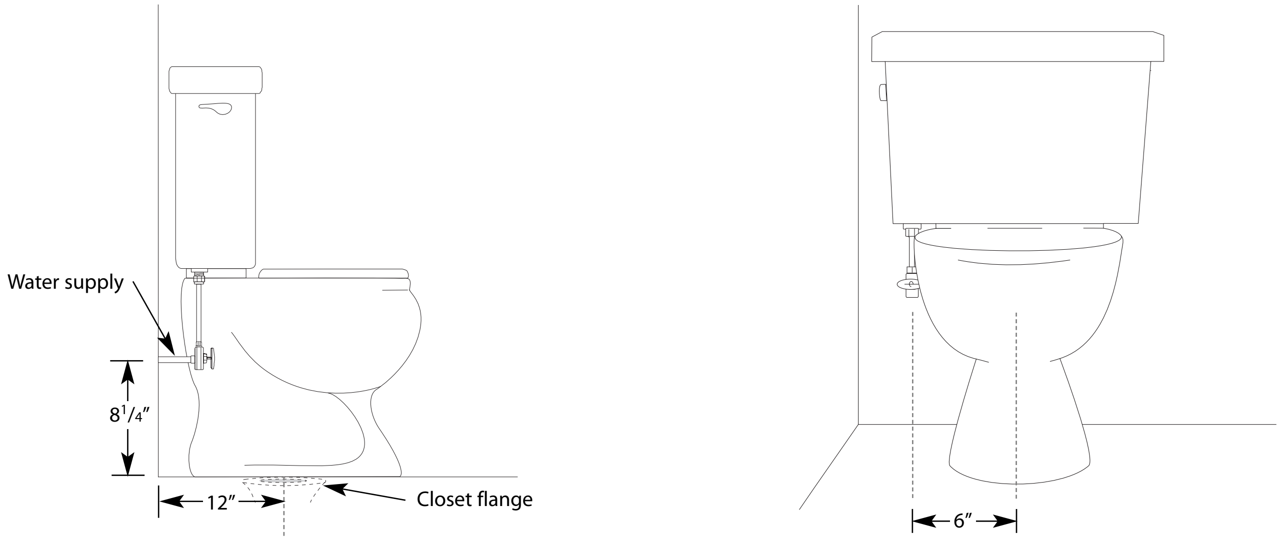


Figure 8
Connecting the water supply to the toilet

Make the water supply connection by running a closet riser from the stop valve to the tank. A closet riser is normally 12 inches long and differs from a sink or lavatory riser in the shape of the flare. Figure 8 shows how to locate the water supply connection and dimensions for the connection between the bowl and the closet flange.

Manhours

Manhours to Install Bathtubs, per each		
Unit	**Manhours**	**Suggested Crew**
Free-standing, enameled cast iron	12.3	1 plumber, 1 laborer
Recessed, enameled steel or enameled cast iron	10.3	1 plumber, 1 laborer
With whirlpool	20.5	1 plumber, 1 laborer
Sunken, enameled cast iron or fiberglass	10.3	1 plumber, 1 laborer
With whirlpool	20.5	1 plumber, 1 laborer
Sunken, acrylic or Americast	12.3	1 plumber, 1 laborer
With whirlpool	24.6	1 plumber, 1 laborer
Electrical installation for whirlpool tub	9.41	1 electrician
Shower fixture over tub with mixer valve, add	3.08	1 plumber
Remove and reset tub in existing opening	8.21	1 plumber, 1 laborer
Install rough-in plumbing for tub	15.4	1 plumber, 1 laborer
Tub/shower unit	1.94	1 carpenter

Manhours to Install Shower Stalls, per each		
Unit	**Manhours**	**Suggested Crew**
Reinforced plastic integral wall surrounds with slip-resistant fiberglass floors, single control faucet, 2 or 3 walls; no door	12.7	1 plumber, 1 laborer
Shower stall, nonintegral, nonassembled units with drain		
Remove and replace shower stall or stall floor (slip-resistant fiberglass floor) in existing opening	7.14	1 plumber, 1 laborer
Shower wall surrounds with adjustable walls	12.7	1 plumber, 1 laborer
Install rough-in plumbing for shower stall	19.0	1 plumber, 1 laborer
Doors		
Single, tempered glass, anodized aluminum frame, including hardware	1.78	1 carpenter
Two bypassing tempered glass, anodized aluminum frame, including hardware	1.94	1 carpenter
Swing door — dual side panels for neo-angle showers	2.37	1 carpenter

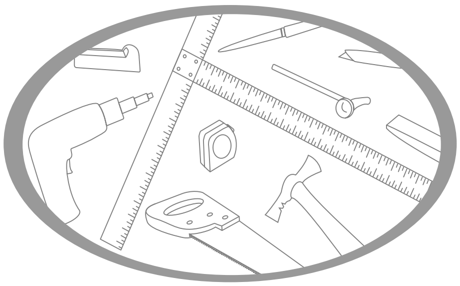
Manhours to Install Tub/Shower Combinations, per each		
Unit	**Manhours**	**Suggested Crew**
Fiberglass reinforced plastic 3-wall stall, 1 piece or multiple piece combination, single control faucet; no door	12.3	1 plumber, 1 laborer
Remove and reset in existing opening		
Shower stall or tub	7.27	1 plumber, 1 laborer
Both shower and tub	7.62	1 plumber, 1 laborer
Plumbing rough-in		
Shower stall or shower/tub	20.0	1 plumber, 1 laborer
Tub only	14.5	1 plumber, 1 laborer
Doors		
Single, tempered glass, anodized aluminum frame, including hardware	1.78	1 carpenter
Two bypassing, tempered glass, anodized aluminum frame, including hardware	1.94	1 carpenter

Manhours to Install Sinks and Lavatories, per each		
Unit	**Manhours**	**Suggested Crew**
Countertop vanity units, with faucets	3.81	1 plumber
Pedestal sinks, with faucets	3.81	1 plumber
Lavatory slab only	2.0	1 plumber
Pedestal only	2.0	1 plumber
Wall-hung vanity units, with faucets	3.81	1 plumber
Remove and reset lavatory in existing opening	2.86	1 plumber
Plumbing rough-in for lavatory	10.0	1 plumber

Manhours to Install Water Closets (Toilets) and Bidets, per each		
Unit	**Manhours**	**Suggested Crew**
Toilets, 1 or 2 piece, vitreous china, including shut-off valve, connections, flanges, and water supply valve	6.15	1 plumber
Bidets, deck mounted, including shut-off valve, connections, flanges, and water supply valve	5.33	1 plumber
Remove and reset toilet or bidet in existing location	2.86	1 plumber
Plumbing rough-in		
Toilet	13.3	1 plumber
Bidet	11.4	1 plumber

For information on related topics, see:

Floor Framing, page 299
Plumbing, page 471
Wall Framing, page 709



Brick Masonry

Brick is a building material that's thousands of years old. Early Babylonian builders made bricks out of mud and straw and dried them in the sun or in kilns. Even today some brick, such as adobe brick, is still made of mud and air-dried. More often, though, brick refers to a fired clay unit. Literally thousands of different variations – in construction, size, color, and texture – of brick are available today.

Making Brick

The clay for brick is dug or quarried, ground into a fine powder, and then reduced to a uniform plastic mass. Sand and water are added, and then the mixture is molded in one of three different processes: soft-mud, stiff-mud, or dry-press.

The first process, soft-mud, uses the most water. The soft, wet clay (20 to 30 percent moisture) is forced into a mold, the excess clay is cut off, and then the molded brick is turned out onto a conveyer belt that carries it into a kiln.

The stiff-mud process uses only enough water to form the clay (12 to 15 percent moisture) into a mass. It's then forced, or extruded, into a continuous mold and then cut with wire into the desired size before being fired.

The third process takes relatively dry clay (only 5 to 7 percent moisture) and compresses it under high pressure into a brick and then fires it. Of the three, dry-processed bricks are the most compact, the strongest, and the best formed.

The firing temperature also affects the performance of brick. As a general rule of thumb, if the same clay and the same manufacturing process have been used, the more durable brick will be the one that's been fired at a higher temperature.

Color

The color of the brick is primarily determined by two things, the amount of iron in the clay and the firing temperature. Of the two, the iron content of the clay has the greatest impact. It's the iron that turns the clay into the distinctive brick-red color when the bricks are fired in an oxidizing fire. The higher the firing temperature, the darker the color will be. If the clay is fired in a reducing atmosphere, the result is a brick with a purplish cast to it.

Brick Sizes

Brick measurements are stated in either nominal or specified dimensions. The specified dimension of the brick is the actual physical size of the brick. The nominal dimension is the specified dimension plus the thickness of the mortar joint on all sides. The standard mortar joint is $^3/_4$ or $^3/_8$ inch. For instance, the specified size of a standard brick is $3^3/_4$ inches wide, $2^1/_4$ inches high, and 8 inches long. The nominal size of the same brick is $4^1/_4$ inches wide, $2^3/_4$ inches high, and $8^1/_2$ inches long. A $^1/_2$-inch joint plus two brick ends conveniently equal one brick length. Note that the dimensions are always given in the same order: width, height, then length.

Properties of Brick

A variety of physical characteristics affect the durability of brick. Some are more important than others, but the standards for the physical properties of brick all are set by the American Society for Testing and Materials (ASTM).

- *Compressive Strength*. Compressive strength refers to the amount of pressure a unit can take. It's measured by applying, and gradually increasing, pressure on a surface that's at a right angle to the bearing surface. True compressive strength is usually far higher than the ASTM standard. For a given clay and forming process, the higher the firing temperature and the longer the firing, the higher the compressive strength. Most brick produced today has a compressive strength of over 6,000 psi. As a result, if a masonry unit fails, it's rarely a failure in the brick itself.
- *Water Absorption*. Water absorption measures the amount of water that a dry brick absorbs in a set amount of time. Bricks are tested in a one- or two-step method. First, a dry brick is soaked in cold water for 24 hours and weighed. Then the same brick is submerged in boiling water for 5 hours and weighed. The results are given as a ratio, called the C/B ratio.
- *Saturation Coefficient* or (*C/B Ratio*). The saturation coefficient reflects the results of the water absorption test. The assumption is that not all of the brick's pores will fill with water during the

cold water test. The boiling water test will fill any remaining pores that can be filled.

This is an important measurement because water that's absorbed into the brick's pores and becomes frozen will affect the durability of the brick, especially if the freezing and thawing cycle is repeated over and over. The stiff-mud process of making brick usually produces a brick with lower absorption rates The absorption rate for the same clay and forming process can be lowered ever more by increasing the firing temperature and length of the firing period.

- *Rate of Absorption or Suction*. The rate of absorption refers to the ability of a dry brick to draw or suck water into its pores. The rate of absorption affects the bond between the brick and the mortar. This bond, in turn, affects the flexural strength and watertightness of the overall masonry unit. If the brick takes in too much water from the mortar, the mortar will stiffen prematurely and lose some of its adhesive properties. Bricks that absorb more than 30 grams per minute per 30 square inches should be wetted first when laying.

  To test the brick, drop 20 drops of water from a medicine dropper in an area the size of a quarter. If the water is still visible after 1 1/2 minutes, the brick is wet enough to lay. If the moisture has been absorbed, the brick should be wetted before using. Because brick should be dry on the surface when it is laid, the best way to wet the brick is to saturate it by soaking or hosing it down the day before or several hours before using. Ideally, wetness should reach 3/4 inch into the brick when the surface is dry. If the bricks are too wet, they may sink into the mortar and have to be relaid. Also wet bricks tend to be slippery and can smear the mortar.

- *Resistance to Freezing and Thawing*. Resistance to freezing and thawing is the best measure of a brick's durability. If a unit meets the ASTM standards for the absorption and saturation coefficient, it doesn't have to meet the standards for resistance to freezing and thawing. The assumption is that if the unit doesn't absorb moisture, it won't be damaged by frost action.

- *Resistance to Abrasion*. Resistance to abrasion is important only for paving brick. Again, given the same clay and forming process, the higher the firing temperature, the more abrasive-resistant the brick.

- *Transverse Strength* (modulus of rupture). Transverse strength refers to the brick's resistance to a load when it's used as a supported beam. In addition, the effects of expansion due to moisture intake are being studied by the brick industry. Fired clay units will eventually expand in an atmosphere of 50 to 60 percent humidity. However, they don't shrink again when the humidity decreases under normal temperatures. Concrete masonry, on the other hand, expands when wet, but shrinks about the same amount as it dries out. It's not clear what effect this change has on the entire brick masonry unit.

As important as the brick is, any failure that may occur in a masonry unit is rarely the fault of the individual brick unit. Rather, the overall strength of a masonry unit depends on the mortar, bond, and workmanship that's put into that unit. If any one of these is poorly selected or executed, the entire unit may fail.

Grades

Brick falls into two general categories: solid masonry units and hollow masonry units. Solid masonry brick may in fact not be solid, but they must be cored no more than 25 percent.

Brick is used for structural or decorative purposes or a combination of both. It's classified by function, with each classification further broken down into grades or types, as specified by the ASTM.

Below are the most familiar grades, those that reflect the resistance of the brick to the effects of freezing and thawing. These are the only real weathering actions that have any effect on brick. The severity of the weathering action is based on the average number of days the temperature falls below freezing and the average annual winter rainfall to which the brick is subjected.

- GRADE SW (severe weathering) highly resists the effects of frost action. It holds up even when frozen and permeated with water. Use SW for foundations or wherever brick comes in contact with the ground, or in climates where it'll be exposed to extremely cold temperatures.
- GRADE MW (moderate weathering). Use for above ground purposes in climates that are warm or only moderately cold.
- GRADE NW (no weathering). Use only for interiors.

Types of Brick

The following are the types of brick most commonly specified for use:

- *Facing Brick*. Facing brick is the most common brick manufactured today and has pretty much replaced building brick as the all-purpose brick. It's a solid masonry unit that you can use whenever appearance is important. The ASTM specifications for facing brick limits the flaws a brick may have and still be called a facing brick. Facing brick comes in two grades related to its resistance to weathering: MW and SW.

- *Building Brick*. You can use building brick rather than facing brick where appearance isn't important. In fact, in recent years the term building brick has come to be used for any flawed facing brick. Building brick is a solid masonry unit that comes in three grades, SW, MW and NW, based on its physical characteristics of compressive strength, water absorption, and saturation coefficient.
- *Hollow Brick*. Hollow brick is, as its name suggests, a hollow masonry unit. It's used when weight is a factor. Hollow brick is cored more than 25 percent. It's classified into two grades, SW and MW, and two classes based on its shell (exterior) and web (the cross wall connecting the face shells) dimensions. The classes are HV40 (the void area is more than 25 percent but less than 40 percent of the total sectioned area) and HV60 (the void area is more than 40 percent but less than 60 percent of the total sectioned area).
- *Paving Brick*. Paving brick is a solid masonry unit that's harder and more durable than facing or building brick. It's designed to be used with or without mortar and can be laid on a bed of sand, gravel, or concrete. Paving brick is divided into three classes based on the compressive strength, resistance to abrasion and resistance to freezing action.
- *Fire Brick*. Fire brick is a yellow brick that's softer than face brick but very high in heat resistance. You can use it to line fireplaces, incinerators, chimney stacks, smelting furnaces, and any other place where masonry will be subjected to high temperatures. Fire brick is made with a high percentage of mineral that increases its heat resistant qualities. You must use a special fireclay mortar with it for maximum effectiveness.
- *Sewer* and *Manhole Brick*. Use sewer and manhole brick in drainage structures. Sewer brick has a low absorption rate and a high resistance to abrasion. Manhole brick, because it's exposed to weather, is designed to resist frost action.
- *Salvaged* or *Used Brick*. You can use salvaged or used brick to create a rustic masonry look. Some people use them as a cost saver, although in fact, clean used brick may be more expensive than new brick. Because the brick's grade and durability can't be determined by appearance alone, you shouldn't use them for exterior walls or load-bearing walls. Bricks absorb cementitious particles that can't always be cleaned from the surface. The presence of these particles may prevent new mortar from bonding well with old or used brick, making them less durable choices for building. As an alternative, use *New Used Brick* to get that rustic look with good durability. It's new brick that's designed to look used.

Building with Brick

Brick is laid flat for walkways and patios or laid in tiers or wythes to build walls. Both the patterns that they're laid in and the way they're joined provide stability and strength to the resulting unit.

Brick Bonds

The bond is the arrangement of brick in rows. The courses, or rows, are designed for both appearance and structure.

Structurally, you can use a bond to tie a wall together or to tie two wythes together. A wythe (or withe or tier) is a wall that's one brick thick. You can lay the brick in any of six positions to give variety to the appearance, but there are four patterns that are used most often: running bond, stack bond, Flemish bond, and English bond (Figure 1).

Brick Walls

Brick walls may be either bearing or nonbearing. A bearing wall supports a load in addition to itself. Nonbearing walls support only their own weight and don't structurally support anything else. However,

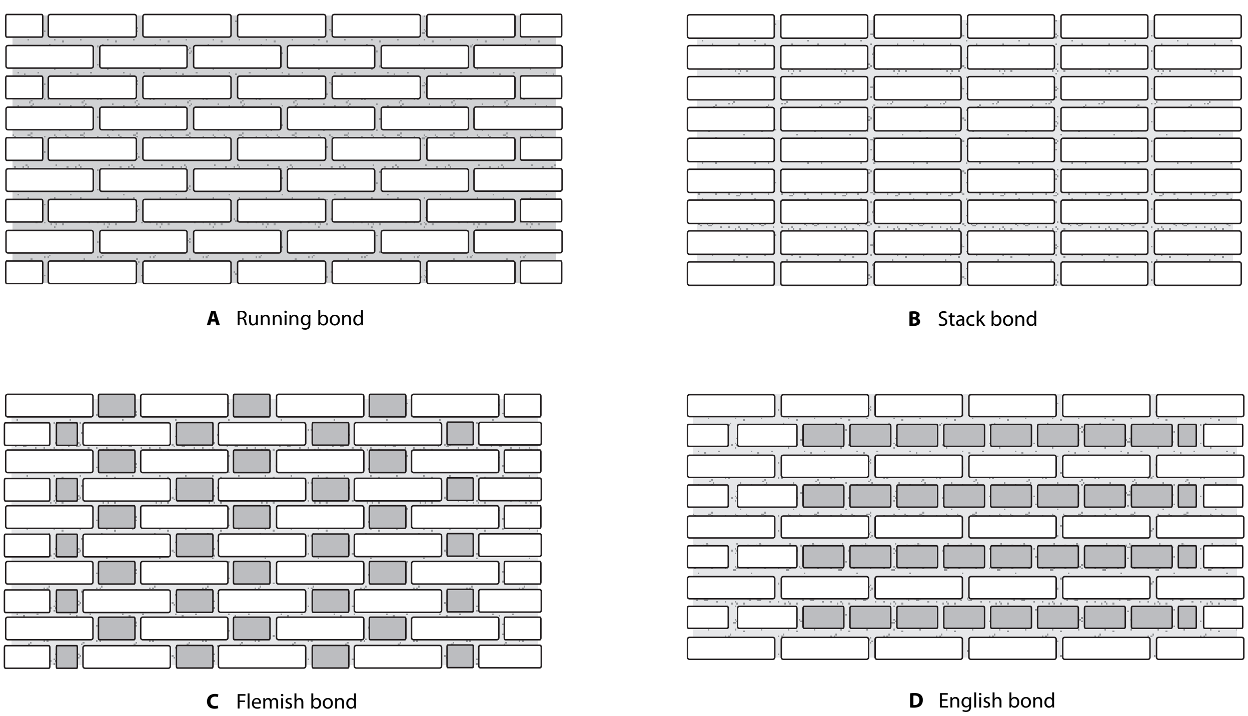
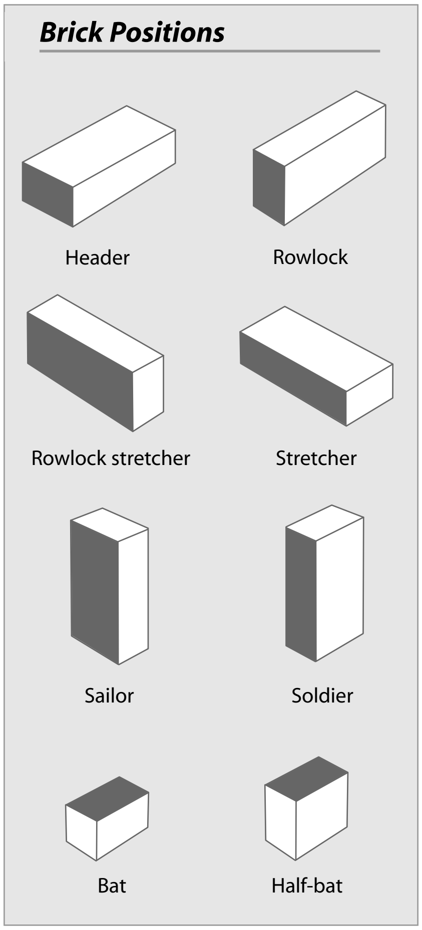


Figure 1
Four basic pattern bonds for brick



even nonbearing brick walls must be structurally sound. Don't build a one-wythe wall higher than 2½ feet unless it's supported by reinforced piers.

Solid brick walls that are more than a single wythe can be up to 24 inches wide. Use headers to tie the wythes together, or place noncorrosive metal ties in alternate courses, spacing them 18 to 36 inches apart.

Cavity Walls

Some builders use cavity walls in place of solid brick walls as a cheaper, lighter-weight option. They are constructed of two wythes with an inner cavity, or dead air space, in between. Besides their lower cost, another advantage of cavity walls is their resistance to exterior moisture. However, building codes only allow cavity walls in areas of low seismic risk.

The outer wythe of a cavity wall is usually only one brick wide, and the inner wall 4 to 12 inches thick. The cavity between them is usually 2 inches wide, but may be more. You can leave the cavity hollow or fill it with insulating material or grout, depending on your design needs. If cavity walls are left hollow, you must put weep holes in the outer wythes to keep moisture from collecting in between the walls and causing damage.

Rowlock Walls

A rowlock wall is built by setting some or all the bricks on edge, either in shiner or rowlock position. Headers, in rowlock position, span the hollow portion of the two wythes and hold them together.

Faced Walls

Faced walls consist of brick bonded to a backup wall. The faced wall and the backup wall are built as a single structural unit. The backup wall may be constructed of a lower grade brick, hollow clay tile, hollow concrete block, or even a poured concrete wall.

Veneered Walls

Veneered walls are probably the most common use for brick today. They are similar to faced walls, except they're not structurally bonded to their backup wall. Instead, the veneer wall is held in place with noncorrosive anchors or tie wires. The backup wall for a veneered wall may be concrete, masonry, metal stud, or even wood-frame construction. If you lay brick veneer over wood, cover the studs with plywood sheathing and tarpaper or felt. Leave a 1-inch space between the paper and brick as dead air space. For other backup wall systems, we recommend leaving a 2-inch space.

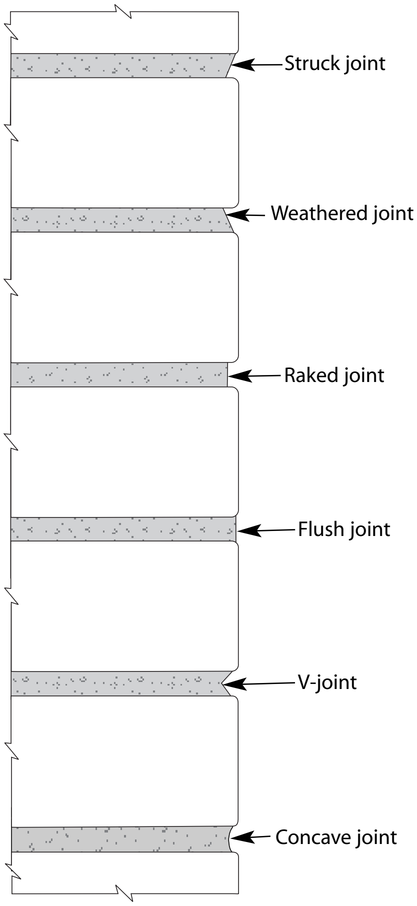


Figure 2
Masonry joints

Movement Joints

Both moisture and temperature cause masonry units to contract or expand. Concrete masonry shrinks, but also expands back to its original size when the atmospheric conditions reverse. Brick masonry, on the other hand, expands but doesn't return to its original dimensions. Consequently, when you use concrete and brick masonry, either together or separately, you need to have movement joints as part of the design. There are two types of masonry movement joints: expansion joints and control joints.

Expansion joints require a highly compressible material in the open joints which will absorb the brick's expansion. Control joints are usually a hard material. They are designed to be placed vertically to control the cracks created by concrete shrinkage.

Mortar Joints

The mortar joints between bricks must be sealed and well formed. Since moisture isn't a problem for an interior wall, the joint can be purely decorative. In an exterior wall, though, use only concave, V-shaped, and grapevine (similar to V-joint, but shallower) joints because they provide the best protection against freezing action. These three joints compress the mortar, which creates a strong bond between the brick and mortar and makes a watertight seal. Another advantage to these joint designs is that they don't create a ledge on which water can rest and freeze.

Because the joint types can make a varied and intriguing visual effect, they are often treated as part of the overall design. The various types of brick joints are shown in Figure 2.

Brick Mortar

Mortar bonds masonry units together and can also compensate for small variations in brick size and cover flaws in brick surfaces. Concrete mortar and brick masonry mortar are sometimes thought to be interchangeable, but they aren't. They have very different characteristics, and one can't be used in place of the other.

Concrete is itself a structural material. It's mixed with a minimum amount of water and poured into nonabsorbent forms where it hardens into a desired shape. Mortar, however, is a binder that structurally joins units together, much like frosting binds two layers of cake together. Mortar uses more water than concrete. When mortar is put between bricks, the water is absorbed into the brick as part of the bonding process. The ratio of water to cement is critical when mixing concrete, but it's far less important in masonry mortar.

Mortar is made up of a cementitious material (usually portland cement), hydrated lime, and sand. Each ingredient has a function and must be accurately proportioned. Here are the important properties of the materials:

- Portland cement is the material that provides bonding strength. (See *Concrete*.)
- Hydrated lime holds water in the mortar and keeps it from getting stiff or sticky. (See *Concrete*.)
- Sand, clean, fine and slightly damp, acts as an aggregate and provides inexpensive bulk.

You mix these three ingredients in their specified proportions, then add clean, potable water to the dry ingredients to make a plastic, workable consistency. Premixed and preproportioned masonry cement mortar mixes are a convenient alternative to mixing cement, lime, and sand yourself. Although the mixes cost more and may not be quite as good, their convenience makes them useful for small jobs.

Property Requirements and Proportion Mixes

Mortar is specified for use in either one or two methods: by property requirements or by proportion. The first defines which mortar to use by the compressive strength needs and allowable water retention and air content. The air content is important because it affects the bond between the mortar and brick.

The second method prescribes the ratio by volume of the cement, lime and water. For instance, 1:$^{1}/_{4}$:3 is 1 part portland cement, $^{1}/_{4}$ part hydrated lime, and 3 parts sand. The ratio is always given in this order. The strength of the mortar depends on the correct ratio of ingredients. The more cement in the proportion, the stronger, and also the more expensive, the mortar. As a general rule of thumb, the sand should be neither less than 2$^{1}/_{4}$ nor more than 3 times the volume of the cement and lime combined.

You can use masonry cement instead of portland cement in the mixture. However, because not all masonry cements are reliable, the Brick Institute of America recommends using portland cement. Both property and proportion mortars come in five types, both identify the types by the letters: M, S, N, O and K. Even though they have the same letters, they aren't equal. Proportion mixes have the greater compressive strength of the two.

Ideally, you should lay brick in temperatures above 40 degrees Fahrenheit. Mortar doesn't set properly in cold temperatures; lower temperatures cause poor bonds. If you must lay brick in cold weather, you must heat the masonry materials, and protect the finished project

Common Volumes of Mortar Materials		
Material	**Sold**	**Position**
Hydrated lime	50 lb. bag	1 cu. ft.
Sand	60 lb. bag (dry), dump in bulk	$^{2}/_{3}$ cu. ft.
Portland cement	94 lb. bag	1 cu. ft.
Masonry cement	70 lb. bag	1 cu. ft.
Ready-mix mortar	80 lb. bag	$^{2}/_{3}$ cu. ft.
Brick (616 = 100 sq. ft., single wythe, with $^{1}/_{2}$-inch joints)	Strap = 100 standard brick Cube = 500 standard brick	16 sq. ft. 81 sq. ft.

Figure 3
Common mortar materials

for 48 hours. Usually a covering of plastic or burlap will be adequate, as mortar generates a small amount of heat while curing. However, in extremely cold temperatures you may need a temporary plastic tent with a heat source to prevent freezing.

Mortar Types

- Type M Mortar is used for general purposes and for masonry that's on or below grade, such as foundations, sidewalks, or retaining walls. Type M is durable and has high compressive strength.
- Type S Mortar is also used for general purposes and has high compressive strength. But it isn't considered to be as strong as Type M. It's used especially in high wind (greater than 80 mph) areas because it has high flexural strength and high tensile-bond strength.
- Type N Mortar is a medium strength all-purpose mortar used in exposed masonry above grade wherever compressive or tensile strength isn't required.
- Type O Mortar is used primarily for interior, non-bearing masonry, although it may be used in exterior applications in mild climates.
- Type K Mortar is a low-strength mortar used for interior partitions.

Figure 3 shows common mortar materials and the volumes in which they are sold. This information is helpful in estimating and job costing.

The dry mix ratios for different types of mortar are given in Figure 4. The table shows mixing proportions that apply to any measuring container, as long as the same container is used for each ingredient. Usually, it's a shovelful.

The table in Figure 5 is a standard starting point for estimating the quantity of mortar required to build a brick wall. This table is based on the unit face area of 100 square feet. It does not allow for openings. As a general rule, the mortar required for a double wythe wall is 2.5 times the single wythe requirement.

Aggregates

Aggregates are inert material, like sand or rock, used to add inexpensive bulk or strength to a mixture. Although they don't interact chemically with the cementitious material, they do provide stability. Aggregates are used in asphalt, cement and plaster. They may be natural aggregates (sand, crushed stone, gravel or vermiculite) or by-

Mortar Proportions				
Type	**Portland Cement**	**Hydrated Lime**	**Sand**	**Ratio**
M	1	1/4	3	1:1/4:3
S	1	1/2	4 1/2	1:1/2:4 1/2
N	1	1	6	1:1:6
O	1	2	9	1:2:9

Figure 4
Mortar proportions

Estimating Mortar Quantities for Bricklaying		
Amount/Standard Brick	**Joint Size**	**Amount/Mortar**
100 sq. ft. single wythe double wythe	3/8 inch 3/8 inch	6.56 16.4
100 sq. ft. single wythe double wythe	1/2 inch 1/2 inch	8.34 20.85
616 standard brick = 100 sq. ft. single wythe with 1/2- inch joints 675 standard brick = 100 sq. ft. single wythe with 3/8- inch joints Add 5 percent to cover breakage and waste		

Figure 5
Estimating mortar quantities for bricklaying

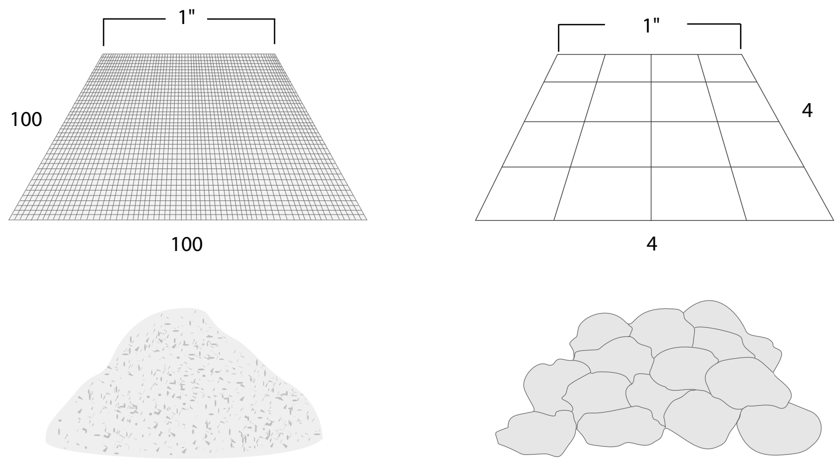


Figure 6
Aggregate sieves

products (blast-furnace slag or cinders). Both the shape and size are important for a strong bond. Rounded aggregate is able to move more freely as it's placed than long, thin or grooved aggregate.

Vermiculite and perlite are lightweight aggregates that are sometimes used in concrete. Although they lack the strength of sand or rock, they do have high insulating qualities. But because of their light weight, you can only use them for nonstructural uses.

Aggregates are designated as either fine or coarse. Anything under $^1/_4$ inch is considered fine; larger than that is coarse. Sands are usually under $^1/_4$ inch, while gravel and rock are larger. Aggregates are further graded in each of these classifications by a process called *sieve analysis*. A sample is poured through a series of vibrating sieves, each having progressively smaller holes. Whatever particles are held on each level are weighed. Then the tester calculates the percentage of small, medium, and large particles.

A sieve is numbered by how many openings in a linear inch. For instance, a No. 100 sieve has 100 openings in a linear inch. A No. 4 only has four openings (see Figure 6). Aggregates larger than a No. 4 sieve are named in fractions of an inch. For instance, $^1/_2$-inch rock is called $^1/_2$-inch rock rather than No. 2. Generally, aggregates larger than $1^1/_2$ inches aren't used except on massive structures such as dams.

Ideally, the aggregate should vary in size, which allows the smaller particles to fill in the voids between the larger ones. The cementing element, whether it's cement, asphalt cement or plaster, binds the mixture together. If the aggregate has too many fine particles (or *fines*) the bond won't be as strong because there's too much surface area for the cement to cover.

To make a predictable mix, keep aggregates clean and dry. Wet sand can hold anywhere from a quart to a gallon of water per 100 pounds of sand. Obviously that has an impact on the amount of water you'll use in mixing.

Admixtures and Color

There are admixtures that you can use with mortar to improve its workability, give it color, reduce water penetration, and speed curing. Mortar itself is usually gray, but you can add colors to achieve different effects in the masonry work. Use colored masonry cement, or mix mineral oxide pigments with white cement to give color. When you do this, the pigment and the dry ingredients should be thoroughly mixed before you add water. After adding the water, stir the mixture until all streaks are gone.

Grout

Grout is a thin, almost soupy, mortar mixture of portland cement, sand, and water, which is poured or pumped. You can use it to structurally bond brick together in the same manner as mortar.

Most frequently, grout is used as fill between two wythes to provide added strength to a masonry unit. You can also use it in aligned, unobstructed vertical spaces in hollow brick or in concrete block. Although you could use mortar instead of grout for these applications, grout provides a stronger joint than mortar.

The size of the aggregate determines whether grout is fine or coarse. Use fine grout in spaces less than 2 inches wide, and coarse grout in wider spaces. If the space is wider than 6 inches, a larger aggregate may be specified.

You can pour grout in one of two ways, termed low-lift grouting and high-lift grouting. You do low-lift grouting as the wall is constructed, pouring every three to four courses. High-lift grouting is done when the wythes are built to full height and then grouted.

Mixing Mortar

Small batches of mortar may be mixed by hand.

Tools

- *Mason's hoe*
- *Mortar box or wheelbarrow*

Small Batches

1. Measure the cement and sand into the box, using different buckets or shovels for each item. Mix thoroughly with a hoe or shovel until the mixture is a uniform gray.
2. Add the lime and mix again until the ingredients are completely blended.

3. Make a well in the middle of the dry ingredients and pour in a little water. Using the hoe, mix the ingredients by pulling the dry part to the center and mixing. Continue to mix until all the dry ingredients have been moistened and the mortar has a smooth, buttery texture.
4. Test the mortar by making a furrow down the center. The indentation should hold its shape, and the mortar should easily slide off of the hoe if you have the correct consistency. If the mortar is too wet or soupy, add proportioned amounts of cement, lime, and sand to stiffen it. Let the mixture stand about five minutes, and then mix it again just before using it.

Large Batches

You can mix larger amounts of mortar easily and efficiently in a power mortar mixer.

1. Put half the required water in the machine. Add half the sand and continue to mix.
2. Add the cement, lime, and the rest of the sand. Continue to mix. As the mixture begins to stiffen, slowly add the rest of the water.
3. Once all of the ingredients have been blended, continue mixing for three to five minutes. Avoid over mixing because it increases the air content of the mortar.

Mortar must stay wet in order for the bonding process to work. If the mortar begins to dry out while you're using it, you can make it workable by retempering, or adding a little water to it, and mixing thoroughly. Although mortar can be retempered more than once, it's better to make small batches and use them up rather than letting mortar sit for too long. The weather on any particular day will dictate how long you can allow mortar to sit and still remain plastic enough for use.

Mortar remains useable longest on cool, cloudy or damp days when the air is still. Hot, dry, windy days will draw the moisture out of the mortar more quickly. To lengthen the life of a batch of mortar, cover it with wet burlap. Generally, you should always use mortar within $2^1/_2$ hours of mixing.

Tools

- *Shovel*
- *Hawk or mortarboard*
- *Trowel*
- *Mortar*

Throwing Mortar

It takes practice to develop a comfortable and correct technique for mortaring brick in place. Practice throwing mortar onto a 2 × 4, which is about the same width as a brick, to get the feel for applying mortar quickly.

Guidelines for Mortaring Brick

Use the following guidelines for throwing mortar:

1. Put a shovel of mortar on a mortarboard or a lesser amount on a hawk. With your trowel, cut away a slice of mortar about the size of the trowel face. Shape it into a roll about the length and width of the trowel blade.
2. Scoop the roll of mortar from behind, snapping your wrist slightly as you lift to hold the mortar on the trowel.
3. To throw the mortar, place the trowel, tip up, at the beginning point of the line. Pull the trowel along the line, turning it over and letting the mortar roll off in a line one brick wide, two bricks long, and an inch thick.
4. Make a very light furrow down the center of the mortar with the tip of the trowel face down. Spread the mortar evenly over the width of the brick.
5. To place the brick in the mortar, butter the end of the brick with a small amount of mortar. Make sure the end is fully covered. Place the brick on the mortar, shoving the buttered end against the adjoining brick. Press down, pushing out excess mortar until the joint is the desired thickness.
6. Trim the excess mortar with the trowel. The mortar must be spread evenly and fully in both the horizontal and the vertical joints. Air pockets in the joint will cause a weakness in the overall wall.
7. If you're laying two wythes with a cavity (dead air space) in between, be extra careful not to drop mortar into it. Roll the brick into place from the outside in, keeping the excess mortar to a minimum on the inside of the cavity. Flatten, don't cut, the interior excess.
8. When the mortar is hard enough to hold a thumbprint, the joint should be struck or tooled. If the mortar is too soft, it may smear. If it's too hard, it'll be difficult to shape.
9. After you finish the joints, use the edge of the trowel blade to scrape off tags. When the joints have hardened a bit, use a soft-bristled broom or brush to sweep the brick again. After the mortar has completely cured, in about a week, clean the mortar stains. We'll cover Cleaning Masonry in more detail later in this section.

Flashing

Flashing is essential to all masonry. In areas that have moderate to high rainfall, it's necessary to use flashing to drain off any moisture that may penetrate a masonry structure. But even in areas that are considered arid, flashing is a must because people inside buildings generate a lot of moisture. Although moisture isn't absorbed through brick, it can come through the mortar, particularly if cracks develop because of movement or mortar deterioration.

Flashing, sometimes referred to as *thru-wall flashing* because it goes through a wythe, serves two functions. It's placed to prevent moisture from seeping in, and it's designed to carry out moisture that collects within the masonry. To do the first job effectively, it's especially important to have flashing at cavity bases (one course above grade) and at window sills. But you should also place it above all openings, projections, recesses, spandrels, wall bases, and roofs. In other words, you need to place it at the tops, the bottoms, and at all horizontal interruptions of walls.

To carry out the second function, you need to install interior flashing to convey the moisture out of cavity or veneered walls. Interior flashing angles downward so that the moisture will follow it down and flow out through weep holes.

Copper, stainless steel, or plastic are all used as flashing materials. Combination products such as copper and felt or Mylar and asphalt are also good alternatives if cost is a consideration. Other products such as zinc, aluminum, lead, and asphalt saturated felt can also sometimes be used. Each of these alternative materials has its drawbacks and you should use them only if the other flashing products aren't available, or in situations for which they're specifically indicated.

The most expensive flashings are the metals. PVC is much less expensive. The initial cost, however, shouldn't be the determining factor in your choice. If the flashing deteriorates or punctures easily, the value of the flashing is lost. Replacing interior flashing is nearly impossible because it means rebuilding the wall. So choose a flashing that will be as permanent as the structure itself.

Flashing comes in varying lengths, shapes and widths, depending on the material. Metal flashing can be formed to the job requirements. Most other materials are easily shaped at the job site as you work. Because the moisture barrier must be continuous, it's necessary to overlap joints by at least 6 inches and to seal the joints with a mastic or adhesive. If the flashing gets cut or punctured, seal it to prevent any moisture from seeping in.

Flashing Installation

Use the following guidelines to install flashing:

1. Grout the first course of brick. The bottom layer of flashing should rest on the grouted brick.

2. In new construction, install the flashing as you lay the brick or block for the backup wall. Embed the flashing in the mortar joints or in reglets, placing the long side to the inside, or backup wall as shown in Figure 7.

3. In existing construction, attach the flashing by nailing the flashing to the existing wall (Figure 8). Remember that you're using flashing to prevent moisture problems, so make sure moisture won't be trapped behind the flashing, or you've defeated your purpose. Either tape or seal the flashing to the existing wall.

4. For either new or existing construction, the flashing should be at least 6 to 10 inches high on the backup wall. Initially, the flashing should extend beyond the exterior wythe. If it doesn't, moisture can become trapped in the mortar and cause long-term damage. When the mortar in the exterior wall is completely set, trim off the extra flashing. You can easily cut most flashing materials with a utility knife.

5. It's inevitable that some mortar may drop into the cavity as the wall is being built. To keep the mortar from blocking the flashing or weep holes, place a layer of clean, washed 3/8-inch rounded gravel on the flashing. Or attach wire to a piece of wood the width of the cavity and set it in the space to block

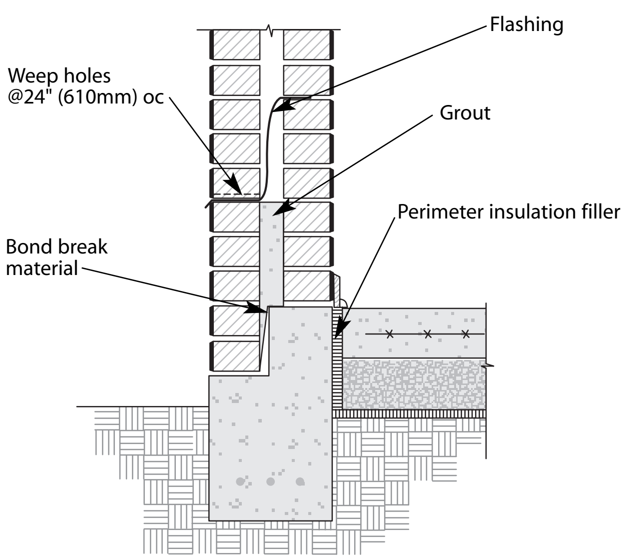


Figure 7

Embed flashing in mortar joint in new construction

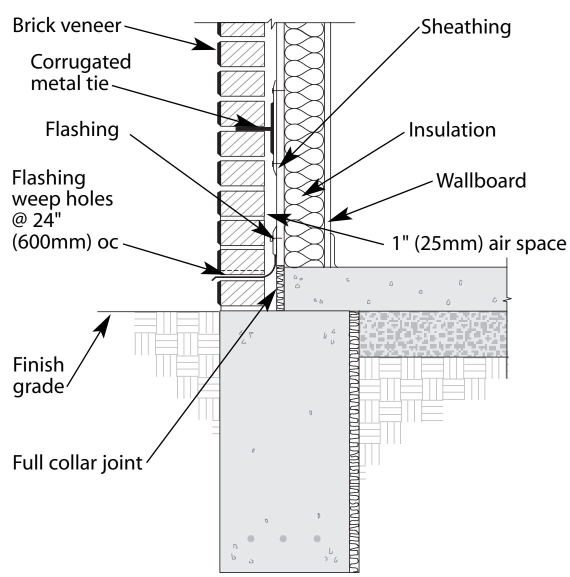


Figure 8

Nail flashing to existing wall in existing construction mortar from falling into the cavity. If you use the wood, it will not only catch excess mortar, but will also trim excess mortar from the joints as you lift it out.

Weep Holes

Weep holes are an integral part of the flashing design, allowing the water to be drawn out more easily.

1. Place weep holes every 16 inches at the base of the cavity and wherever there's flashing. Weep holes should rest on the flashing.
2. The most effective weep holes are made by leaving out the head joints every two or three bricks along the wall. You can also put oiled rods, rope, or pins in the head joints and remove them before the mortar sets, or use metal or plastic tubing or a wicking material to ensure a hole, although these last are less effective choices.

Laying Brick

Solid clay masonry is heavy. One cubic foot weighs 123 pounds, or 10 pounds per square foot for each inch of thickness. Consequently, any brick wall or structure, even brick veneer, must be laid on a solid concrete footing. (See *Concrete*.) In cold climates, you must extend the footing below the frost line. In warmer climates, make the footing at least as deep as the width of the brick wall, and twice as wide. You need good drainage around the footing and you need to make sure it's far enough away from trees that their roots won't cause the wall to crack or buckle as the trees grow. As with any concrete footing, allow the concrete to set and cure for several days before building anything on it.

Although it may seem to slow your brick-laying pace, it's essential to use your level frequently. If any one brick is out of plumb, it will affect every course above it. It's much easier to correct an out-of-plumb brick as you lay it than to try to correct it when it's two courses back.

Tools

- *Mason's line*
- *Line pins*
- *Line blocks*
- *Brick trowel*
- *Story pole or spacing rule*

Guidelines for Bricklaying

1. Clean and dampen the surface of the footing. Stake and lay a line to get perfectly straight corners and walls. Snap a chalk line on the footing to use as a line for the front of the wall.
2. Begin with a dry run. Place the first course of brick on the concrete, spacing the bricks according to whether you plan to use a $^3/_8$-inch or $^1/_2$-inch joint. Use your finger or a piece of plywood to quickly and evenly space the brick. By dry-laying

Bricklaying Terms

Bed —	*the process of placing the brick in the mortar.*
Bed Joint —	*the horizontal layer of mortar in between rows, or courses, of brick.*
Butter —	*spreading mortar on a brick with a trowel.*
Closure —	*a whole brick, or a portion of a brick, used to complete a course in the same bond pattern.*
Course —	*a horizontal row of bricks.*
Head Joint —	*the vertical layer of mortar in between brick.*
Lead —	*a section of wall that's built up and stepped back, or racked, to establish alignment.*
Point —	*to trowel mortar into a joint after the bricks are laid. This may include filling in nail holes, voids, or other flaws in the mortar joint.*
Repointing —	*see Tuckpointing.*
Struck Joint —	*a joint that has had the excess mortar removed with a trowel.*
Tags —	*bits of excess mortar that need to be cleaned off.*
Tooled Joint —	*a joint that has been shaped and compressed with a special tool.*
Tuckpointing —	*the process of filling in joints with fresh mortar after the old mortar has been chiseled out.*

the brick, you can anticipate problems in the layout. If necessary, space them a little bit farther apart to avoid having to cut too many bricks.

3. Remove all the bricks but the two end ones, which you'll bed first. Wrap a line around two loose bricks and set one of these bricks crosswise each end, or corner. Make the line taut and hang a line level on it. Use shims if necessary to adjust for level differences between the ends.

4. Mix a small amount of mortar, just enough for the two corner bricks. Throw a line of mortar 1 inch thick along the chalk line. Don't furrow for the first course. Lay the first corner brick in the mortar and press it down until the mortar is the desired thickness, either $^{3}/_{8}$ or $^{1}/_{2}$ inch thick.

5. Tap the brick into place, using your level to make sure the brick is plumb lengthwise, widthwise, and crosswise. Check against the story pole or spacing rule, too. The top of the brick should be level with the first line. Move to the other end of the line and repeat the process with the other end brick. Allow these two bricks to set up for an hour or two.

6. Next, mix enough mortar to lay the first course of brick. Work from both ends toward the center. Throw enough mortar for two bricks at a time, buttering the end of the second brick to butt up against the end of the first.

7. Butter the closure, or last brick on both ends and slide it into place. Again, use your level with each brick to make sure that it's plumb in every direction. Allow the first course to set for an hour.

8. Once the first course has set, begin laying brick in the least conspicuous corner or end. Unless you're using a stacked bond, start the next course with a half brick. Lay two more brick, and then begin the next course with the brick appropriate to your bond. Remember to furrow the mortar for these courses.

9. Build up a lead five courses high by continuing to step back, or rack, the brick up. Repeat the process at the other end. Continue to carefully level every brick and each course as you build. Check each course against your story pole.

10. Stretch a line between the leads by inserting line pins into the mortar at each end or using line blocks. Lay the next course, working in from each lead. If you use line pins, remove them after each course is completed and fill in the mortar holes.

11. Try to keep the mortar off of the brick as much as you can. It'll all have to be cleaned off eventually. Use your trowel blade to scrape the excess off at each joint. Occasionally check to see if the mortar is thumbprint hard. When the mortar is firm enough to hold the print, it's time to tool or strike the joint.

Multi-Wythe Walls

Apply the same concepts you use for a single-wythe wall to building multi-wythe walls. You simply vary the bond pattern and the number of wythes. The most important thing is to make the wall structurally sound. You do this by tying the wythes together, either with brick used as headers or with noncorrosive metal ties. If you use brick, at least four percent of the wall must be headers. If you use ties, place them 16 to 36 inches apart, depending on the tie system you use.

Ties

Metal ties are made of stainless steel or hot-dipped galvanized steel, both corrosion resistant. You must securely embed ties in both the front wythe and backup wythe (or backing). They also must be stiff enough to transfer loads between the wythes. Although numerous kinds of metal ties exist, the more common types fall into the three broad categories listed in Figure 9.

Type	Example	Use
Unit ties	Rectangular Z-tie Corrugated	Two or more wythes, either solid or hollow Two or more wythes, solid only *Only* low-rise, residential veneer over wood frame
Joint reinforcement	Ladder Truss Tab	All are used in multi-wythe, cavity, and grouted masonry walls
Adjustable ties	Z-tie Ladder Truss Slot	Cavity, veneer/steel stud, and veneer/concrete walls; allow in-plane differential movement and adjust for unaligned courses

Figure 9
Metal ties

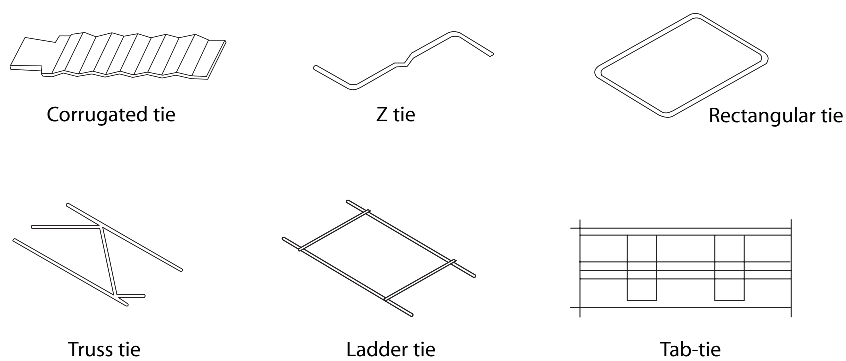


Figure 10
Metal ties

Regardless of the system you use, ties should be staggered from course to course. Figure 10 shows types of metal ties.

Veneered Walls

A veneered wall is designed to carry only its own weight. But because even its own weight can be an enormous amount (100 square feet of brick weighs over 2 tons), it quickly becomes obvious why you must have a solid foundation for even a veneered wall. If you're adding the veneer to an existing structure, you may have to add a footer or foundation as well. Or you can bolt steel angles to the existing foundation one foot below grade. For the section below grade, mortar 4-inch concrete block to the foundation, leaving no cavity. For new construction, it's just as easy to place a brick ledge in the foundation and lay the brick on that.

Above grade, the process of building a veneered wall is the same for new construction or remodeling:

1. Cover the existing siding or new sheathing with building paper.
2. Lay the first course of brick and grout the cavity.
3. Attach the flashing, and begin laying courses of the veneer.
4. a.) When using a wood stud backing, make the cavity 1 inch wide. Use corrugated metal ties to attach the veneer to the backing. Stagger the ties no more than 24 inches apart horizontally and 24 inches apart vertically.

   b.) If you're building the veneer over steel studs, make the cavity more than 2 inches, but less than 3 inches in width. Place the ties in a staggered pattern, a maximum of 24 inches apart horizontally and 18 inches apart vertically.

   c.) For a veneered wall with a concrete backing, make the cavity less than 2 inches, with the ties staggered 24 inches vertically and 24 inches horizontally.
5. Leave a narrow air space ($^1/_8$ inch) at the top of the wall beneath the soffit. Use either fascia board or a piece of wood molding to hide the gap.

Mortarless Brick

Brick is occasionally used without mortar for walks or patios. If you lay brick in this manner, it's important to lay a solid base and perimeter so the bricks don't shift. Use either sand or gravel for the base, depending on the soil underneath. Drainage is important, so if the subsurface soil won't allow for drainage, use 4 inches of gravel with a top layer of very fine gravel.

1. Dig a paving bed deep enough to allow for a sand or gravel base and the thickness of the paving brick. Allow 2 inches for a sand base, 5 inches for gravel.
2. Build the border either with landscaping ties, redwood, or brick.
3. If you're using a sand base, carefully level, or screed the surface. Moisten the sand, tamp it, add new sand, spray, and screed it again. Do the same for each layer of gravel if that's your base. Although gravel doesn't require as much tamping or wetting as sand, you'll still want to make sure it's compacted. As you screed, make sure you have a slope designed in. About $^1/_4$ inch for every foot should be enough to avoid standing water problems.

4. Place a layer of 15-pound roofing felt over the base, overlapping the pieces by 6 inches. The roofing felt will keep weeds and grass from growing up through the base and the brick. With a utility knife, cut holes in the base to allow water to drain down.
5. Lay the brick, starting in the least obvious corner, pressing them together tightly as you work. Use your level and a rubber mallet often to keep your rows even and consistent.
6. When you've finished laying the brick, spread a layer of dry sand over the brick and sweep it into the joints. Repeat this step every two days until the bricks are firmly in place and the joints are filled.

Laying Brick with a Dry Mortar Mix

Another option for laying walks and patios is to use a dry mortar mix.

1. Prepare the bed as described above, digging to a depth of 5 inches. Spread and screed 3 inches of gravel.
2. In a wheelbarrow, mix 1 part portland cement to $5^1/_2$ parts masonry sand, blending the two thoroughly. Spread and screed this mixture on top of the gravel. *Do not use water at this point*.
3. Lay the brick directly onto the sand and cement mixture, starting in the least obvious corner. Press the bricks together tightly as you work. Use your level and a rubber mallet often to keep your rows even and consistent.
4. Sweep the mortar mixture into the brick joints. Be sure the joints are fully filled. Remove excess mortar. Gently hose down the brick to set the mortar until all the joints are saturated. Be careful not to wash any of the mortar out of the joints. If you have to replace mortar later, it will result in a weaker joint. Apply an occasional light mist of water while the mortar is curing.

Cutting Brick

You need the same materials and use just about the same methods to cut brick, concrete block or stone.

Cutting Method

1. Draw a line where you want to cut the brick, block, or stone. For stone, try to find the stone's natural grain. Place the masonry on dirt or sand.

Tools and Materials

- *Safety goggles*
- *Leather gloves*
- *Pencil*
- *Straight edge*
- *Brick or stone chisel*
- *Small sledgehammer*

2. Wearing goggles and gloves, gently score along the lines by tapping the chisel with a sledgehammer.
3. After scoring all four sides, put the chisel into the etched line, blade facing toward the waste end. Hit the chisel with the sledgehammer in one hard, clean move. The masonry unit should break neatly in two. For fieldstone, after scoring on both sides, place a 2 × 4 under the stone about an inch before the line. Use a sledgehammer to knock off the waste.

You can also cut masonry with a power saw and a masonry blade. Use either a diamond tipped or carbide masonry blade. Wearing goggles and gloves, make several cuts. Start with a shallow one, and make each successive pass deeper than the last until the cut is complete.

Brick Repair

Even the best laid wall may need repair somewhere down the road. Tree roots or poorly designed footings can cause the ground to heave and the mortar holding the wall together to break down. If care wasn't taken in laying the masonry, the natural weathering process of freezing and thawing, along with the possibility of moisture penetration, can cause mortar to deteriorate. And, of course, age alone may eventually cause mortar to fall apart.

Most of the time failure in brickwork occurs in the mortar joint. The brick unit itself is far stronger than the mortar. It's important to fix a crack or crumbling mortar when it first occurs, before moisture can penetrate into the mortar through the crack and cause further damage. When a crack occurs, you should try to figure out its source and correct it. If you don't, you'll eventually have to fix it again.

Tuckpointing

Repairing mortar is called *repointing* or *tuckpointing*. In a sense, repointing is like laying brick. So the things that are important to consider for successful bricklaying — such as temperature, brick absorption, and the correct mortar mix — are just as important to remember in repairing mortar.

Try to match the replacement mortar with the type of mortar used originally. If you don't know which type was used, refer to the mortar descriptions on page 60 and match the type as closely as possible to your current situation. Before you actually start repointing, mix a small batch to match mortar colors. Remember that mortar lightens as it dries. You may need to add a coloring agent to get it close to the original color.

Tools and Materials

- *Safety goggles*
- *Small sledgehammer*
- *Cape chisel or tuck-pointer's plugging chisel*
- *Stiff bristled brush*
- *Air compressor (optional)*
- *Water and hose*
- *Hawk*
- *Pointing trowel*
- *Joint filler*
- *Mortar (mixed a little stiffer than for bricklaying)*
- *Joint finishing tool*

Tuckpointing Guidelines

Use the following guidelines to repoint damaged mortar.

1. Wearing safety goggles, chip the loose mortar out of the joints using a sledgehammer and chisel. Take care not to damage the brick. Chisel the mortar out to a depth of 1 inch or to a point where the mortar is firm and intact, whichever is deeper.
2. Brush out all of the loose mortar. Blow out any remaining dust with compressed air, or use a hose to flush it out. Leave the brick slightly damp so that it will absorb the mortar better.
3. Mix a small amount of mortar and place it on a hawk. Starting with the vertical joints, firmly push mortar into the joint with the pointing trowel. Next do the horizontal joints, using either a pointing trowel or the joint filler. You might be able to slide mortar off the hawk and into the joint with the joint filler. If a joint is deep, repoint in layers, allowing each layer to set slightly before pushing in the next layer. Be careful not to smear mortar on the existing brick.
4. When the joints are filled and the mortar is thumbprint hard, strike the joints. Use a joint finishing tool to match the existing joints.

Replacing Damaged Brick

A broken or crumbling brick is far rarer than deteriorating mortar, but it's just as serious a problem. If it isn't fixed, moisture can easily penetrate into the wythe and cause even more serious damage. For large areas of brick that have to be replaced, remove the brick from the top down. Rebuild the area just as you would lay new brick, course by course.

Here's the procedure for relaying individual bricks or small areas:

1. Wearing safety goggles, use a hammer and chisel to chip out the brick and the mortar from the joints around the brick. Or drill the mortar out of each of the four corners around the brick. Take care not to damage the surrounding bricks.
2. Brush all the loose mortar away. Blow out the remaining dust with compressed air, or use a hose to flush it out. Leave the brick slightly damp so that it'll absorb the new mortar better.
3. Mix a small amount of mortar. Butter the bottom of the opening; then butter the top, ends, and back side (if this is for a multi-wythe wall) of the brick. Place the brick on the hawk and push it into the space. Tuck in more mortar as needed to prevent air pockets. When the mortar is thumbprint hard, strike off the joint with the appropriately shaped tool.

Cleaning Brick Masonry

The real beauty of masonry is that it requires so little maintenance. However, new masonry, and occasionally existing masonry, needs some cleaning to look its best. Unfortunately, if you are careless with cleaning you can ruin the look of an otherwise attractive wall. Most masonry cleaning problems are the result of one of the following situations.

1. *The masonry wasn't completely saturated with water before and after cleaning*. If the masonry isn't wet enough, the cleaning solution will be absorbed into the masonry instead of staying on the surface. This can cause mortar smear, white scum, or the development of efflorescence, or green stain.
2. *Poorly mixed or overly concentrated chemicals were used for cleaning*. These can discolor masonry because they may wash cementitious materials out of the mortar joints or actually etch the mortar. The result, especially with lighter shades of masonry, is acid burn. Green or brown stains may appear as well.
3. *The metal in doors, windows, and trim corrodes.* If these parts aren't well-protected during cleaning, the acids in the cleaning solutions can corrode the metal in them. The acids can also damage trim materials such as limestone and cast stone.

Cleaning Methods

Cleaning is commonly done by one of three methods: bucket and brush hand cleaning, pressurized water cleaning, and sandblasting. Bucket and brush hand cleaning is used far more than the other methods because it requires the least specialized equipment and skill. But even this method requires attention to detail. Regardless of the method you use, be sure to wear appropriate protective gear and follow the manufacturers' directions for using both the equipment and chemicals.

Basic Cleaning Preparation

For cleaning with any of the three methods, you should always begin with these basic steps:

1. Make sure the mortar is completely set and cured. Wait at least one week between laying and cleaning. Don't wait too long, however; after about six months, mortar smears and splatters are too difficult to remove.

2. Dry clean the masonry and mortar by scraping the larger pieces of mortar off with a wooden paddle or other nonmetallic tool. Do not use metal on new masonry. Metal marks will oxidize and cause rust stains, which will then require more cleaning.

3. Mask off any area that you won't be cleaning, especially wood, metal, glass, limestone, or cast stone surfaces. You should also cover the ground with straw, sand, sawdust, or plastic sheeting.

Bucket and Brush Hand Cleaning

After following the basic preparation steps:

1. Choose the appropriate cleaning solution according to the cleaning guide in the table beginning on page 79. Test the solution on a test panel or in an inconspicuous area first. Ideally, you should allow a week between testing and using.

2. Saturate the area to be cleaned with water, flushing from the top down. Thoroughly saturate the area below where you're working as well so it doesn't absorb any run-off from above. Limit the area you're cleaning at one time to about 20 square feet. On warm, windy days evaporation is faster, so you'll need to work accordingly.

3. Specific instructions vary depending on the manufacturer and the cleaning solution you use, so be sure to read and follow the directions on the package carefully. As a general rule, apply the cleaning solution from the top of the area down. Let the solution sit on the masonry for 5 to 10 minutes. Using a stiff fiber brush, scrub the masonry. If some spots resist cleaning, use a nonmetallic tool to chip away or scrub them.

4. Rinse the area thoroughly. If you don't, a white scum may form from chemicals absorbed into the masonry.

Pressurized Water Cleaning

If you have a large area to wash or you have a structure that would be cumbersome or inefficient to wash by hand, a pressurized water cleaning system is a good alternative. You can rent these systems for under $100 a day and they aren't complicated to run. Although nozzle pressures range from 400 psi to 3,000 psi, the Brick Institute of America suggests that you use no more than 700 psi of pressure on masonry. More than that may damage the masonry or mortar. A nozzle in the 400 to 700 range uses 3 to 8 gallons of water per minute. Follow the equipment manufacturer's guidelines; some cleaning solutions aren't recommended for certain systems.

After completing the preparation steps:

1. Saturate the area to be cleaned with water, flushing from the top down. Thoroughly saturate the area below where you're working also so it doesn't absorb any runoff from above. Limit the cleaning area to about 20 square feet. Evaporation is faster on warm, windy days, so work accordingly.
2. Apply the cleaning solution, either with a low-pressure orchard sprayer, 30 to 50 psi, or with the high-pressure nozzle.
3. Leave the cleaning solution on for about five minutes. Start at the top and thoroughly flush the wall down.

Sandblasting

Sandblasting is by far the most complicated and expensive of the three cleaning procedures. If it's done improperly, you can scar the brick and mortar joints. In spite of the inconvenience and expense, some contractors prefer sandblasting because they don't have to worry about chemical reactions on the masonry surface.

You can usually rent a sandblaster and the necessary protective clothing and safety equipment for about $150 to 200 a day. You'll also need a tow-behind air compressor. There are a wide range of materials you can blast with, such as silica sand, crushed quartz, granite, white urn sand, or even crushed nut shells, as long as they're clean and free of dust. Of these, silica sand is the one most commonly used because it's readily available and fairly inexpensive.

Do the preparation before you proceed with sandblasting; the masonry should be dry and well cured. Then test clean several areas from different distances and angles. Be careful to use the sandblaster on the brick and not the mortar. Don't sandblast light or heavily sanded, coated, or slurry finished brick.

Cleaning Guide for New Brick

The guide from the Brick Industry Association (Figure 11) should help you in selecting the proper cleaning method for use with various brick types and surfaces.

Removing Stains from Masonry Units

Use the following guidelines to remove stains from masonry. If you don't know the cause of the stain, the method you need to remove it can be an endless guessing game. To narrow the possibilities, you can do a simple test to determine if the stain is organic or inorganic. Brush concentrated sulfuric acid onto the stain. If it's an organic material, the stain will turn black. Generally, household bleach or oxalic acid is fairly effective in removing organic stains. Figure 12 gives suggestions on where to find cleaning and masking material.

Cleaning Guide for New Masonry

Brick Category:	*Red and red flashed*
Cleaning Method:	*Bucket and brush hand cleaning* *Pressurized water* *Sandblasting*
Remarks:	*Hydrochloric acid solutions, proprietary compounds, and emulsifying agents may be used.* *Smooth texture: mortar stains and smears are generally easier to remove; less surface area exposed; easier to presoak and rinse; unbroken surface, thus more likely to display poor rinsing, acid staining, poor removal of mortar smears.* *Rough texture: mortar and dirt tend to penetrate deep into textures; additional area for water and acid absorption; it's essential to use pressurized water during rinsing.*
Brick Category:	*Red, heavy sand finish*
Cleaning Method:	*Bucket and brush hand cleaning* *Pressurized water*
Remarks:	*Clean with plain water and scrub brush or light pressure and plain water. Excessive mortar stains may require use of cleaning solutions.* ***Sandblasting is not recommended.***
Brick Category:	*Lightly colored units: white, tan, buff, gray, specks, pink, brown, and black*
Cleaning Method:	*Bucket and brush hand cleaning* *Pressurized water* *Sandblasting*
Remarks:	***Do not use muriatic acid!*** *Clean with plain water, detergents, emulsifying agents, or suitable proprietary compounds. Manganese colored units tend to react to muriatic acid solutions and stain. Light colored brick are more susceptible to "acid burn" and stains, compared to darker units.*
Brick Category:	*Same as light colored units, plus sand finish*
Cleaning Method:	*Bucket and brush hand cleaning* *Pressurized water*
Remarks:	*Lightly apply either method. (See notes for light colored units.)* ***Sandblasting is not recommended.***

Figure 11
Cleaning guide for new masonry

Cleaning Guide for New Masonry (continued)

Brick Category:	*Glazed brick*
Cleaning Method:	*Bucket and brush hand cleaning* *Pressurized water*
Remarks:	*Wipe glazed surface with soft cloth within a few minutes of laying units. Use soft sponge or brush plus ample water supply for final washing. Use detergents where necessary and acid solutions only for very difficult mortar stain. Use no more than 1 part acid to 25 parts clean water. Do not use acid on salt-glazed or metallic-glazed brick.* ***Do not use abrasive powders***.
Brick Category:	*Colored mortars*
Cleaning Method:	*Method is generally controlled by the brick unit.*
Remarks:	*Many manufacturers of colored mortars do not recommend chemical cleaning solutions. Most acids tend to bleach colored mortars. Mild detergent solutions are generally recommended.*

Courtesy: Brick Industry Association

Figure 11 (continued)
Cleaning guide for new masonry

Internally Caused Stains

Brown Stain (Manganese) —

Identifying Characteristics: Occurs on mortar joints of masonry containing manganese colored units, causing tan, brown, nearly black, or gray oily streaks on the brick face.

Cause: When manganese colored brick comes into contact with acid, even acid rain, brown stain may occur.

Remarks: Brown stain is difficult to remove permanently.

Removal Method for Difficult Stains:

1. Mix a solution of 1 part acetic acid (80 percent or stronger), 1 part hydrogen peroxide (30 to 35 percent), and 6 parts water. Use extreme caution with this mixture. Wear protective clothing and goggles and work in a well-ventilated area. You may substitute a premixed solution of peracetic acid for the acetic acid and hydrogen peroxide, but it's also dangerous and may be difficult to find.

2. Thoroughly wet the masonry and apply the solution. Do not scrub. When the stain has disappeared, rinse the surface thoroughly.

Sources of Cleaning and Masking Agents	
Agent	**Supply Source**
Aluminum chloride	Pharmacist
Ammonia water	Supermarket
Ammonium chloride	Pharmacy
Ammonium sulfamate	Nursery and garden stores (or substitute a weed killer)
Acetic acid (80%)	Commercial and scientific chemical supply firms
Hydrogen peroxide (30-35%)	Commercial and scientific chemical supply firms
Kieselguhr	Commercial, scientific chemical and swimming pool supply firms
Lime-free glycerin	Drug stores
Linseed oil	Hardware and paint store
Oxalic acid	Commercial and scientific chemical supply firms
Paraffin oil	Hardware stores
Sodium citrate	Pharmacist
Sodium hydrosulphite	Pharmacist or photographic stores
Sodium hydroxide (caustic soda)	Supermarket (drain cleaning)
Talc	Drug stores
Trichloroethylene	Commercial and scientific chemical supply firms, possibly service stations or supermarket
Trisodium phosphate (TSP)	Paint stores, some hardware stores and supermarkets
Varsol	Service stations
Whiting (or substitute kitchen flour if you can't find whiting)	Paint manufacturers (or supermarket)

Figure 12
Cleaning sources

Removal Method for New or Light Colored Stains:

1. Use a solution of 1 pound of oxalic acid crystals and 1 gallon of water. Or, use a commercial solution.
2. Thoroughly wet the masonry and apply the solution. Do not scrub. When stain has disappeared, rinse well.

Efflorescence —

Identifying Characteristics: Appears as a white, powdery deposit on the face of brickwork.

Cause: Salts, such as sodium or magnesium, in the brick or mortar are brought to the surface by water.

Remarks: This is very common and will often disappear on its own with normal weathering, particularly "new-building bloom." Persistent efflorescence may mean a moisture or drainage problem in the structure, which must first be fixed before you can eliminate the stain.

Removal Method:

Brush off, using a stiff-bristled brush, or wash the deposit off with water alone or a diluted muriatic acid solution followed by a thorough rinse. Do not use muriatic acid on light-colored masonry.

Green Stain (Vanadium Salts) —

Identifying Characteristics: Yellow or green efflorescence develops on red, buff or white brick.

Cause: Green stain is usually caused by washing the masonry with an acid solution.

Remarks: Store brick off the ground under protective covering, and don't use acid solutions.

Removal Method:

1. Flush masonry with water.
2. Use a solution of ½ pound potassium or sodium hydroxide to 1 quart of water. Wash or spray the solution on the wall and leave it for 2 to 3 days.
3. Hose down the masonry, thoroughly washing off the white salt remaining on the wall.

Externally Caused Stains

Bitumens (Asphalt, Tar or Pitch) —

Removal Method:

1. Scrape off excess bits or clumps. If necessary, apply dry ice to tar to harden it. Chip or pry it off.
2. Scrub stain with scouring powder and water. For heavy stains, use kerosene mixed with an emulsifying agent. Rinse well.

3. For small areas or particularly deep stains, make a poultice with talc or other inert material mixed with benzene, naphtha, kerosene, or trichloroethylene. Leave it on until it's dry, brush off with stiff-bristled brush, and then scour and rinse.

***Bronze or Copper* —**
Removal Method:

1. Mix, in dry form, 1 part ammonium chloride (sal ammoniac) or aluminum chloride and 4 parts powdered talc. Add enough ammonia water to make a thick paste, or poultice.
2. Place the poultice on the stain and allow it to dry.
3. Brush off. Repeat the process if necessary.
4. Scrub and rinse stain area.

***Chewing Gum* —**
Removal Method:

1. Use ice to harden the gum, if necessary, and chip or scrape off as much as possible.
2. Make a poultice of denatured alcohol and talc and apply it to the stain. When dry, brush off, scrub area with scouring powder and rinse.

***Dirt* —**
Removal Method:

1. If brick texture isn't too rough, use scouring powder and a stiff-bristle brush to clean dirt off.
2. For moderately rough textures, use a solution of 1 pound of oxalic acid crystals to 1 gallon of water. You may add ½ pound of ammonium bifluoride to the solution to speed up the reaction. However, ammonium bifluoride can etch brick, so be very cautious when using it on smooth brick. Let stand for 3 hours then scrub and flush with water.
3. For very rough textures, use high pressure steam cleaning.

***Egg* —**
Removal Method:

1. Using a nonmetallic container, dissolve 1 pound of oxalic acid crystals in 1 gallon of water.
2. Thoroughly wet the masonry surface and apply the solution to the wall with a brush.
3. Scrub and rinse.

***Graffiti* —**

Removal Method:

Use a commercial spray-paint remover; follow manufacturer's directions.

***Iron or Iron Rust* —**

Removal Method for Large Stains:

1. Spray or brush the wall with a mixture of 1 pound oxalic acid crystals per gallon of water. You may add ½ pound of ammonium bifluoride to the solution to speed up the reaction. However, ammonium bifluoride can etch brick, so be very cautious when using it on smooth brick.
2. Let it stand for 3 hours; then scrub and flush with water.

Removal Method for Small Stains

1. Mix 1 part sodium citrate in 6 parts lukewarm water. Add 7 parts lime-free glycerin. Combine with whiting or kieselguhr to make a thick paste.
2. Use a trowel to apply the poultice. Allow to dry and scrape off. Repeat until stain has disappeared. Rinse thoroughly.

***Mildew* —**

Removal Method:

1. Mix 1 ounce laundry detergent, 3 ounces trisodium phosphate (TSP), 1 quart chlorine bleach, and 3 quarts water.
2. Apply solution with a soft brush; rinse well.

***Mortar Smears* —**

Removal Method:

1. Remove large pieces with a nonmetallic tool.
2. Use a commercial brick cleaning compound, such as Sure Klean, 600 by PROSOCO. Follow manufacturer's instructions.

***Moss* —**

Removal Method:

1. Use commercial weed killer.
2. If problem persists, use the method recommended for removing mildew listed above.

***Oil or Grease* —**

Removal Method:

1. Scrape off excess. Scrub with scouring powder or masonry detergent. Flush with water.
2. For stubborn stains, use a commercial degreaser.

***Paint (Dry)* —**

Removal Method:

1. Scrape off as much of the paint as possible, or scrub it off with steel wool.
2. Use a commercial paint remover, in the form of a gel solvent; scrub off the residue with scouring powder and water.
3. For large areas, sandblasting may be the most efficient method. Refer back to the Cleaning Guide for New Masonry to make sure the brick type can be sandblasted.

***Paint (Wet)* —**

Removal Method:

1. Soak or blot up as much paint as possible, trying not to spread the stain as you work.
2. Use a commercial paint remover, or a mixture of 2 pounds of trisodium phosphate in 1 gallon of water.
3. Apply the mixture and allow it to stand until the paint is softened. Scrub and rinse.
4. For stains that persist, treat the same as dry paint.

***Smoke* —**

Removal Method:

1. Using a stiff bristle brush, scrub with a scouring powder that contains bleach. Or, use a commercial emulsifying agent. Rinse thoroughly.
2. For small stains, apply a poultice made with trichloroethylene and water or talc and laundry bleach. Use only in a well-ventilated area. Let stand, then rinse well.

***Straw or Paper* —**

Removal Method:

1. Brush on household bleach and allow to dry. Rinse. Repeat applications may be needed.

2. Or, spray or brush the wall with a mixture of 1 pound oxalic acid crystals per gallon of water. You may add ½ pound of ammonium bifluoride to the solution to speed up the reaction. However, ammonium bifluoride can etch brick, so be very cautious when using it on smooth brick. Let stand, then rinse well.

***Welding Splatter* —**

Removal Method:

Use the same method as for removing iron stains.

***White Scum* —**

Don't confuse white scum (a grayish-white on the face of the brick) with efflorescence. It's caused by not saturating the wall before, or rinsing after, using an acid solution.

Removal Method:

1. Some commercial products are available. Follow the manufacturer's instructions.
2. Or, make a mask consisting of a mix of linseed oil (10 to 25 percent) and Varsol (a refined solvent), or paraffin oil (2 to 50 percent) and Varsol. Mix small batches of various concentrations and test them on the stain.
3. Brush the mask on the brick. To determine its effectiveness, allow it to stand 4 to 5 days in 70 degree or above weather.
4. Weathering will eventually remove both the mixture and the white scum.

Painting Brick

Brick is generally chosen as a building material because it's naturally attractive and low in maintenance. However, sometimes you may want to paint the brick to increase light reflection or for decorative purposes. Once brick is painted, its maintenance demands are the same as for any other painted surface. You'll probably have to repaint it every three to five years.

Adequately preparing the surface before painting minimizes future problems. First, remove loose mortar and repoint the joints as necessary. Next, thoroughly wash the brick surface, using a power washer if possible. Avoid using an acid solution on the brick. Otherwise, depending on the type of paint you use, you'll have to neutralize the surface before you paint.

Paint for masonry falls into three general categories, each with its own characteristics. They are cement-based paint, water-thinned emulsion paint, and solvent-thinned paint.

Cement-Based Paint

Cement-based paint actually has portland cement, lime, sand, and other additives in it. You apply the paint in a thickness of $^1/_8$ to $^1/_4$ inch, which helps seal porous areas and make the masonry highly water resistant. Cement-based paint adheres well and is air permeable, allowing the wall to breathe. You can buy the paint in powder form and mix it with either water or epoxy. Cement-based paint is more difficult to apply than the other two types because of its texture, but it provides good coverage. You can apply it with either a trowel or special spray equipment. In many parts of the country, cement-based paints are no longer available because latex paints are so much easier to use.

Water-Thinned Emulsion (Latex) Paint

Water-thinned emulsion paint, more commonly known as latex paint, has the advantage of being inexpensive, fast drying, and easy to apply and clean up. Also, latex paint is permeable, which keeps it from peeling or blistering from trapped moisture. Because latex breathes and allows moisture to pass through, you can use it over damp surfaces. Another advantage of latex paint is that it's alkali-resistant. You don't have to mess with neutralizing washes or a curing period before you apply it, a real bonus for new construction.

Apply a primer or base coat first. For both the primer and finish coat or coats, use a brush, roller, or spray equipment. Brush application is probably the best, especially on coarse-textured masonry.

Solvent-Thinned Paint

The most common solvent-thinned paints are *oil-based* and *alkyd paints*. Solvent-thinned paint isn't recommended for exterior masonry, largely because it's nonporous. Nor should you use it on new brick until the brick has weathered. Ideally, the brick should be allowed to weather a year to allow any salts or minerals in the clay to rise to the surface. You can artificially age brick by hosing it down several times a day for three months, but for most interior masonry, and even some exterior masonry, such a process is far too impractical to be of any use.

Before you paint, clean the masonry well. Neutralize the brick if an acid solution has been used on it (refer back to Green Stain on page 82). First apply an oil-based primer or base coat to the dry, clean wall, followed by the finish coat. You can apply the paint with a brush, roller, or spray equipment. (See also *Paint*.)

Manhours

Manhours to Lay Brick			
Type	**Unit**	**Manhours**	**Suggested Crew**
Standard brick wall assembly			
4" thick wall, single wythe, veneer facing	SF	.211	1 bricklayer, 1 bricktender
8" thick wall, double wythe, cavity filled	SF	.464	1 bricklayer, 1 bricktender
12" thick wall, triple wythe, cavity filled	SF	.696	1 bricklayer, 1 bricktender
Standard face brick	SF	.211	1 bricklayer, 1 bricktender
Brick pavers (2 units per SF)	SF	.193	1 bricklayer, 1 bricktender
Chimney, standard brick, 4" thick			
16" × 16" with one 8" × 8" flue	VLF	1.49	1 bricklayer, 1 bricktender
20" × 20" with one 12" × 12" flue	VLF	1.49	1 bricklayer, 1 bricktender
28" × 16" with two 8" × 8" flues	VLF	2.27	1 bricklayer, 1 bricktender
36" × 16" with two 12" × 8" flues	VLF	2.60	1 bricklayer, 1 bricktender
Chimney, standard brick, 8" thick			
24" × 24" with one 8" flue	VLF		1 bricklayer, 1 bricktender
28" × 28" with one 12" × 12" flue	VLF		1 bricklayer, 1 bricktender
36" × 24" with two 8" × 8" flues	VLF		1 bricklayer, 1 bricktender
44" × 24" with two 12" × 8" flues	VLF		1 bricklayer, 1 bricktender

Manhours to Paint Brick, per SF		
Application	**Manhours**	**Suggested Crew**
Cleaning/preparation	.070	1 painter
Paint, 1 coat, latex flat		
Brush (180 SF per gal.)	.014	1 painter
Roller (124 SF per gal.)	.009	1 painter
Spray (160 SF per gal.)	.007	1 painter
Paint, 2 coats, latex flat		
Brush (120 SF per gal.)	.024	1 painter
Roller (85 SF per gal.)	.016	1 painter
Spray (105 SF per gal.)	.012	1 painter

Manhours to Clean/Point Brick, per SF		
Job	**Manhours**	**Suggested Crew**
Cleaning brick		
Hand cleaning, brushing		
light (100 SF per hour)	.010	1 bricklayer, 1 bricktender
medium (75 SF per hour)	.013	1 bricklayer, 1 bricktender
heavy (50 SF per hour)	.020	1 bricklayer, 1 bricktender
Water blasting (250 SF per hour)	.004	1 bricklayer, 1 bricktender
Steam cleaning (75 SF per hour)	.013	1 bricklayer, 1 bricktender
Sandblasting (50 SF per hour)	.013	1 bricklayer, 1 bricktender
Tuckpoint (repoint) brick, cut out joint and regrout, (30 SF per hour)	.033	1 bricklayer, 1 bricktender

For information on related topics, see:

Concrete, page 141

Concrete Block, page 189

Concrete Reinforcing, page 201

Fireplaces and *Chimneys*, page 291

Framing Materials and Planning, page 363

Glass Block, page 375

Painting, page 427

Siding, page 611

Stone Masonry, page 655

Wall Framing, page 709

Cabinetry

Cabinet making and installation has changed substantially within the last generation of carpenters and builders. Previously, residential carpenters could rough frame, install interior and exterior trim, and build the windows and cabinets on site. A house was truly site built. Today, the vast majority of houses are created with many assembled or partially-assembled components, particularly the cabinetry. Very few builders can afford the time to build cabinets on site. And very few customers would want to pay them to take that time. These days, most cabinets are factory built. Even "custom" cabinets are built and finished in a cabinetmaker's shop and installed the same way as factory-built cabinets.

Site-Built Cabinet Basic Components

Figure 1 is an illustration of a site-built cabinet. Site-built cabinetry is built in place and attached to the walls and floor. Here are the basic components of a cabinet.

- *Platform:* The first thing built is the platform that forms a base for the cabinetry, shown in Figure 2. The platform is continuous and follows the layout of the base cabinets. It's usually built with a 2 × 4 base covered with plywood or particleboard.
- *Cabinet backs or ledgers:* Site-built cabinets are often built without a back. Instead, the carpenter levels a 1 × 4 ledger and attaches it to the wall at the finished cabinet height. It's fastened with screws or lag bolts at 16 inches on center. If a back is needed, it's built of plywood or particleboard fit to the finished cabinet height.
- *Partitions:* Partitions are placed between cabinet uses, such as open cabinets and drawer stacks. Partitions are cut to fit from the back of the cabinet to the face (Figure 3).
- *End pieces:* End pieces cover the cabinet ends from the floor to the finished cabinet height. Exposed end pieces are built of a veneered wood to match the cabinet face and doors.

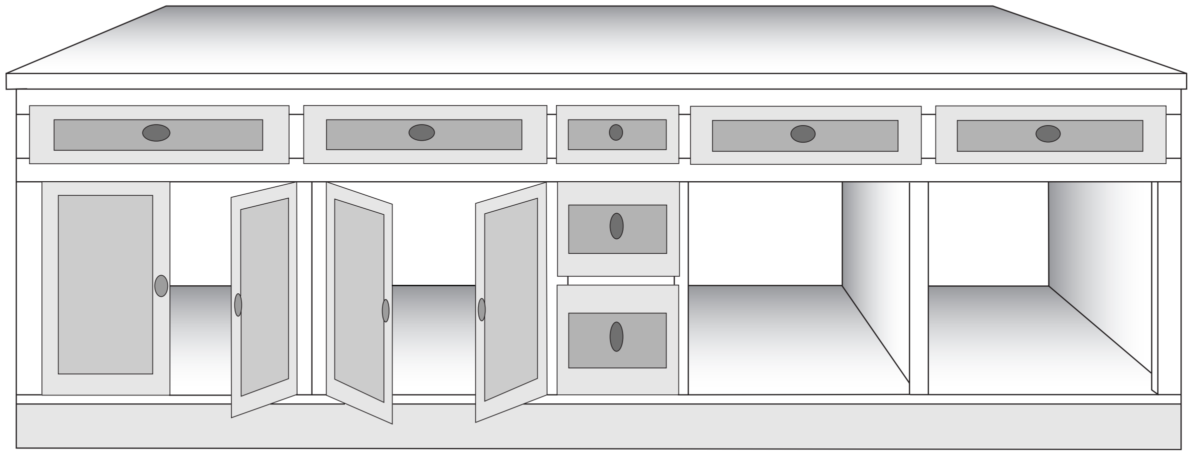


Figure 1
Site-built cabinet

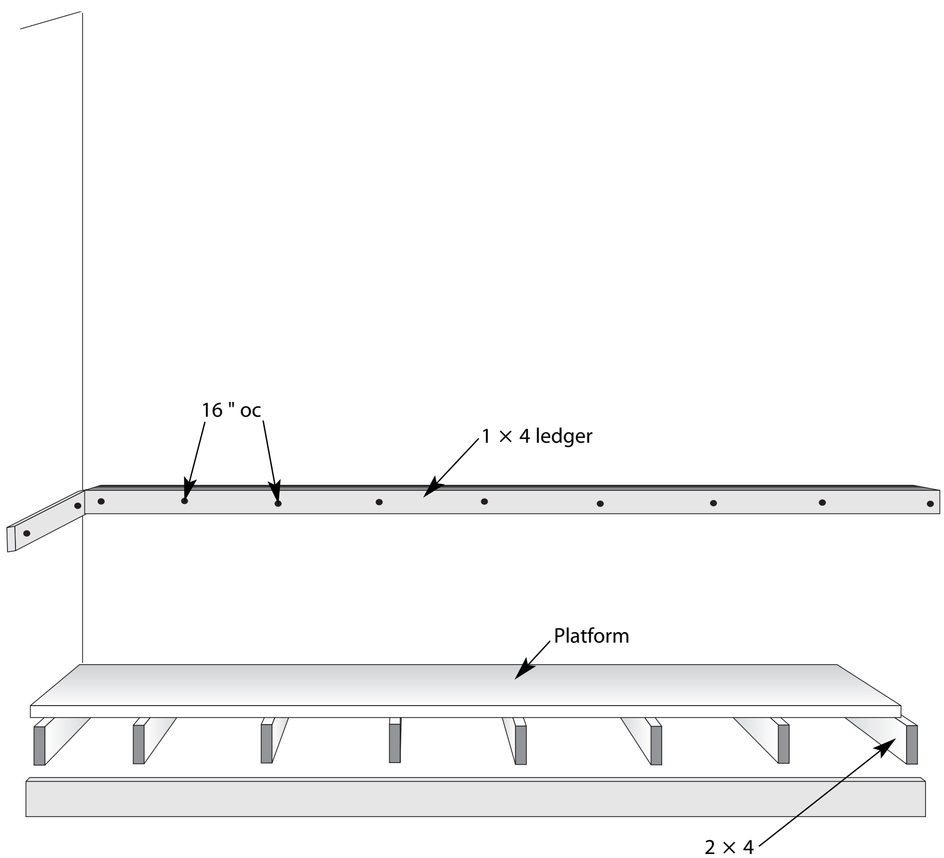


Figure 2
Cabinet platform and ledger

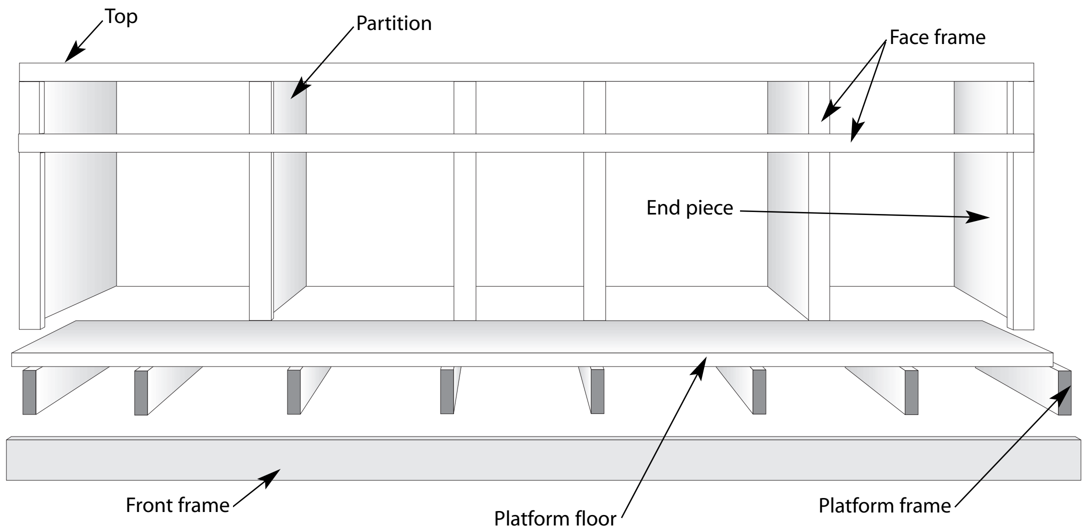


Figure 3
Basic cabinet components

- *Face frame:* A face frame, built of $^3/_4$-inch boards approximately $1^1/_2$ inches wide, is attached to the end pieces and partitions. The face frame and cabinet top are usually constructed of hardwood or other solid wood.
- *Doors and drawers:* Doors and drawers are built from a variety of panels or solid woods. Many choices are available for installation hardware.
- *Cabinet top:* The cabinet top is mounted with small angle brackets on the ledger strip and face frame and fastened with screws.

Box Cabinets

With few exceptions, today's cabinets are *box* cabinets. This term refers to the method of construction and assembly. Box cabinets are made in factories or cabinet shops. The components of a box cabinet include drawer units, base units, and individual wall units. You can assemble these into a complete kitchen at the job site.

Box Cabinet Language

Wall units range in width from 12 to 48 inches and in height from 12 to 42 inches, depending on the manufacturer. While there may be some variation in the way manufacturers catalog individual pieces, almost all indicate wall units with a W followed by the width and the height of the unit. W3624 refers to a wall cabinet 36 inches wide by 24 inches high. Unless otherwise stated, a wall cabinet is usually 12 inches deep. Additional letters may be added to further describe the cabinet. For instance, LS may designate a lazy Susan and MW may designate a cabinet with a microwave shelf.

Base units range in width from 12 to 48 inches. Base units are designated with the letter B and two digits to designate the width. Unless otherwise designated, base cabinet dimensions are 34$^{1}/_{2}$ inches high and 24 inches deep. Base cabinets also have one top drawer to match each swing door on the cabinet. Any additional letters further describe the unit. A B18/POVB may, depending on the manufacturer's code, designate an 18-inch wide base unit with a pull-out vegetable bin.

Corner design in both base and wall cabinet layout take a little extra planning. One option you can use when one bank of cabinets butts into another is a base corner blind (BCB). That blocks off the dead space in the corner. Or you can use a base cabinet diagonal (BCD36), or a base cabinet diagonal lazy Susan (BCD36LS) to open up usable corner space in base units. You can also use a wall corner cabinet (WCC). Check with your cabinet supplier for a manufacturer's specific cabinet designations.

Cabinetry Checklist

- ❑ *Add the individual cabinet widths and compare the sum to the overall wall space that will receive cabinets.*
- ❑ *Do the wall cabinets align with the base cabinets?*
- ❑ *Have you allowed for fillers in corners so that drawers and doors will open without hitting other doors, drawers, or hardware?*
- ❑ *Do the doors swing the right way?*
- ❑ *Have you specified finished veneered back and end panels where they will be exposed?*
- ❑ *Have you specified the hardware, including drawer glides, door hinges and drawer pulls?*

Cabinet Styles

Cabinets are available with or without face frames — the part you can see between the doors and drawers. The standard box comes with a traditional face frame. The hinges on these cabinets may be either hidden or exposed.

Cabinets without face frames are often called European-style cabinets. When the doors are closed on a European cabinet, no face frame is visible. This is made possible by European hinges, which allow the doors to swing in a way that prevents them from binding with the next door.

When initially introduced, European cabinets were finished with plastic laminates for a clean, bold appearance. Face-frame cabinets continued to provide the traditional look with woods and door styles. These two styles have crossed over so that today, any door style and look is available on either cabinet style. To simplify cabinet assembly, many manufacturers make a cabinet style they call "European" that is actually a face frame cabinet with a full overlay door. This gives the European look without requiring a separate assembly method.

Standard Cabinet Measurements

These are the standard installation measurements:

- Base height: 34$^{1}/_{2}$ inches

- Countertop height: 36 inches
- Height of wall cabinets above countertop: 15 to 18 inches
- Top of wall cabinets above floor: 84 inches
- Top of wall cabinet to ceiling (if no soffit): 12 inches
- Wall cabinet, one door: 9 to 24 inches wide
- Wall cabinet, two door: 27 to 48 inches wide
- Appliance cabinets: 12 to 18 inches high, 30 to 36 inches wide
- Sink base, single door: 24 to 48 inches
- Sink base, two door: 27 to 48 inches
- Drawer base, four-drawer (drawers stacked vertically): 15 to 24 inches wide
- Blind corner base: 36 to 42 inches wide

Planning and Ordering Cabinets

Don't order cabinets until the final budget is set. To stay within that budget, you'll have to consider the layout, the quality of construction, and the number of optional items.

When planning a cabinet layout, you'll most likely work with a supplier's representative experienced in kitchen and bath layout. Make sure the client's chosen layout provides an efficient work triangle. A kitchen should have comfortable distances between the sink, stove and refrigerator. The layout must provide ample storage with as few wasted spaces as possible. Wasted spaces are usually found in hard-to-reach corners.

For the sake of economy, the layout should include larger cabinets where possible. One 32-inch cabinet is less expensive than two 16-inch cabinets. Avoid using narrow cabinets. The inside of a drawer in a 12-inch base cabinet is approximately 8 inches wide. There aren't a lot of things you can put in an 8-inch drawer.

Quality of Construction

Cabinets are manufactured with a wide range of available features and construction quality. Most cabinets use a combination of solid wood and engineered wood products such as plywood or particleboard. Top-of-the-line cabinets are built with solid wood doors and face frames and plywood boxes covered with hardwood veneers. The three common groups include premium, standard, and basic cabinets. But you'll find many overlapping features at your supplier, as quality is a continuum instead of three distinct groups.

These are generally considered *premium* features:

- All plywood boxes with hardwood veneers
- Top-quality drawer glides on both sides of the drawer
- Fully-adjustable European hinges
- Solid wood doors, face frames and drawer sides
- Higher-cost hardwoods such as cherry
- Full-depth adjustable shelving
- "Hand-rubbed look" finish.

These are *standard* features:

- Lower-grade plywood or veneered particleboard or fiberboard boxes
- Full-depth drawers with double drawer glides (not as heavy as premium)
- Adjustable hinges
- Particleboard drawer sides
- Solid wood doors and face frames, usually oak
- Acceptable finish with even coloring and uniform coatings.

Finally, here are the *economy* features:

- Metal or plastic corner brace/fastening piece
- Short drawers with single drawer glides
- Base cabinet shelves are one-half depth
- Box sides are often $^3/_8$-inch particleboard
- "Wood grain" vinyl covering on interior and exterior of boxes and drawer sides
- Solid wood face frames but may have mixed species stained to look like oak
- Veneered particleboard doors with nonadjustable hinges
- Worst case finishes include uneven coloring with an inconsistent sheen

Some manufacturers work on a semicustom basis, allowing you to order optional upgrades in most of their lines. But you have to be careful with these options. This flexibility also makes it easy to quickly blow a budget by upgrading feature by feature, until you've gone from economy to premium.

Layout options include lazy Susans, appliance garages, microwave shelves and roll-out base cabinet shelves. Most manufacturers will have these features, and more.

The most basic option in all cabinet grades is door style. The least expensive door is flush veneered particleboard. The most expensive door is a raised panel, solid wood door with double cathedral arches. In between are various combinations of framed plywood or solid wood raised panel configurations.

Hardware options center around strength and durability. Higher-quality hardware also provides additional adjustment features. One of the first upgrades in hardware is opting for double drawer glides instead of a single center glide. Remember though, all double glides are not equal. You can find a range of quality and weight here as well.

The traditional standard hinge is also the most basic. These hinges face mount on the face frame and to the back of the cabinet door. They're made for both overlapping doors as well as inset, or rabbeted, doors. European-type hinges have become increasingly popular. Homeowners like the fact that they're hidden, giving clean lines to the cabinetry. Installers like their range of adjustments. If a door has a slight, but acceptable, warp, the installer must "spring" a regular hinge to get the door to fit properly with traditional hinges. European hinges provide a built-in adjustment.

Critical Points in Cabinet Layout

Before you begin installing cabinets, first identify the critical points. Critical points include overall space limitations such as the distance from a corner to a doorway. They also include self-imposed limitations, like a window location where a sink needs to be centered. Consider the following guidelines:

1. Sketch out overall dimensions as well as centerline dimensions to critical items such as windows. Also get dimensions from the most critical, or inflexible, position, such as an inside corner.
2. Beginning with the base units, lay out critical cabinets such as a sink base centered below a window and a lazy Susan in the corner. Be sure to include the refrigerator and kitchen range as critical units. Always separate refrigerators, ranges, and sinks from each other with a cabinet unit to provide countertop work space.
3. Fit in the other cabinets between the critical units and keep in mind any optional units such as drawer stacks. Choose from available cabinet widths that will provide a pleasing layout. Remember that for the same overall dimension, two larger cabinets are less expensive and often offer more utility than three smaller ones.

4. Where standard cabinets meet in the corners, place a filler (usually 3 inches) to ensure that drawers or doors won't bind against opposing cabinets. You'll also need a filler where standard cabinets don't completely fill the space between the critical areas.
5. When you've finished an acceptable layout for the base cabinets, you're ready to place the wall units. Again, start by identifying the critical areas, including those already identified for the base units. Next, identify any specialty units for the wall units, such as an appliance garage or microwave shelf, as well as standard units like a 30-inch wall unit over the range to accommodate the range hood.
6. After placing critical wall units, fill remaining spaces with units which line up with the base units if possible. As with the base units, fillers may be needed for any odd dimensions between critical areas. However, avoid fillers whenever possible.
7. Specify door swings on single door base and wall units. As a rule, place the hinge toward the corners, with all doors opening toward the center of the run. Have the doors open toward accessible space or the space where the homeowner would most likely be standing.
8. Many cabinets come with a black toe kick on the individual boxes. You can order an optional full-length toe kick that's stained and finished to match the cabinets.
9. Islands, peninsulas, and exposed ends need finished veneered panels. Specify cabinets that require finished panels or the wholesaler will assume only the face frame will be exposed.

Cabinet Layout

First, check the walls and floor for level and plumb. If you find a corner out of plumb, you'll have to shim either the upper or the base cabinets to make the cabinets line up. Also, check the floor and walls for any uneven areas that may also require shimming. Follow these layout steps:

1. Start with a clean installation area. You'll be measuring, leveling and marking on the floors and walls. A cluttered room makes all of these tasks harder.
2. Mark the base cabinet layout on the floor.
3. Check the floor for level. Mark the highest point in the area where you'll install the base cabinets. This includes up to 24 inches away from the wall. If this is a split installation, with

cabinets in two different areas, mark the highest point in both areas, as well as the highest overall point. In most cases you'll just find slight variations in the floor, without any distinct ridges that require extensive fitting. In extreme cases, you may have to shape the cabinet base to the high point by scribing and sanding it.

4. Measure up $34^1/_2$ inches from the highest floor point for standard kitchen base cabinets. Starting from the $34^1/_2$-inch mark, draw a level line to indicate the top of all of the base cabinets. This line will measure more than $34^1/_2$ inches from any lower floor areas. In these areas, you'll have to shim the cabinets to bring them up to the level line.

5. Place the straightedge on this line to find any variations in the wall. Note protruding as well as recessed areas. The backs of the cabinets need to be shimmed away from the wall in the recessed areas to keep the face of the cabinets straight.

6. Check L- and U-shaped layouts for square. A framing square is too small for all but the smallest installations. Use multiples of 3, 4 and 5 to check for square using a tape measure. Using a 7-foot by 10-foot "L" as an example, multiply 3, 4 and 5 by 2. This will give 6 feet, 8 feet and 10 feet. On the 7-foot wall, measure 6 feet out from the corner. On the 10-foot wall, measure 8 feet from the corner. If the wall is perfectly square, the diagonal measurement from the 6-foot mark to the 8-foot mark will be 10 feet. While it's always best to have a square installation, it's not as critical for the cabinet placement as it is for the countertops.

Cabinet Installation

In kitchen remodeling, there's an important rule you need to know: *Never* remove the old cabinets until every piece of the new cabinets has been delivered and accounted for. The kitchen is the heart of most homes, and having a kitchen that's not functioning doesn't make anyone happy.

It's best to install the wall cabinets first, before you do the base cabinets. This allows for easier access to the wall cabinets during installation — you don't have to reach over anything. It also avoids the risk of the base cabinets getting scratched while you're leaning over them to work on the wall units.

> ***Tools***
>
> *Tools preferred by most cabinet installers include:*
>
> - *Level*
> - *Square*
> - *Straightedge*
> - *Two cordless drills: one for use with drill bits and the other for use as a screwdriver*
> - *Cabinet jack to support wall cabinets during installation*
> - *Belt sander*
> - *Table saw (a small lightweight portable is usually adequate)*
> - *Clamps*

Fastening Methods

The basic cabinet fastening method is to screw through the fastening strip at the back of the cabinet into a wall stud. Use 3-inch drywall or deck-type screws. Use 2-inch screws to fasten the face frames of the cabinets together. If it's necessary to compensate for an uneven floor or wall, place shims behind or under the cabinets for proper alignment before you place the screws.

You need 2-by blocking to secure island and peninsula cabinets to the floor. Fasten these blocks to the floor, then secure the base cabinets to the blocking. While you need to make sure the floor blocking is secure, it doesn't need to be as strong as the ceiling blocking that supports island and peninsula upper cabinets. In new construction, the ceiling blocking should be placed during framing. If it's missing, or if you're working on a remodel, place blocking in the ceiling from the attic space. If this isn't possible, you'll have to fasten the blocking to the ceiling joist from the kitchen, then patch the drywall.

Installing Plywood Backing Behind Drywall

You won't always find the backing that will hold the cabinets securely to the wall where you need it. You can place the backing behind the drywall where it's needed in just about the same way you'd repair a drywall hole. Follow these installation steps:

1. To minimize drywall repair later, trace the cabinet placement on the wall.
2. Cut a square hole inside the tracing. Keep the cutout to finish the repair.
3. Place a sturdy piece of plywood inside the hole, using a temporary screw as a handle. Secure it with glue and screws.
4. Place the cutout back in place and screw and/or glue it to the plywood.
5. Now you can place the cabinet over this backing and fasten it to the plywood.

Preparing for Installation

To prepare the cabinets for installation, remove the doors and drawers (and remember to mark each door as it's removed so you know which door goes with which cabinet). Removing the doors and drawers serves two purposes. First, it makes the cabinets lighter and easier to handle. Second, it prevents nicks and scratches if a door or drawer opens unexpectedly as you're moving, lifting or tilting the cabinets into place. It's generally easier to remove the hinge from the face frame than from the door. But when the hinge is left on the door, take care not to scratch adjoining doors if they're stacked together.

Do the layout for floor and wall placement at full face-frame dimension. The face frame of almost all cabinets extends beyond the sides by approximately $^1/_4$ inch. If you're working with a critical placement, allow for this difference between the face and back of the cabinets.

Locate and mark the studs that you'll use for support in the cabinet layout. Then measure off of the layout to transfer the stud locations to the cabinets. That way you can start the screws before lifting the cabinet in place. To locate a screw inside a cabinet, remember to subtract the overhang of the face frame (usually $^1/_4$ inch) as well as the thickness of the box side (usually $^3/_8$ or $^1/_2$ inch). A carpenter's folding rule with a slide works well for this. If the face frame overhang is $^1/_4$ inch and the side is $^3/_8$ inch, extend the slide on the folding rule out $^3/_5$ inch. Then measure from the layout line to the center of the stud. Push the slide on the rule in to subtract for the overhang and the side, and place the end of the rule against the edge of the side. Now, simply mark the same measurement on the inside of the cabinet without having to subtract any fraction.

Installing Wall Cabinets

Follow these steps to install the first cabinet:

1. Place the cabinet in position with the screws already started.
2. Plumb the edge of both faces. When working alone, this is every bit as tricky as it sounds. Use a cabinet jack or stand to hold the cabinet if you don't have a helper available.
3. If both walls are plumb, both edges should also be plumb without placing shims. Then you can just screw through the fastening strips at the back of the cabinet into the framing studs.
4. When shims are required, first place screws into the locations that don't require shims. This will stabilize the cabinet while you place the shims. Finish by shimming as necessary and placing screws through the shims. If you're following good framers and drywallers, very little shimming will be necessary.

Here's how to install the additional cabinets:

1. Place the cabinet in position with the screws started.
2. Place the face frame snugly against the face frame of the adjoining cabinet.
3. Fasten the cabinet to the wall with a minimum of screws.
4. Clamp the face frames of the two cabinets tightly together.

5. Check the new leading edge to make sure the cabinet is plumb when set. You should be able to assume that if the first cabinet is plumb, the remaining units will be plumb as well. You may occasionally encounter poorly-made cabinets that are out of square. If the cabinets start running out of plumb, measure the top and bottoms. If they're not exactly the same, you may need to plane one side. However, consult with your supplier before attempting to plane.

6. Drill a pilot hole for a 2-inch screw through the edges of the two adjoining face frames. For a cleaner appearance, place the screws where they'll be covered by the hinge when you rehang the doors. Ream the pilot hole so that the screw will be flush when set, or use screw collars for a cleaner finish. Some cabinet suppliers provide screw collars with their cabinets.

7. Screw the cabinet face frames tightly together and remove the clamps.

8. Place the remaining screws and shims as required.

9. Repeat these steps until all of the units are placed.

Installing Base Cabinets

1. Begin the installation in the corners and work out from there. If you're installing a straight open run, start with a plumb line indicating the first wall and base units

2. Place the first cabinet. Because the base cabinets will stand on their own, starting the screws before setting the cabinet in place isn't as helpful as it was with the wall units.

3. If necessary, use shims to bring the unit up to the level line you marked on the wall during layout. If the straightedge check during layout indicated an uneven wall, you may need shims on the back of the cabinet to keep the face straight.

4. Check the face and leading edge for plumb. Shim as required.

5. Screw the base cabinet to the wall.

6. Follow the steps above for installing additional cabinets for the remaining base units.

Completing the Cabinet Installation

To complete the installation, install the doors and drawers. But don't be too anxious to see the finished look. Before placing the doors and drawers, first complete the boxes by installing any additional veneers for exposed sides and backs, as well as any extra moldings and trim.

Veneers

If you ordered veneers for exposed cabinet sides or backs, they should have come sized to fit. For large pieces, use a combination of glue and small brad-type nails. An air-powered pin gun is ideal for this task because it leaves a very small head to fill. You can just use glue for small pieces on the exposed ends of smaller wall units.

Moldings

The amount of molding you use is a personal preference. The two basic moldings are flat screen stock and outside corner. Use small-head nails or an air-driven pinner to install these moldings. You may use $^1/_4$-inch × $^3/_4$-inch flat screen stock moldings where the top of the cabinets meet the soffit, where two veneers butt together, and down along the side of the cabinet where the back meets the wall. Flat moldings are a convenient way to cover up poor fits where you had to shim the back of the cabinet, or where you have an uneven soffit. If you don't need moldings to cover any blemishes, don't use them. Many people feel that the cabinets have a cleaner look without them.

Use outside corner moldings when a veneer edge is exposed. This is found most often on islands and peninsulas where veneers are used on both the sides and backs.

Occasionally, an installation calls for wider detail such as crown or bed moldings at the top of the wall cabinets. Because of their width, always allow for these moldings in establishing the cabinet height or the soffit size. Standard cabinets held tight against the soffit won't have room for a wide molding between the doors and soffit. Ideally, the soffit should be built narrower to allow for the cabinets to be set at standard height.

Installing the Door and Drawers

Doors and drawers are the last step in the cabinet installation. First, hang the doors by simply replacing the screws into the same holes they were removed from. Check all doors for proper alignment with neighboring doors. Check the reveal and alignment of paired doors. Apply felt or vinyl stickers to the outside corners to quiet them as they close against the face of the cabinets.

Check for warped doors. If the cabinets are installed properly, a flat door should close with the top and bottom both fitting tight against the frame. If there's a gap at the top or the bottom, either the door is warped or the cabinet has a twist that should have been shimmed out. If the problem isn't obvious, check the frame with a level. Depending on the hinge type, you may be able to adjust the hinge so that both edges close evenly. If the door is too warped for adjustment, call the supplier. Don't leave it this way. It will get worse over time, and so will your reputation.

Finally, slide in the drawers. There shouldn't be any adjustment needed for the drawers, but check them for proper alignment. Drawer stacks should align vertically. There should also be an even reveal between drawers. To adjust a drawer, you'll probably have to reset the glide on either the cabinet or the drawer.

Manhours

Manhours to Install Cabinets		
Unit	**Manhours**	**Suggested Crew**
Wall cabinets, 30" high, 12" deep		
12" wide, 1 door	.461	1 carpenter
18" wide, 1 door	.638	1 carpenter
24" wide, 1 door	.766	1 carpenter
30" wide, 2 doors	.911	1 carpenter
36" wide, 2 doors	1.03	1 carpenter
48" wide, 2 doors	1.16	1 carpenter
Wall cabinets, above appliance, 12" deep		
12" high, 30" wide, 2 doors	.461	1 carpenter
15" high, 36" wide, 2 doors	.638	1 carpenter
18" high, 18" wide, 2 doors	.537	1 carpenter
18" high, 36" wide, 2 doors	.911	1 carpenter
Corner wall cabinets, 30" high,12" deep		
24" at each wall	1.03	1 carpenter
Blind corner wall cabinets, 30" high		
24" wide, 1 door	1.03	1 carpenter
36" wide, 1 door	1.32	1 carpenter
42" wide, 2 doors	1.20	1 carpenter
Base cabinets, 34 1/2" high, 24" deep		
12" wide, 1 door, 1 drawer	.461	1 carpenter
18" wide, 1 door, 1 drawer	.766	1 carpenter
24" wide, 1 door, 1 drawer	.911	1 carpenter

Manhours to Install Cabinets (continued)		
Unit	**Manhours**	**Suggested Crew**
Drawer base cabinets, $34^{1}/_{2}$" high, 24" deep		
15" wide, 4 drawers	.638	1 carpenter
18" wide, 4 drawers	.766	1 carpenter
24" wide, 4 drawers	.911	1 carpenter
Sink base cabinets, $34^{1}/_{2}$" high, 24" deep		
24" wide, 1 door, 1 drawer front	.740	1 carpenter
30" wide, 2 doors, 2 drawer fronts	.766	1 carpenter
42" wide, 2 doors, 2 drawer fronts	.911	1 carpenter
Two door base cabinets, $34^{1}/_{2}$" wide, 24" deep		
27" wide, 2 doors, 2 drawers	1.25	1 carpenter
36" wide, 2 doors, 2 drawers	1.35	1 carpenter
42" wide, 2 doors, 2 drawers	1.50	1 carpenter
48" wide, 2 doors, 2 drawers	1.71	1 carpenter
Blind corner base cabinets, $34^{1}/_{2}$" high		
36" to 39" at wall	1.39	1 carpenter
39" to 42" at wall	1.50	1 carpenter
45-degree corner base, revolving, $34^{1}/_{2}$" high, 36" wide	2.12	1 carpenter
Utility cabinet, 66" high, 12" deep (no shelves)		
18" wide	1.32	1 carpenter
24" wide	1.71	1 carpenter
Utility cabinet, 66" high, 24" deep (no shelves)		
18" wide	1.24	1 carpenter
24" wide	1.71	1 carpenter
Oven cabinet, 66" high, 24" deep		
27" wide, single or double oven	2.19	1 carpenter
Microwave cabinet, with trim		
21" high, 20" deep, 30" wide	.986	1 carpenter

For information on related topics, see:

Painting, page 427

Trim, page 673

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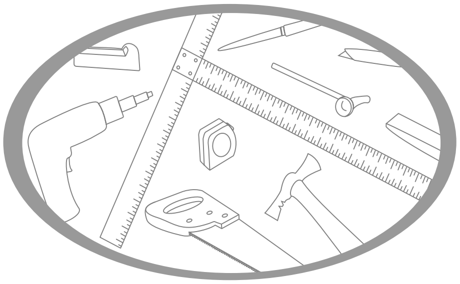


Carpet

Although carpets are often considered part of the decor, they also have functional purposes. They insulate cold floors, absorb noise, and cushion impact.

Types of Carpet

Carpets are constructed one of three ways: woven, needle-punched, or tufted.

- *Woven* carpets are woven on a loom, much like fabric, which is an expensive process. The advantage is that the weaver can create elaborate designs.
- *Needle-punched* carpets are made by using thousands of barbed needles to punch layers of carpet fibers through a mesh fabric core. These thick, felt-like carpets are resistant to water, insects, mold, and sun, so they're ideal for indoor-outdoor carpet.
- *Tufted* carpets are constructed by stitching big yarn loops through a backing fabric. A layer of latex glues the loops to the backing. Another layer of backing material is attached for extra strength and stability.

Because the weaving process is so expensive and needle-punching lacks versatility, over 90 percent of American carpets are tufted. Both tufted and woven carpets begin with a loop pile. The loops may be level or multilevel. In a multilevel design, the loops may be random heights or carved in a clear pattern. Berbers and most commercial carpets are loop pile.

In cut pile carpets, the loops are cut, which produces the even surface of the more luxurious velvets or plush carpets. A combination of the two can be found in cut and loop carpets, which gives the rug a sculpted look. Of the three textures, the loop pile is the most durable and is best for high traffic areas.

Regardless of the construction method, all carpets have either a jute or a polypropylene backing. Foam may be used as the secondary backing in tufted carpets. See Figure 1.

Jute, a natural fiber, is strong and durable. In wet or very damp conditions, though, it may mildew. And if it stretches, it won't spring back to its original shape. It's also imported, which makes it more expensive than polypropylene as a backing material.

Polypropylene is strong and durable, resistant to mildew, and it'll only stretch about 1 to $1^1/2$ percent. In other words, a 10-foot piece would have less than 2 inches of give. So once the carpet is stretched, it maintains its shape even if it gets soaked.

Foam or cushion backing isn't as strong as either jute or polypropylene. But because it also acts as the padding, it's cheaper than jute- or polypropylene-backed carpet. Carpet with foam backing is glued down rather than stretched and tacked into place.

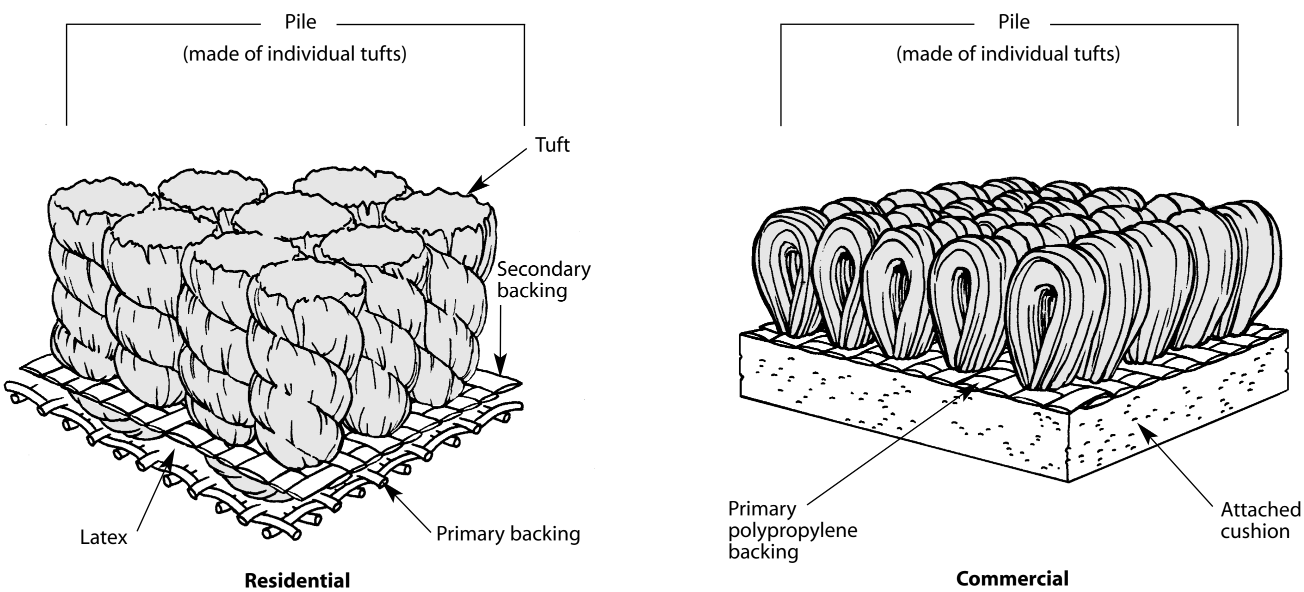


Figure 1
Carpet profiles

Styles of Carpet

Each carpet texture comes in a variety of styles.

Loop or Multilevel Loop Carpets

Most commercial carpet is a tightly twisted, very dense, very low-level loop pile. Generally, it's the most durable but least luxurious of all carpet styles. Figure 2a shows a level loop.

A Berber carpet has a looser loop, and comes in level loop or multi-level loop styles. Although it isn't as durable as commercial carpet, it'll still perform better than a cut pile or the cut and loop style carpets. Because of its texture, Berber is considered less formal than cut pile carpet.

Cut Pile Carpets

Velvets and *plushes* are dense, level-cut pile carpets (see Figure 2b). The tufts have very little twist, so the ends blend together for a smooth, velvety surface. That's why velvets show footprints and may show shading. They're best suited to low traffic areas.

Saxony textured carpet (Figure 2c) is similar to velvet carpet except that the tufts have more twist. Although the extra twist means the surface isn't quite as velvety as the plushes, it also means the carpet will be more durable.

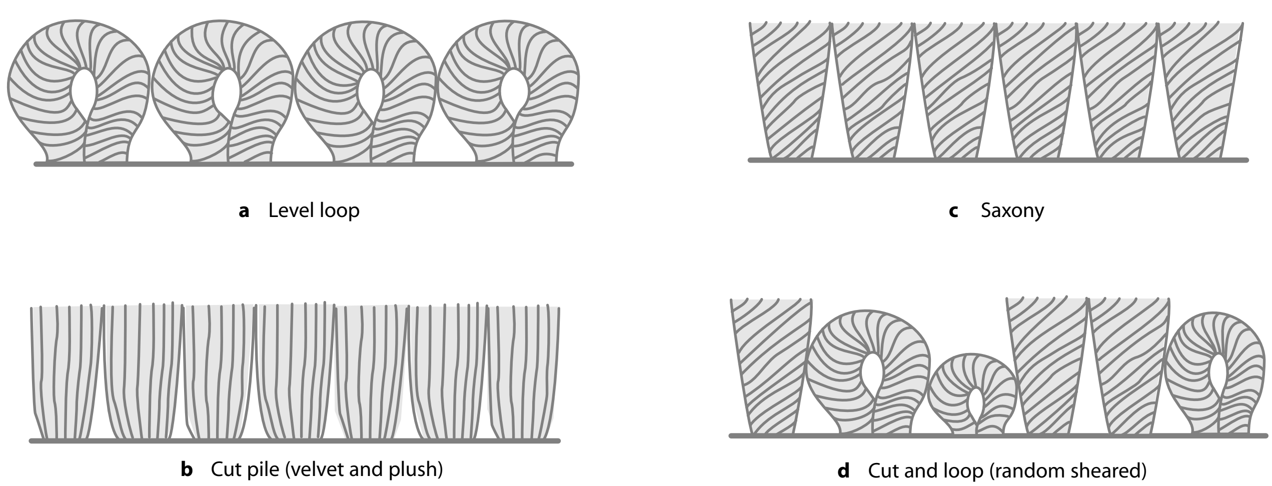


Figure 2
Carpet styles

A *frieze*, *twist* or *trackless* style is a textured plush that has tightly curled or twisted tufts that give the carpet a pebbled or nubby look. Frieze carpets are very durable because the texture hides dirt and footprints.

Cut and Loop Carpets

In *tip-sheared* carpet, the tufts are all the same height, with some of the loops cut and some not. This blend creates a softer look than level loop carpet, but it also shows more foot traffic.

Random-sheared carpet (Figure 2d) is similar to tip-sheared except they start with multilevel loops, and only the highest loops are cut. Although it, too, has a more luxurious feel than level loop, it doesn't wear as well as tip-sheared carpet.

Manufacturers offer a confusing range of fibers, textures and warranties, making it almost impossible for the novice buyer to compare "apples to apples." In the past, the industry has used face weight (the weight of a square yard of its face fiber) to signal better grades. But because this can be misleading — cheap shag carpet could weigh more than a good quality low-level loop commercial carpet — the trend is away from weight and toward a standardized system that measures the quality and durability of a carpet.

Carpet Values

In determining value, you should consider the five following factors: the fiber, the amount of yarn and twist, the density, the pile height, and the warranty.

The Fiber

Carpets come in both natural and synthetic fibers. First let's look at the natural fibers.

- *Wool:* Years ago nearly every carpet was made of wool. Today it's used almost exclusively in woven area rugs because it's expensive and also because some people are allergic to wool. Also, wool "pills" or balls as it wears, which many people find unattractive. Still, some prefer wool because it's softer and more resilient than man-made fibers. Varying grades of wool are used in carpet, with virgin wool (wool that's never been used before) being the most desirable. Presently the best grades come out of New Zealand.
- *Cotton:* Although cotton was commonly used in the past, today it's found only in throw or area rugs. Cotton lacks the durability of the other fibers.

By far the majority of carpets manufactured today are made of synthetic fibers.

- *Nylon:* Nylon is the best and the most commonly used man-made fiber because it's longer wearing, more resilient, and more stain resistant than the other synthetics.
- *Acrylic* and *polyester:* These fibers are soft like wool, but they lack the durability of nylon. Also, like wool, they "pill" or ball as they wear. Because of these drawbacks, acrylic and polyester fibers are best used for low traffic areas.
- *Olefin:* A strong, durable synthetic, olefin is highly resistant to water. It's often used for outdoor carpeting and heavy traffic areas. Although olefin isn't as resilient as nylon, it's usually less expensive so it may be a good choice if your budget is limited.

Manufacturers also create blends of synthetic fibers, or synthetic fibers and wool, to take advantage of the strong points of one fiber and compensate for the weaknesses of another.

Amount of Yarn and Twist

Better quality carpets have more yarn in each tuft. Each individual carpet tuft is twisted; the tighter the twist, the longer the carpet will last. The twist gives the carpet its spring, or resilience. As tufts lose their twist, the carpet begins to mat and show traffic wear.

The twist should be easy to see and should be even, tight, and clean, right to the tip. In better carpets the twist is heat-set so it will keep its resilience longer.

Density and Pile

Density refers to the number of tufts or loops. *Pile* is the height of the tufts. Obviously, the more tufts per square inch, the better the carpet. This is a better measure of carpet quality than the face weight. High-density carpet will resist crushing and matting, allowing the carpet to retain its shape longer. A high density also helps keep dirt and stains on the surface where they can be cleaned before they're absorbed into the tufts or backing. To check the density, bend the carpet back. The higher the density, the less backing you'll see. A high pile hides stains and dirt better than a low pile.

Warranty

Manufacturers offer a variety of stain treatments under a variety of names. This can be confusing for consumers. The brand name is less significant than the warranty, which is the true indicator of the carpet's durability. Stain, wear, static, crushing and matting, and general performance warranties may be given. It's important to compare warranties carefully. A good warranty is clearly defined. For instance, if the carpet loses more than 10 percent surface pile, the manufacturer will replace it. Other warranties may be vague, promising to stand behind the product in case of "abnormal performance." They're often full of exceptions, and apply only to the original buyer.

Carpet that comes with less than a five-year stain and wear warranty is probably a poor value. Five- to 10-year warranties are standard in the industry, and some manufacturers offer up to 15-year warranties on their higher-end carpet.

Carpet Padding

Except for carpets that come with foam or cushion backing, all carpets require some kind of padding. The padding adds to the overall cost, of course, but it also adds as much as 50 percent to the life of the carpet. The padding keeps the carpet from slipping, adds insulation, and absorbs noise.

The padding, rather than the carpet itself, cushions up to 90 percent of foot traffic. A medium padding thickness is best. A pad that's too thin will tear, wear, or disintegrate quickly. An extra thick pad, although it feels luxurious, can make walking or balancing more difficult and tiring. Also, a padding that's too thick for the carpet will put too much stress on the carpet backing, and it'll eventually delaminate.

Padding comes in a variety of thicknesses, densities, and materials. Generally, padding will vary from $^1/_4$ inch to $^1/_2$ inch in thickness and from 1 to 3 pounds per cubic foot weight. Although urethane foam is the most common material used, hair or felt, rubberized felt, and sponge rubber are also common.

- *Urethane foam:* Urethane foam is mildew resistant and durable. You can use it in all types of traffic areas. Squeeze urethane foam to test its quality; it should retain at least half its thickness.
- *Hair or felt padding:* Both wear well and give firm support. However, both lack mildew resistance, and are subject to stretching.
- *Rubberized felt:* This has the firm support and long wear qualities of regular felt padding, but because of the rubberized backing, it doesn't stretch. The felt portion, however, is still not mildew resistant.
- *Sponge rubber:* Sponge rubber is best suited for high traffic areas because it's durable and resistant to mildew.

Carpet Labels

Manufacturers and retailers put their labels on the back of their carpet samples. Three typical ones are the mill label, fiber producer label, and backing label. The mill label names the carpet mill, style, construction, and content. The fiber producer label, which is the most important for performance, gives the warranties against stains, dirt, static, and wear. High-quality carpets may also carry a backing label from the manufacturer of the backing.

Carpet is dyed in batches and identified by the lot number in which it was dyed. Because there may be some subtle differences in color between different lots, the supplier should make sure entire jobs come from single dye lots. For small jobs, the supplier may have enough carpet in stock and can deliver it immediately. The larger the job, the more likely it is that you'll need to order through a supplier or directly from a carpet mill in order to get the same dye batch. Typically, you should allow from three to six weeks when ordering. The supplier will be able to give you a more exact time estimate.

Carpet Installation

Carpet can be laid over any kind of subfloor that's clean, dry, and level. If the floor surface is too uneven, put down some underlayment. Otherwise, make sure all the bumps are sanded smooth and all the dips, holes and cracks filled. If the carpet will be installed with adhesive, the subfloor should also be free of wax. Oil-base paint may also interfere with the adhesive, so sand or use an abrasive to rough up a floor surface that's painted.

As with any floor covering, if you lay carpet over concrete, make sure that the concrete is completely cured. The moisture from uncured concrete will rot out some carpet backings and cause mold or mildew in others. Vinyl or asbestos floors may also accumulate moisture when covered with carpet, so check with the carpet supplier before you install over these materials as well.

Figuring Yardage Needed

Carpet generally comes in continuous rolls, 12 feet or 15 feet in width. It's sold by the square yard. To figure out how much yardage you need, use the following formula.

Multiply the length you'll be covering in feet by the width in feet, adding 3 inches to each dimension. Divide this amount by 9 to get the square yardage.

For instance, for a room that's 14 feet by 15 feet:

14'3" × 15'3" = 217.3 sq. ft.
217.3 ÷ by 9 = 24.15 sq. yds.

Allow an extra inch for overlap at the seams. Also, because of the manufacturing process, some carpets, especially those that are rubber backed, may actually be up to an inch less in usable width than the stated width, so add an extra inch to compensate.

The fewer the seams there are in a carpet, the better it will wear. If you must have seams, avoid placing them in high traffic areas. Keep in mind that the carpet pattern and pile, or nap, must always be laid in the same direction. That may mean you'll have to increase the yardage you need. Whenever possible, lay the carpet so that the pile faces *away* from windows. Sunlight shining directly into the carpet pile will cause the carpet to fade.

Figuring the Manhours

A skilled carpet layer can install about 10 square yards of carpet an hour, assuming the room doesn't have extra corners to cut around. For sewing seams, figure about 5 hours a yard. An experienced carpet layer can do about 8 steps an hour when installing carpet on stairs. Of course inexperienced carpet layers will take longer.

Installation Methods

Carpet, or any other floor covering, should be the very last thing installed except for shoe moldings. Doors should be hung before the carpet is installed, but removed during installation. Carpet layers usually take care of removing and replacing the doors.

Most carpet installers don't have a carpentry background. Make sure they remove the doors by pulling the hinge pins and not by removing the screws and hinge. Ideally, you should anticipate the height of the carpet and trim the doors to allow for the carpet before you hang them. In the real world, for a tight-fitting door, chances are you'll have to plane down the bottom of the door a little more after the carpet's in place.

Carpet can be secured in place using one of three different methods, or a combination of these methods:

- white latex adhesive
- pressure-sensitive, double-faced tape
- wooden tack strips

In some areas, you may still hear the term "tackless" strip used for wood tack strips. However, "tack" strip is pretty much the accepted name for these strips now.

Adhesive Method

> ***Tools and Materials***
>
> *You'll need the following for laying carpet with white latex adhesive:*
>
> - *Chalk line*
> - *Straightedge*
> - *Carpet knife*
> - *Linoleum knife*
> - *A $^3/_{32}$-inch notched trowel (follow adhesive manufacturer's recommendations)*
> - *White latex adhesive*
> - *Seam adhesive*
> - *Small paint brush*

You can lay cushion-backed carpet with either adhesive or carpet tape. Carpet tape, although easy to use, doesn't hold as well as adhesive. However, removing carpet that's held down with tape is fairly simple, if that needs to be a consideration.

Use the following as a guide for laying carpet with adhesive:

1. Loose lay the carpet and trim off the excess to within $1^1/_2$ inches of the length and width of the room. Use a carpet knife and make your cuts on the back side of the carpet. You'll trim the edges to an exact fit after the carpet is glued down. To ensure a snug fit at corners, make vertical cuts up from the floor at inside and outside corners.
2. If you'll need a seam, lay the carpet out where the seam is to be, taking care to match the pile direction and patterns exactly. Overlap the edges at the seam by 1 inch. At each end of the top piece of overlapping carpet, measure in 1 inch and snap a chalk line on the carpet between the marks. Repeat for the bottom layer of carpet. Place a straightedge along the line and cut through both pieces with a carpet knife. (Professionals sometimes cut a zigzag line rather than a straight one and then stitch the two pieces together. A zigzag line is nearly invisible. The eye can pick out straight lines, but doesn't follow angles as easily.)
3. Snap a line on the floor where the two pieces will meet. Align the first piece along the seam line. Pull or roll the wall edge side toward the middle of the room. Spread the adhesive according to the manufacturer's directions. Let the adhesive set until it's tacky. The time will vary depending on the adhesive used, but it's usually about 10 to 15 minutes.
4. Slowly unroll the carpet over the adhesive. As you unroll it, smooth out bumps and push out air bubbles. Using your feet, or a 2 × 4 held at a 45-degree angle, move over the entire surface that's been glued. Start from the middle and work toward the walls. Be careful not to let adhesive get onto the carpet fibers that won't be trimmed.
5. Repeat with the other piece. At the seam, spread the adhesive on the back of the piece. Apply seam adhesive to the edges of each piece and push them into place by hand. Again, be careful not to get glue on the carpet fibers.

6. To trim the edges to the walls, use a linoleum knife to crease the carpet along the wall where it meets the floor. Then use a carpet knife and cut along the crease, slanting the blade toward the wall for a snug fit. Finish up by replacing the shoe molding, and installing thresholds at doors.

Tape Method

Keep in mind that although tape makes carpet laying quick and easy, it doesn't make for a durable job. Still, for some situations, tape is ideal because it allows you to easily pull up the carpet and remove the traces of the tape.

Tools and Materials

You'll need the following for laying carpet with carpet tape:

- *Chalk line*
- *Straightedge*
- *Carpet knife*
- *Linoleum knife*
- *2-inch and 5-inch pressure-sensitive, double-faced tape*
- *Seam adhesive*

Laying the Carpet

Use the following as a guide for laying carpet with tape:

1. Lay 2-inch tape along the entire perimeter of the room. For added stability, set diagonal tape strips 1 inch apart across the room. Do not remove the top layer of paper on the tape.
2. Fit the carpet according to the steps just outlined. When the carpet is cut to size, pull one half of the carpet back from the wall and toward the center of the room. Peel the paper off the tape and roll the carpet onto the tape. Press the carpet firmly to the tape.
3. Repeat with the other half of the carpet. Trim the edges, replace shoe moldings, and install the thresholds to finish the job.
4. For seams, use 5-inch tape down the center of the seam. Paint the carpet edge with seam adhesive and press the pieces down onto the tape.

Tack Strip Method

Wooden tack strips are still the most common means of attaching carpet to the floor. They come in 4-foot lengths and have a series of tiny pins sticking up out of them, about $^1/_4$ inch high, which are angled at 60 degrees. Nail the wood strips to the floor around the perimeter of the room with the pins angled toward the wall. The carpet is stretched or "hooked" over the pins to attach it to the strips.

Laying the Carpet

Use the following as a guide for laying carpet with tack strips:

1. Install the tack strips $^1/_4$ inch from the wall around the perimeter of the room. Make sure the pins are facing toward the wall. It's OK to butt the corners.

> ***Tools and Materials***
>
> *You'll need the following for laying carpet with tack strips:*
>
> - *Chalk line*
> - *Straightedge*
> - *Row cutter*
> - *Linoleum knife*
> - *Wooden tack strips*
> - *Hammer and nails*
> - *Padding*
> - *Staple gun*
> - *Utility knife*
> - *Knee kicker (can be rented)*
> - *Power stretcher for large rooms (can be rented)*
> - *Hot-melt tape*
> - *Heat-bond iron (can be rented)*

2. Spread out the padding, laying it up to the edges of the tack strips. Use a utility knife to trim it along the strips. Staple the padding in place to the floor every 6 to 12 inches.
3. Fit the carpet to the room using the steps outlined under the *Adhesive Method*. Cut the back side of cut-pile carpet, using a utility knife. If you're installing loop-pile carpet, trim it face up, using either a utility knife or a row cutter. This way, you avoid accidentally trimming off loops.
4. For rooms that require a seam, cut the carpet as described under the *Adhesive Method*. Turn the carpet pieces face down and butt the seam edges together. Place hot-melt tape over the seam joint, and slowly run the heat-bond iron over it. When the tape is set, turn the carpet face up.
5. Begin securing the carpet to the tack strips at a corner. Using a knee kicker, bump or kick your knee against the pad. At the same time, use your fingers to hook the carpet over the pins on the tack strip. Do another kick or two on each wall in the same corner.
6. Move to an adjacent corner and use the knee or power kicker to attach the carpet as described above. Then do the diagonal corner. With the knee kicker, secure the carpet along the first two walls between the completed corners. Kick the carpet into the final corner, and then secure the two remaining walls.
7. When the entire room is stretched onto the tack strips, trim around the walls. Cut the excess carpet to $^3/_4$ inch. Push the excess down between the tack strip and the baseboard. Install the shoe molding and thresholds.

Installing Carpet on Stairs

Because stairs get such heavy, concentrated traffic, choose the most durable quality carpet that the client can afford. Carpeting a staircase is more involved than carpeting a wide open space, but it's really no more difficult. You cover each riser separately, which makes the process more time consuming. Cutting and placing the pieces for each stair is similar regardless of whether you use cushion-backed or standard carpet. Of course, with the cushion-backed carpet, you should use adhesive or tape instead of tack strips.

To find the amount of carpet and padding you need, measure the height of the riser and the depth of the tread, and add 2 inches. The measurement of the carpet padding will be the depth of the tread, half the height of the riser, and 2 inches. Cut the padding 2 inches narrower than the carpet width.

Laying the Carpet

Use the same materials that you use for laying carpet with tack strips. See the list under *Tools and Materials*. Use the following as a guide for laying carpet on stairs:

1. Nail tack strips $^{1}/_{2}$ inch from the bottom of each riser, pins pointing down. Attach another strip $^{1}/_{2}$ inch from the back of the tread; face the pins toward the riser. Nail tack strips on each side of the tread, $^{1}/_{4}$ inch away from the wall or skirtboard, with pins pointing toward the wall.
2. On each step, place padding against the tack strip at the back of the tread. Staple it in place every 4 inches. Wrap the padding over the tread nosing to the middle of the riser and staple the bottom halfway down the riser.
3. With the carpet pile facing toward the bottom step, secure the first carpet piece to the tack strip at the bottom of the first riser. Stretch it over the nosing and knee kick it over the tack strip at the back of the tread.
4. When you have the carpet secured to the back of the step, use the knee kicker to hook it over the tack strips on each side of the step. Cut the excess carpet to $^{3}/_{4}$ inch. Push the excess down between the tack strip and the skirtboard or wall. Tuck in the excess carpet at the point where the tread and riser meet; trim as needed.

Carpet Repair

Tools and Materials

- *Utility knife*
- *Matching carpet piece*
- *Pressure-sensitive, double-faced tape*
- *Seam adhesive*
- *Small paint brush*

Carpets can sustain many types of damage that require repairs. If you have access to extra pieces of the original carpet, you can usually make the repair with a patch.

Patching Carpet

Use the following as a guide for making patch repairs:

1. Using a metal straightedge, cut out the damaged area. Cut the replacement patch, matching the size, pattern, and pile direction exactly.
2. Place tape into the patch area. If possible, set the tape under the surrounding carpet as well. Paint the carpet edges with seam adhesive. Press the patch into place and weigh it down until the adhesive sets. Check the adhesive manufacturer's instructions for how long to apply pressure. The time will vary by brand.

Carpet Troubleshooting

Advise your clients to keep the carpet label or their dated sales slip with the manufacturer, pattern number, style name, color, and fiber content. That'll make it easier to repair or replace sections of carpet if the need ever arises. Figure 3 covers common carpet problems, their causes and solutions.

Carpet Maintenance

The vacuum is a carpet's best friend because dirt is its worst enemy. Light vacuuming (three passes of the machine) twice a week and a thorough vacuuming (seven passes) once a week will add years to the life of the carpet. In addition, shampooing the carpet every one to three years will also keep it looking its best.

Carpet Cleaning

There are four common methods of deep cleaning carpets:

- *Foam spray* — For light, spot cleaning only. Spray on and scrub in with a sponge. Let carpet dry, then vacuum.
- *"Dry" powder* — For light to medium soiled areas. Hand or power-brush powder into carpet. The powder has a cleaning solvent in it that releases the dirt from the carpet and then evaporates. Vacuum up the residue. For spot cleaning, powders are the most efficient method. Although they can certainly be used for an entire carpet, wet shampooing or steaming will be more thorough.
- *Wet shampoo* — May be used to clean large areas of carpet. Rent a powered rotary-brush carpet cleaner that uses shampoo and water to scrub the carpet. The biggest drawback for wet shampooing is that it can leave too much water and detergent residue in the carpet. It may also damage plush carpets because it's difficult to completely draw out all the water. In damp climates, this can cause mildewing which can break down the carpet backing. Use this method only as a last option.
- *Steam* — May be used for large areas or entire carpet. The steam equipment pressures the detergent deep into the carpet pile for a thorough cleaning, while at the same time, a vacuum sucks up dirt and water. This is a slower process than a wet shampoo, and you must be careful not to get too much water in the carpet. However, if done correctly, steam cleaning is the best choice for a thorough job.

Problem	Causes	Solution
Buckling, puckering	Moisture between carpet and subfloor either from high humidity or moisture in subfloor; poor quality foam or rubber padding; or carpet inadequately stretched when first installed.	Restretch the carpet with a power stretcher, not with knee kicker.
Burns	Usually cigarettes.	Use a curved fingernail scissors to trim burned fibers; clean with soapless cleaner and sponge with water. If the burn is too large or in low pile carpet, it may need to be patched.
Corn-rowing	Long pile yarns tend to separate into rows, especially in heavy traffic areas or if carpet is always vacuumed in the same direction.	Change direction of vacuum strokes; use a grooming tool, such as a carpet rake, and vacuum with a beater bar.
Pressure indentations	Heavy furniture left in one place for a long time.	Hold steam iron a few inches above the dent (***never put an iron directly on carpet fibers***), gently brushing fibers up with your fingers as you steam.
Fading	Dirt; high humidity and temperature; too much sunlight.	Vacuum frequently; change air filters in heating and air conditioning systems; use window coverings to block direct sunlight.
Footprints	Problem is common with deep-cut pile carpet.	The only solution is to install carpet with lower pile.
Fuzzing	Common in older loop pile carpet; dirt makes problem worse.	Trim fuzzy fibers; vacuum more often.
Odors	New carpet and padding may have an odor.	Odors should disappear several weeks after installation; provide good ventilation; frequent vacuuming will speed process.
Pile crushing	Heavy traffic.	Use vacuum beater-brush or pile groomer and vacuum against the crush.
Pilling (small balls of fiber and lint)	Some carpet fibers are prone to pilling; condition is made worse by heavy traffic.	Trim with scissors.
Shading	Light reflecting differently off the tips of the tufts than the sides.	No permanent solution; this is part of the design of the carpet. Vacuum so the pile all goes in one direction to temporarily even out the shading and make the carpet appear the same color all over. Any disruption in the surface, such as walking on it, will bring shading back.
Shedding	Normal for new carpet, particularly wool.	Vacuuming will pick up excess; eventually carpet will stop shedding.
Snags	Sharp objects or furniture catching loops.	***Do not pull***; trim short snags; long ones may need to be retufted or reglued by a professional.
Sprouting (tufts that stick up)	Occasional tufts not cut level with nap; more common with new carpet.	Clip off with a scissors; ***do not pull***.
Stains	Many and varied; most common are spills and pets.	Immediately clean up as much of the spill as possible while fresh; refer to the section on Stain Removal, page 120 for specific types of stains.
Static	Low humidity.	Use a humidifier; when buying new carpeting, look for anti-static protection.

Figure 3
Common carpet problems and solutions

- *Dry chemical* — This is a soap-free cleaning process, much like spot cleaning, but on a larger scale. The biodegradable chemicals, which are sprayed into the carpet, bubble the dirt up to the surface where the chemicals and dirt can be vacuumed up. Because far less water is used than with wet shampooing or steaming, there's less chance of damaging the carpet backing. Also, because the process doesn't use soap, no residue is left to attract more dirt, allowing the carpet to stay clean longer.

Regardless of the method you use, test the carpet in an inconspicuous location first to make sure the fiber is colorfast. Make sure you completely remove all the detergent from the carpet or it'll actually trap more dirt in the future. And finally, don't get the carpet too wet because excess water remaining in the carpet can cause mildew, damage the backing, or even break down the subfloor.

Removing Stains and Spots

You may have to tackle carpet stains whether you're working in new construction or remodeling. The stains can be on old carpeting, or brand new carpet that you just installed. Either way, knowing how to remove stains will save either you or the homeowner the cost of replacing an otherwise good carpet. Try the following cleaning methods first. If the stain is old or stubborn, you may have to call in a professional carpet cleaner.

Basic Cleaning

1. Remove as much of the spill as possible. Always scrape or blot from the outside toward the center to avoid spreading the stain.
2. Using warm water and a clean white cloth or paper towel (never a printed towel), blot up the excess liquid. DO NOT RUB! Continue until no more stain shows on the towel.
3. If the stain remains, make a solution of 1 teaspoon non-bleach liquid laundry detergent to 1 quart water and apply it to the stain. Let it set for five minutes, and repeat step 2 until the water and detergent are both removed.
4. Place a $^1/_2$-inch stack of clean white paper towels on the spot. Weigh the towels down on the spot and leave them overnight to absorb any remaining liquid.
5. Vacuum when dry, then brush the pile to match surrounding carpet.

Stain Removal

Method A —

Follow *Basic Cleaning* steps 1 through 5 listed above.

Use for the following stains:

Beer	Ice cream
Candy (sugar)	Mayonnaise
Chalk (vacuum first)	Milk
Chocolate	Mud (vacuum first)
Dirt or clay (vacuum first)	Wine (white)
Glue (white)	

Method B —

1. Follow *Basic Cleaning* steps 1 and 2.
2. Apply dry cleaning fluid with a dry towel. Blot, don't rub. Repeat this step as needed.
3. Follow *Basic Cleaning* step 4.

Use for the following stains:

Asphalt	Hand lotion
Ballpoint ink	Linseed oil
Butter	Machine oil
Cooking oil	Mascara
Felt-tip pen	Paint (latex, oil)
Foundation makeup	Petroleum jelly
Furniture polish	Shoe polish (paste)
Gravy	Tar
Hair oil	Typewriter ribbon
Hair spray	Wax (paste)

Method C —

1. Follow *Basic Cleaning* steps 1 through 5.
2. If the stain remains, mix 1 teaspoon of household ammonia with $^1/_2$ cup of 3 percent hydrogen peroxide. Apply to stain and cover with plastic wrap. Let stand two to three hours. Repeat this step as needed.
3. Follow *Basic Cleaning* step 2 then 5.
4. After the stain is removed, blot with white vinegar.

Use for the following stains:

Berries	Lemonade
Blood (use cold liquids)	Mercurochrome
Catsup	Mixed drinks (alcoholic)
Coffee	Mustard (allow to dry first)
Dyes (blue, black, green, red)	Pet foods
Fruit drinks	Soft drinks
Fruit juice	Tea
Kool-Aid	Toothpaste

Miscellaneous Stains —

Candle wax:

1. Scrape off excess. Cover with a clean brown paper bag. Iron over bag with warm iron until wax is absorbed by bag. Change bag to clean area as needed. DO NOT let iron touch carpet fiber.
2. Follow Method B.

Chewing gum:

1. Pull or scrape up excess. Use an ice cube to freeze remaining gum. Shatter with a blunt object, then vacuum up the pieces.
2. Follow with Method B.

Urine/feces:

1. Follow *Basic Cleaning* steps 1 through 3.
2. Apply a solution of 2 tablespoons white vinegar mixed in 1 quart water. Blot with clean paper towels.
3. Follow *Basic Cleaning* steps 3 through 5.

Vomit:

1. Follow Method A, then Method C.

Manhours

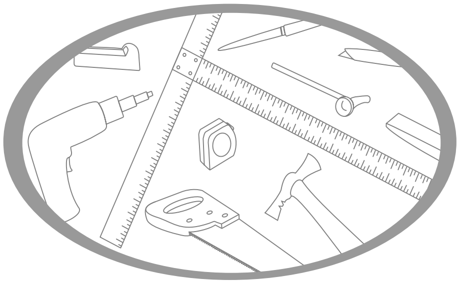
Manhours to Install Carpet			
Item	**Unit**	**Manhours**	**Suggested Crew**
Carpet, with pad/tack strips and hot melt seams	SY	.143	1 floorlayer
Carpet, glue-down	SY	.143	1 floorlayer
Box steps, per riser	Each	.088	1 floorlayer
Wrapped steps, open riser, per step	Each	.152	1 floorlayer
Sewn edge treatment, per riser	Each	.143	1 floorlayer
Circular steps, per step	Each	.327	1 floorlayer

For more information on related topics, see:

Adhesives, page 25

Floor Framing, page 299

Flooring, page 359



Ceramic Tile

Tile is an ancient building material that's both practical and decorative. The Babylonians and Sumerians used beautifully glazed tiles 5000 years ago, both to add color and design and to protect the sun-dried bricks with which they built their temples and palaces. Today, tile is still used to dress up a structure as well as guard against the damage caused by moisture and sun.

Porosity

Ceramic tile is generally classified into four categories by its porosity, or the amount of water it will absorb.

Impervious tile is the densest and, therefore, the least porous. It absorbs less than 0.05 percent of its own weight in moisture, making it ideal for exposure to weather. You can use it for any exterior use such as walks or patios. Impervious tile usually has to be special ordered.

Vitreous tile will absorb less than 3 percent of its own weight in moisture, making it the least porous of the common tiles. It's suitable for exterior and interior uses. Typically, vitreous tiles are used for lining pools and basins because of their low porosity.

Semivitreous tile absorbs from 3 to 7 percent of its own weight in moisture. It can tolerate freezing and thawing conditions and may be used for interior (bath or shower walls) or exterior purposes (walks or patios).

Nonvitreous tile is the most porous of the tiles. It will absorb over 7 percent of its weight in moisture. This makes it unsuitable for exterior use, but you can use it for walls, floors and countertops.

Keep in mind that even with vitreous tile, water can sometimes seep through the grout and cause problems in the backing. For kitchens and baths you need to use a water-resistant backing like greenboard or cement-based backer board finished with a water-resistant joint compound. (See *Drywall*.) Greenboard is designed to prevent moisture absorption even when the board is torn. Another option is to trowel on a waterproof membrane before spreading the bonding material.

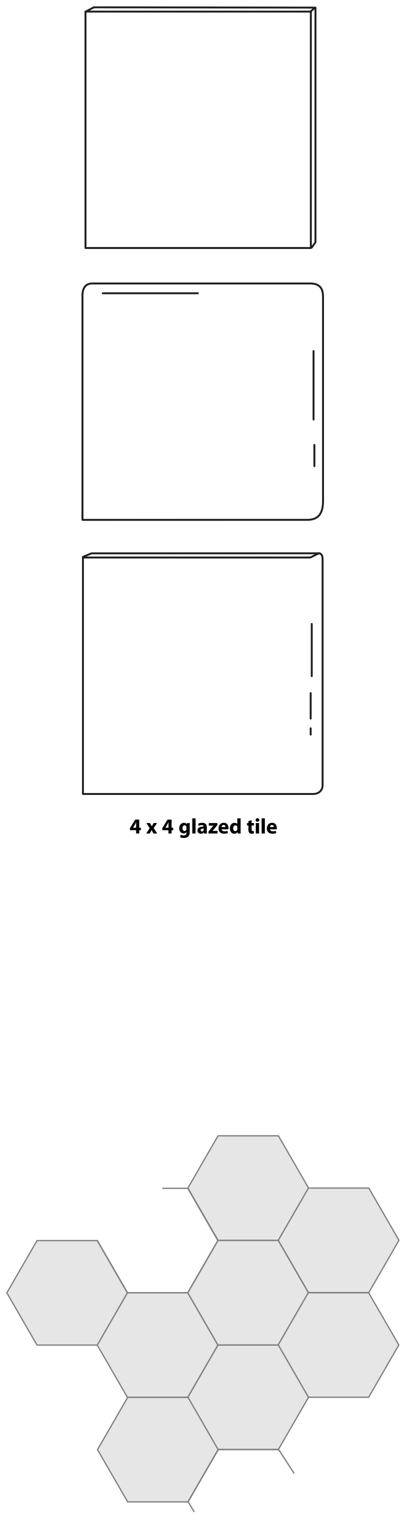


Figure 1
Typical glazed tile

Glaze

The glaze, or finish, on tile varies from a highly reflective glaze to a matte glaze with little or no sheen. Like the porosity, the glaze affects whether or not a tile can be used for exterior purposes. And the glaze may be glass smooth, rippled, textured, mottled or some other pattern, including some that imitate other surfaces, like marble or granite.

Durability

Glazed tile falls into one of four classifications according to its durability, particularly in terms of wear and abrasion resistance.

- *Group 1, Very Light Stress:* Use these tiles only in light traffic areas such as bedrooms and bathrooms, where soft shoes are worn and where there aren't rough contaminants.
- *Group 2, Light Stress:* Use in areas of light traffic where normal shoes are worn and where there may be small amounts of rough contaminants. Dining rooms, living rooms, and kitchens generally fall into this group.
- *Group 3, Medium Stress:* Use in medium traffic areas where there may be rough contaminants and normal shoe use, such as hallways or entryways.
- *Group 4, Medium-Heavy Stress:* Tile in this group will tolerate frequent traffic, normal contaminants, and normal shoes. Stairs and most commercial uses, such as schools, restaurants, and offices, require this category.

Traffic areas like garages and supermarkets that are subjected to the most wear are best covered in unglazed, vitreous tile.

Size and Shape

In addition to porosity, finish, and durability, tile is also categorized by size and use. They range from mosaic (1 inch square) to pavers (12 inches square). The two most common shapes are square and hexagonal. Most tile is also available with end and corner pieces that are glazed on the exposed edges. See Figure 1.

The smaller tiles really aren't any more difficult to lay than large ones because they come attached to a sheet of paper, or scrim, usually in 1-foot squares. Face-mounted tiles, which come with paper, are set and then the paper is removed before grouting. Back-mounted tile has either perforated paper, fiber mesh, or resin that becomes part of the tile installation system (Figure 2).

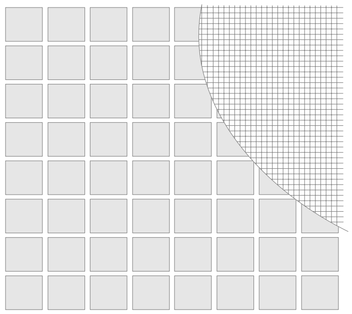


Figure 2
Mosaic tile with sheet backing

Mortars and Mastics

Tile can be secured in place with a variety of mortars and mastics, which are called *bonding* or *setting* materials. Figure 3 is a chart that shows the advantages and disadvantages of common mortars and mastics.

Generally, when quality is a concern, mortars are better than mastics. They're stronger and hold up better to prolonged exposure to water or heat. The word adhesive is often used to mean either mortar or mastic. Technically, though, adhesive refers to additives in the mortar or mastic.

Type	Method	Primary uses	Suitable backings	Waterproof?	Advantages	Disadvantages
Portland cement mortar	Thick bed: 3/4-1" on walls, 1 1/4" on floors	Walls and floors	Masonry, concrete, wood or steel stud frame, rough wood floors, plywood floors, foam insulation board, drywall, plaster	Yes	The thick bed allows for plumbing and squaring surfaces; high structural strength	More difficult to apply; absorptive tile set on plastic mortar bed must be soaked
Dry-set mortar (thin-set)	Thin bed: 3/32"	Walls and floors	Masonry, drywall, glass mesh mortar units, cured portland cement mortar beds, ceramic tile, dimensional stone	Yes; but doesn't form a water barrier	Easy to use; water-cleanable, non-flammable, good for exterior work	Doesn't allow for plumbing and squaring of surfaces
Latex-portland cement mortar	Thin-set	Walls and floors	Similar to dry-set mortar	No	Less rigid than portland cement mortar	For areas exposed to constant moisture (swimming pools, showers, etc.), needs to dry 14 to 60 days, depending on climate and whether tile is indoors or outdoors
Epoxy mortar	Thin-set	Floors	Concrete, wood, plywood, steel plate, ceramic tile	No	High bond strength, high impact resistance, high chemical resistance; high temperature resistance available	More expensive; shorter open time; heat cured, which reduces workability in warm weather
Furan mortar	Thin-set	Floors	Concrete, wood, plywood, steel plate, ceramic tile	No	High chemical resistance, quick setting	Higher cost; difficult to use
Epoxy mastic (epoxy adhesive)	Thin-set	Floors, walls, and counters	Plywood, drywall	No	Easy to apply; has high bond strength	Not as resistant to chemicals or solvents as epoxy mortar
Organic mastic (organic adhesive)	Thin-set	Floors, walls, and counters	Dry areas: drywall, plaster, portland cement mortar, concrete, masonry Wet areas: portland cement mortar, concrete, masonry, and for walls, greenboard	No	Flexibility	Bond strength varies from one manufacturer to another; some are flammable; not suitable for exterior use or swimming pools; low chemical and solvent resistance

Figure 3
Mortar and mastic chart

Portland cement mortar is the conventional way to lay tile. It includes cement, sand and sometimes lime, mixed in these ratios:

- Floors — 1:6
- Walls — from 1:5:$^1/_2$ to 1:7:1

Lime increases the workability of the mortar and makes it stickier. However, it also decreases the mortar's strength. When laying floor tile, you don't need the stickiness because the tiles stay in place. For tiling walls, the stickiness helps hold the tiles in place as you're laying them.

Portland cement mortar can be tricky for a novice to use. It's easier to use dry-set, or *thinset* as it's also called, or organic mastics. Mortars require mixing and have a short pot life (the length of time a material is usable after mixing). The portland cement mortars are spread in a thick bed that's $^3/_4$ to 1$^1/_4$ inch deep. The thinset mortars are applied only $^1/_{32}$ to $^1/_8$ inch thick. Mastics are solvent- or latex-based and come premixed.

As with any bonding material, both mortar and mastics work best in conditions that are neither too cold nor too hot. For both, the temperature should be at least 50 degrees, but ideal temperatures are probably between 70 and 85 degrees. If the surface is too cold, the mortar or mastic will take a lot longer to set. If it's too hot, they'll set too quickly.

Grout

Grout is used to fill in the exposed spaces between tiles or pavers. You can also add to the overall design of the tile work by coordinating or contrasting the grout and tile colors.

Grout comes in a variety of materials. Portland cement is the most common, often with additives to give it increased flexibility, uniformity, hardness, mildew resistance and whiteness. If you mix your own cement grout, use the following ratios of cement to sand:

- Joints up to $^1/_8$ inch wide: 1:1
- Joints up to $^1/_2$ inch wide: 1:2
- Joints over $^1/_2$ inch wide: 1:3

To increase the workability of the mortar, you can add up to $^1/_5$ part lime.

Don't bother to mix your own, though, unless you have a large area to grout. Although it's more expensive, it's also a lot easier to buy a powdered mix, which only requires you to add water and mix. Directions will vary depending on the mix and the manufacturer. Follow them carefully. There are also two general rules to follow. First, be careful not to add too much water, which will weaken the grout. Second, don't overmix. You may end up with too much air in the grout, which also weakens the bond. The pot life of the grout varies by product. Check the pot life on the label, and mix only what you can use in that amount of time. Stir it periodically to extend the usable time. You can't add water to (or *retemper*) grout, so if it begins to harden, toss it out.

There are other bases you can use for special requirements, such as a high tolerance to chemical and temperature ranges. But epoxy, furan and silicone rubber are more difficult to apply and are more expensive than portland-cement based grout. Check Figure 4 for the advantages and disadvantages of different kinds of grout.

Whenever you use a grout with sand in it, use a rubber-faced trowel to avoid scratching the tiles' surface. And use caulk rather than grout to seal any place that tile meets another surface.

Because grout is a cementitious material, it cures and hardens as it hydrates. The slower the grout loses moisture, the stronger the bond will be. When you grout in hot weather, rapid moisture loss can pose problems. Ideally, the temperature should be between 50 and 70 degrees. This isn't always realistic, though. To prevent, or at least minimize, these problems you can follow a few precautions:

Type	Uses	Waterproof?	Tile must be soaked?	Damp curing necessary?	Exterior use?	Stain resistance	Crack resistance	Advantages	Disadvantages
Commercial portland cement grout	Glazed wall tile, ceramic mosaics, quarry & paver tile	Yes	Yes	Yes	Yes	Low	Low	Takes color additives	Poor stain resistance; requires 72 hours damp curing
Sand-portland cement	Ceramic mosaics, quarry & paver tile	Yes	No	Yes	Yes	Very low	Very low	Inexpensive	Must be mixed accurately
Dry-set	Glazed wall tile, ceramic mosaics	Yes	No (except in very dry conditions)	No, but may result in greater strength	Yes	Low	Low	Easy to work with	Requires 72 hours damp curing
Latex-portland cement	Glazed wall tile, ceramic mosaics, quarry & paver tile	Yes	Yes	Yes	Yes*	Very good	Average	Latex adds workability to grout; easier to spread; cures faster	Requires special cleaning procedures and materials
Epoxy	Ceramic mosaics, quarry & paver tile	Yes	No	No	Yes*	Excellent	Very good	Has excellent chemical resistant properties; resists heat up to 140º F.	Higher cost; requires special skills to install
Furan	Quarry & paver tile	Yes	No	No	Yes*	Excellent	Average	Has excellent chemical resistant properties; resists heat up to 350º F.	Higher cost; requires special skills to install; available only in black

** Check manufacturer's instructions.*

Figure 4
Grout chart

- Latex admixtures retain moisture and slow the cure time. At an added 3 to 5 cents per square foot, they're well worth the extra cost.
- Keep the unmixed grout and the water for mixing in a cool spot. Use ice water to mix the grout, and then keep the mixture in a shady spot.
- Dampen the tile before grouting, and keep it wet while you work. This will also make cleanup easier.
- After grouting, cover the tile with kraft paper to slow the cure, especially if the tile is in the sun. Don't use polyethylene. Although it will keep the moisture in longer, it can cause the grout to spot. Keep the tile covered for three days.
- If it's not possible to cover the tile, mist the grout several times a day according to the manufacturer's directions.

Tile Backerboard

Because wood expands and contracts, tile shouldn't be installed directly over plywood. Often, the solution is simply to install drywall over the plywood and lay the tile on the drywall. But problems arise when you're laying the tile in a wet area like a shower or an exterior that's exposed to the weather. To resolve this, many contractors use a cementitious backerboard such as *Wonderboard* or *Durock*. Backerboard adds strength and stability to interior and exterior walls, floors and ceilings, much like drywall.

Unlike drywall, though, backerboard won't crumble or buckle when wet. It isn't, however, a water barrier. If you use it in a wet area and the substrate behind the backerboard can't tolerate moisture, you'll have to also use a moisture barrier, such as Tyvek, or waterproof membrane between the backerboard and the substrate.

Another advantage to using backerboard is that it's fire rated. Use the following as a general guideline:

- *1-hour wall (load bearing):* 20-gauge 3$^5/_8$-inch steel studs with $^7/_{16}$-inch backerboard on one side and one layer of $^5/_8$-inch Type X drywall on the other side. Place mineral fiber insulation batts in between studs.

  2- × 4-inch wood studs with $^7/_{16}$-inch backerboard covered with ceramic tile on one side and one layer of Type X drywall on the other side. Place mineral fiber insulation batts in between studs.
- *2-hour wall (nonbearing):* 20-gauge 3$^5/_8$-inch steel studs with $^7/_{16}$-inch backerboard covered with $^5/_{16}$-inch ceramic tile set in $^3/_{32}$-inch thinset mortar on one side and two layers of $^5/_8$-inch Type X drywall on the other side. Place mineral fiber insulation batts in between studs. (See Fire rating under *Drywall*, page 243.)

Backerboard generally comes in 3-foot widths, and lengths from 4 to 8 feet. It ranges in thickness from $^1/_4$ inch for flooring underlayment to $^7/_{16}$ inch or $^1/_2$ inch for walls and ceilings. The size availability varies with the manufacturer.

Tools

- *Circular saw with carbide blade*
- *Utility knife*
- *Straightedge*
- *Measuring tape*

Cutting Backerboard

Use the following guidelines to make your cuts:

1. For long cuts, use a circular saw.
2. Make smaller cuts with a utility knife and a straightedge. Score through the fiberglass mesh on one side of the panel. With your knee or a piece of wood as a brace, snap the backerboard at the scored line. Cut through the mesh on the opposite side.
3. For cutouts and holes, score through the mesh on both sides of the panel. Punch out the hole with a hammer. If necessary, smooth up the rough edges with a rasp or file. You can also use a homemade rasp made by sandwiching a scrap of backerboard between two pieces of wood.

Tools and Materials

- *$^3/_4$-inch round counter-sunk stainless steel washers over screws or nails for use at all joints that abut a framing member*
- *$1^1/_2$-inch galvanized roofing nails or $1^1/_4$-inch screws (Hi-Lo, Rock-On) for wood framing or plywood*
- *$1^1/_4$-inch screws (Hi-Lo, Rock-On, S-12) for steel framing*
- *Hammer*
- *Screwdriver*
- *Thinset mortar (exterior or interior), latex-portland cement mortar (exterior or interior), or organic mastic (interior walls)*
- *2-inch fiberglass mesh tape*
- *Trowel*

Installing Backerboard

Install backerboard only when the temperature is above 40 degrees, and be sure the temperature is at least 50 degrees when you apply mortar.

Installation

1. Place backerboard against the studs, which should be spaced no further than 16 inches on center. The smooth side should face out if you're using a mastic. For thinset mortar, place the textured side out. Leave $^1/_8$-inch to $^3/_{16}$-inch spacing between horizontal and vertical joints and corners. Leave the same amount of space where the backerboard butts up against a dissimilar material.
2. Secure the backerboard with nails or screws, spacing the fasteners no more than 8 inches on center. Place the perimeter fasteners within $^1/_2$ inch to 2 inches of the edge. Set all heads flush.
3. Fill the gaps with whatever bonding material you're using, thinset mortar or mastic. You don't need to tape floors and countertops beyond this point — they're ready for mortar and tile. You do need to tape joints and corners on walls and ceilings. Apply a thin skim coat to the joints and corners. As you work, embed fiberglass mesh tape in the mortar or mastic. If you're using like materials (mastic on mastic or mortar on mortar), you don't need to let the material dry before tackling the next step. If you're changing materials, let the first layer dry before proceeding.

Ceramic Tile Installation

For the most durable results, tile work requires adequate preparation each step of the way. The first layer is the base, or substrate. It must be suitable and correctly prepared. The second layer is the setting or bonding material of mortar or mastic, which cements the tile to the substrate. The third step is the grout after the tile is set in place. And finally, if necessary, the tile may be sealed to further protect the finish.

A team of two tile setters can install about 30 square feet of ceramic floor tile in mortar in about an hour. Adhesive-backed tile goes a little faster. Walls take a bit longer; figure about 20 square feet for conventional mortar-based tile.

Laying ceramic tile countertops takes considerably longer since there's a lot more fitting and cutting. Two tile setters can lay roughly 4 to 5 square feet an hour.

Substrate

The substrate is a complicated piece of the system. If it's not installed correctly or you've used the wrong material for the job, the grout will crack and the tiles may loosen. For specific details, consult with the architect or, at the very least, the tile supplier.

Install tile only over a smooth, flat surface. Concrete, cement board, mortar bed, drywall, or even a previously-tiled surface all make a good base for tile. The surface must be free of dirt, loose paint, wax, grease, or anything that may prevent the bonding material from sticking to the surface. Don't try to tile over wallpaper. It will loosen and come down in entire sheets (tile and all). Tightly fasten anything that might eventually separate from the wall, such as paneling or loose tile, before installing tile over it.

Ideally, to prevent cracks in the grout, you shouldn't lay tile directly over wood without first installing a waterproofing membrane. Waterproofing membranes can be a flexible sheet, which serves as just a waterproof system. Or you can use a liquid/paste that you trowel on. Some of them work as both a waterproof system and a setting bed. Glass mesh, such as Wonderboard, is also sometimes used as a backing or underlayment over plywood. When necessary, tile can be installed over a double-wood subfloor. But you should leave $^1/_4$ inch gaps between sheets of the top layer to allow for expansion and contraction. For added insurance, don't lay tile over a wood subfloor and underlayment that, combined, are less than $1^1/_4$ inch thick.

Likewise, don't install tile over vinyl without covering it first with a rigid underlayment such as cementboard. Vinyl doesn't easily absorb adhesive, and it may have enough give in it that cracks will occur.

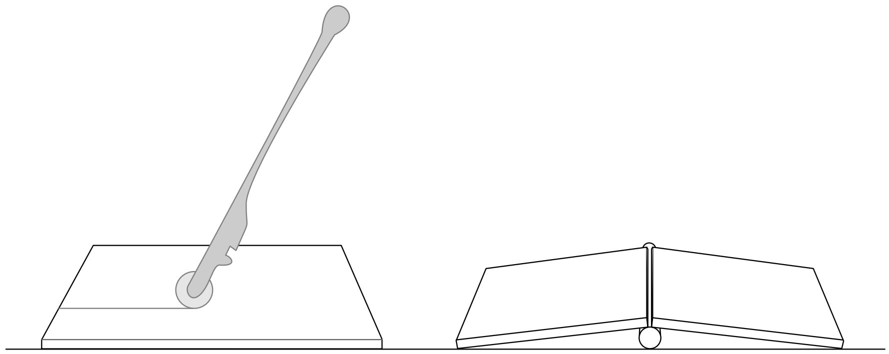


Figure 5
Cutting tile by scoring with a glass cutter

Existing concrete surfaces in meat processing or cooking areas need special cleaning and preparation before you can install thinset tile. Oil and grease affect the bond, so they need to be neutralized first.

Cutting Tile

As a rule of thumb, always cut with the glazed surface up. If the back side has ridges, cut with the grain, not across it. Smooth the rough edges with 80-grit carbide sandpaper or with a tile rubbing stone like Carborundum. The real key, of course, is to practice on scraps until you get the hang of doing it.

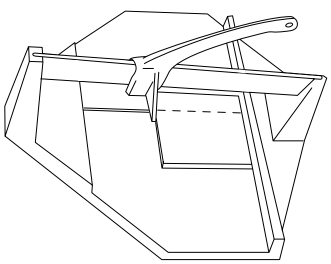


Figure 6
Tile cutter used to score and break tile

Straight Lines

Glass cutter: A glass cutter is quick and easy for small jobs (Figure 5). Mark the tile with a sharp crayon or pencil. Using a straightedge, score the tile's face with the glass cutter. To break, place the tile over a finishing nail and press evenly on both sides of the tile.

Tile cutter: A tile cutter is nice to have for cutting large amounts of tile. See Figure 6. Tile suppliers will often loan or rent cutters. Align and secure the tile in place; then pull the cutter across the surface. Press the handle to break the tile. Consider buying a tile cutter if you do many tile jobs. A good tile cutter costs several hundred dollars.

Tile nippers or *biters:* If you have a long, narrow strip to cut off, score it first; then nibble off the pieces with nippers (Figure 7).

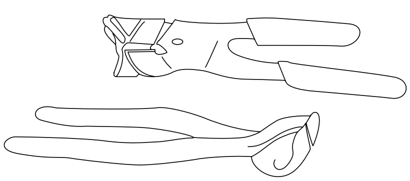


Figure 7
Tile nippers

Curves and Shapes

Tile nippers or *biters:* Use tile nippers to cut shapes or curves. Mark the line to be cut, and then use a glass cutter to cut out the largest chunk you can. Then nibble off small pieces with the tile nippers to make the desired shape, with the straight edge on the glazed side. Don't try to bite out too much at one time, or the tile will chip or break.

Work from both outside corners toward the center rather than from a single corner to the middle. This takes some skill, and maybe a bit of luck sometimes. Be sure you have a few spare tiles on hand.

Rod blade: Another option for curves is to use an abrasive rod on a coping saw or a hacksaw. Protect the tile between two pieces of wood, and secure it in a vise before cutting.

Holes

Carbide bit: Gently score the starting point for the hole. Place a ring of plumber's putty around the starting point, and put water in the ring. Carefully drill, keeping the spot wet as you work.

Tile Layout

In large areas, the tile will look best if the border tiles are the same width, with none of them less than half a width. To do this, either use graph paper to plot the layout, or plan it directly on the floor or wall. Begin by finding the center of the length and width of the room (or height and width of the wall). Snap a chalk line for each so the lines intersect at a 90-degree angle (Figure 8). If a door, fireplace, or window is the focal point, you can use that as the center point. Then position the tiles as noted below in Figure 9.

- Length and width are both even: place point A at center
- Length and width are both odd: place point B at center
- Length only is odd: place point C at center
- Width only is odd: place point D at center

Snap a chalk line or mark with a pencil to plot the layout lines where the tiles will line up.

In small spaces where the borders are clearly visible, begin flush with the most obvious corner and work out.

For a bathroom, begin with the bath or shower enclosure. Allow $^1/_4$ inch plus the height of the tile above the bath, and snap a chalk line. That $^1/_4$ inch allows room to caulk the area where the tile meets the tub. Begin laying tile in the corner that's most visible, working up and out. Use this horizontal line as your reference point for the rest of the bathroom, which means you'll almost certainly have to trim tiles at the opposite wall. But visually, the tile line will be consistent throughout the room. If you'll end up with a very thin row of tile, consider spacing the tiles slightly further apart. A few rows with very slightly wider grouting probably won't be noticeable. Just don't wait until you're three rows away before deciding to use this trick.

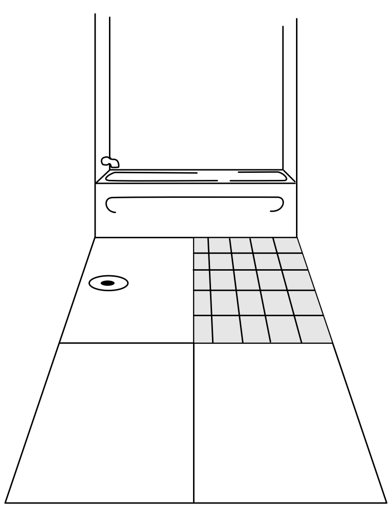


Figure 8
Layout with centerlines

Two common patterns are the jack-on-jack and the running bond, or broken joint (Figure 10).

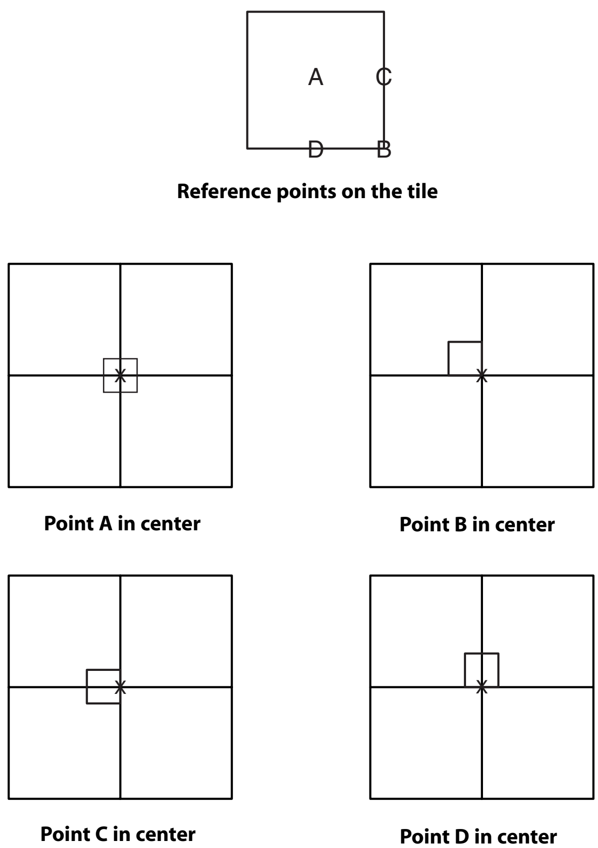


Figure 9
Ceramic tile layout

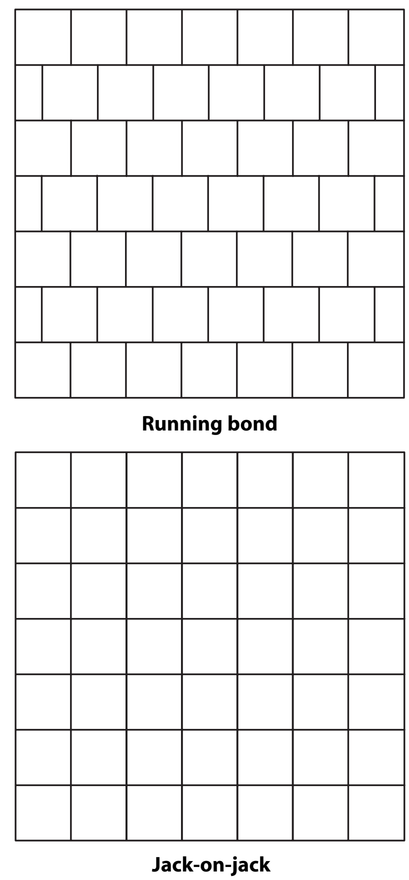


Figure 10
Tile patterns

Setting the Tiles

Don't try to work in too large an area at once. For the novice, a 3 × 3 foot area, or what you can tile in about 15 minutes, is a good size to start with. If the setting material develops a skin, use the notched trowel to rework it. If it dries out and loses its stickiness, you'll have to remove it and put a fresh coat down.

Remember that both mortar and mastic have a short pot life. You don't want to be scrambling around for tools or cutting tiles after you've mixed your bonding material. Wait to mix it until the substrate is completely ready and marked off, all of your tools are in place, and you have any needed tiles cut to size. Then you can mix the mortar or open the mastic and begin working.

Using the right trowel notch size will ensure better coverage for adhesives. (See Figure 11.) Which trowel you use depends on the thickness of the tile you're setting. The notches should leave ridges about two-thirds the thickness of the tile.

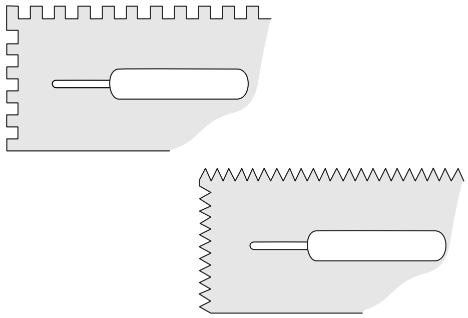


Figure 11
Notched trowels for spreading mastic

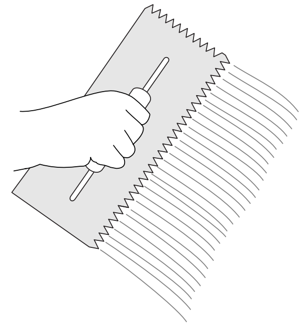


Figure 12
Using a notched trowel to spread tile mastic

Tools and Materials

- *Tape measure*
- *Chalk line*
- *Jury stick*
- *Level*
- *Cutting tools*
- *Spacers (or 6d nails)*
- *Trowels*
- *Tile beater*
- *Rubber mallet*

Tools You Can Make

A jury stick and a tile beater are two tools that are handy for installing tile; both are easy to make.

- *The jury stick is a handy measuring method. Measure and mark along the stick where each new row of tiles should go; this of course includes the tile height and the mortar.*
- *The tile beater is used to level up tiles in the setting material. Make one by covering a 2 x 4 with a firm but soft padding such as carpet or newspapers and a* towel.

Tilesetting

1. Spread the setting material with the flat side of the trowel held at a 35- to 40-degree angle. Work it in all directions. Go back over it with the notched side (Figure 12). Make sure the entire area is evenly covered, but don't spread the mortar or mastic beyond the layout lines for the grid you're working in.

2. Press the tiles into place. Twist them slightly as you set them, but don't slide them into place. If excess setting material squeezes up between tiles, wipe it away immediately with a wet sponge. Also, clean out a groove for the grout to go in later. Because this is a tedious job, do yourself a favor. Use a trowel with small enough notches to minimize the problem. Some pieces you may have to *back-butter* (spread the setting material on the piece itself).

3. Check each tile to make sure it's level and spaced correctly. Use the jury stick as a guide, adjusting tiles immediately if needed. Place spacers or 6d nails between rows as needed to keep the tiles evenly spaced (Figure 13). Occasionally, lift up a placed tile to make sure it's completely and evenly coated with setting material. Level tiles with the tile beater.

4. With a wet sponge, carefully clean excess mortar or mastic as you go. When finished, wash your tools immediately according to the manufacturer's instructions.

5. Allow the tile to cure according to the manufacturer's instructions, wetting and covering as directed. Mortars usually require a minimum of 24 to 72 hours. For wet areas such as swimming pools and showers, the recommended curing time may be as long as 28 to 60 days. Some mastics cure in as little as two hours.

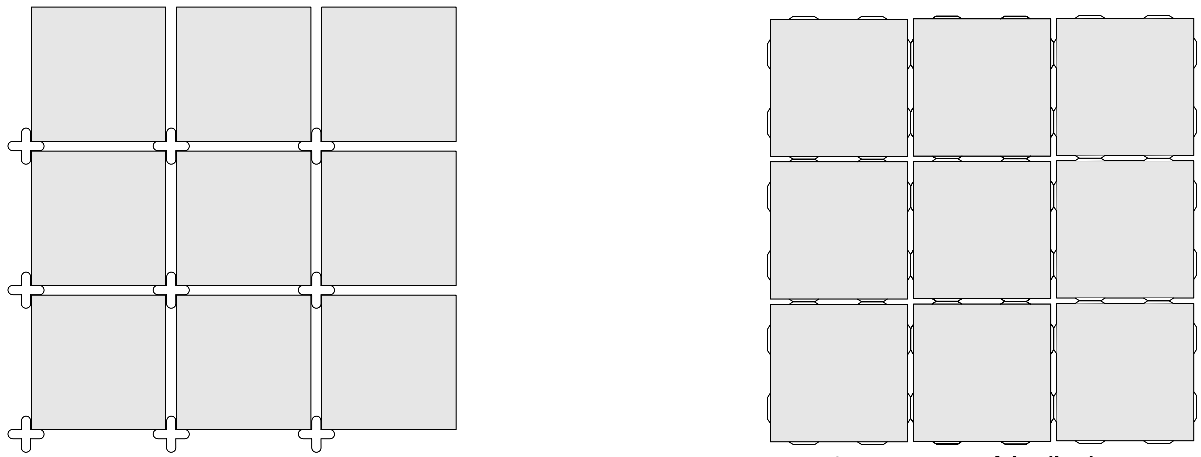


Figure 13
Tile spacers

Grouting Tiles

1. Remove the spacers between tiles. Dampen the tiles with clean water and a sponge. Highly-porous tiles need extra water in the joints to keep them from drawing the moisture out of the cement in the grout, weakening the bond.
2. Mix the grout, about as much as you can use in a 10-minute span.
3. With a rubber grout float, spread the grout over the tile in a back and forth motion. As you spread, set the float at a 45-degree angle, which will force the grout into the joints (Figure 14). Scrape off the excess grout with the edge of the float.
4. Let the grout set for 10 to 20 minutes before starting to clean. If you begin too early, you'll pull the soft grout out of the joints. Vitreous and semi-vitreous tile may need to set slightly longer.
5. Thoroughly wring out a clean sponge and wipe the tiles in a circular motion (Figure 15). Rinse the sponge in clean water and wring it out often. As you clean, you should be removing the excess grout that stands above the level of the tiles. Figure 16 shows the correct level for the grout.
6. Wait about 30 to 45 minutes or until the joints are firm and a cement haze forms on the tile. Wipe the haze off with clean cheesecloth. If some of the haze is stubborn, use a damp sponge to clean it off. Or use a commercial cleaner recommended by the manufacturer.
7. Allow to cure according to the manufacturer's instructions. Most recommend that you lightly mist the tile and grout two to four hours after wiping off the haze. Then cover it with kraft paper, taping the edges to seal the tile. Leave it alone for three days. If this is impractical, lightly mist the grout several times a day for three days.

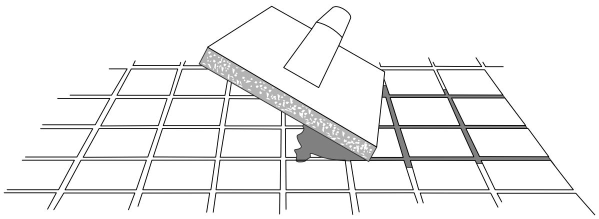


Figure 14
Spreading grout with a rubber float

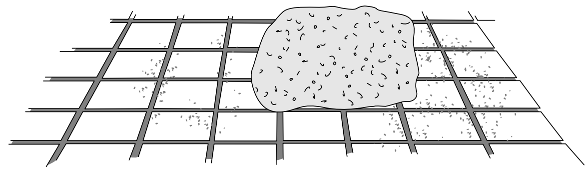


Figure 15
Removing excess grout with a wet sponge

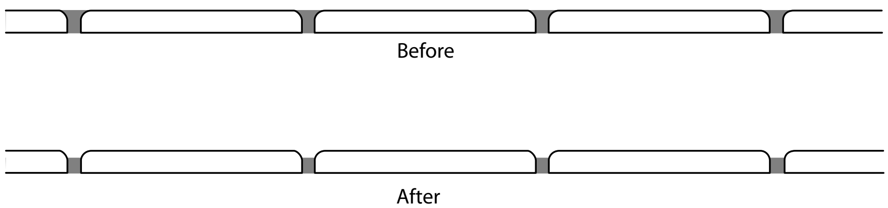


Figure 16
Grout level after cleaning

8. When grout has cured, vacuum any remaining dust and small pieces. Apply a bead of ceramic tile caulk wherever the tile meets another surface. Smooth it out with a wet finger.

Sealers and Finishes

To further protect the tile and grout, you can apply a sealer or a finish to the tile. Sealers and finishes reduce water, grease, and dirt stains. Sealers are sometimes used with porous tiles to reduce staining by the grout, referred to as grout release. They may also be used to give the tile a wet look.

Refer to the manufacturer's guidelines for the length of time the tile should cure before sealing. Also, products vary considerably in application methods. Some require only a single coat; others may take up to four coats for maximum effectiveness. Follow the manufacturer's directions.

Tile Repair

Although tile is an extremely durable material if installed and used correctly, it's not unbreakable. Most tile repair work involves repairing grout, which can loosen and crack or even fall out. When this happens, the process for repairing the grout is similar to placing it in the first place.

Repairing Grout

Use the same type of grouting material that was used originally. Matching the color may be difficult. Keep in mind that the grout will dry to a lighter color.

1. Remove all the loose grout from the joint. Use a grout saw or chisel to remove grout that isn't loose but needs to be replaced. Vacuum the remaining dust.
2. Wet the joint for better absorption. Follow the grouting steps under Grouting Tiles on page 137. For single tiles, you can often just use your finger to force grout into the joint.

Repairing Tile

Whenever you have to remove a tile, wear safety goggles and gloves to protect yourself from flying tile chips.

1. With a grout saw or chisel, remove all the loose grout from the joint surrounding the broken tile. Use a hammer and chisel to chip out the tile and old mortar or mastic. See Figure 17.
2. Thoroughly clean off the dust and small pieces. Butter the back side of the new tile to within $^1/_4$ inch of the edges (Figure 18). Press into place so that it's flush with the other tiles and the excess mortar or mastic squeezes out evenly from all four sides (Figure 19). Clean off extra setting material, removing excess from surrounding joints as well. Wall tiles may need to be taped in place to hold them while they cure.
3. Allow to cure according to the manufacturer's instructions.
4. Dampen the joints. Grout by following the steps under Grouting Tile on page 137.

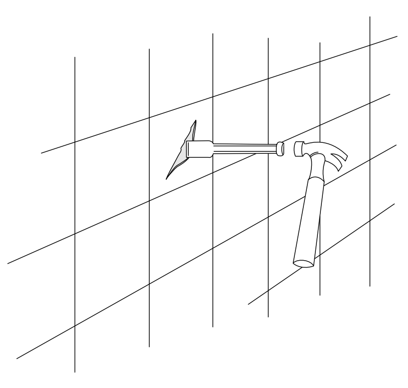


Figure 17
Remove damaged tile with a cold chisel

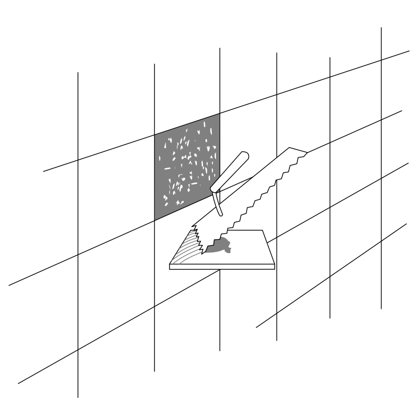


Figure 18
Spread mastic on the back of the replacement tile

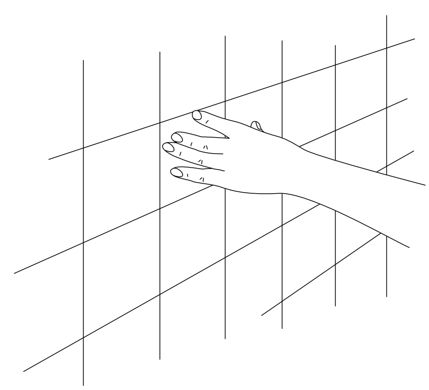


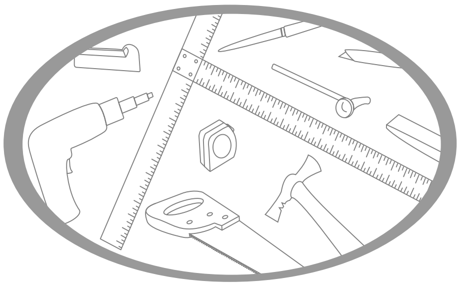
Figure 19
Place new tile

Manhours

Manhours to Lay Ceramic Tile, per SF		
Type	**Manhours**	**Suggested Crew**
Wall tile, $4^1/_2$" × $4^1/_2$", with backmounted tile		
Adhesive set	.242	1 tilesetter, 1 helper
Conventional mortar	.444	1 tilesetter, 1 helper
Dry-set mortar	.296	1 tilesetter, 1 helper
Floor tile, backmounted		
Adhesive set	.205	1 tilesetter, 1 helper
Conventional mortar set	.381	1 tilesetter, 1 helper
Dry-set mortar	.254	1 tilesetter, 1 helper
Countertop and backsplash, $4^1/_2$" × $4^1/_2$"		
Adhesive set with backmounted tile	.333	1 tilesetter, 1 helper
Conventional mortar bed with grout	.352	1 tilesetter, 1 helper

For information on related topics, see:

Adhesives, page 25
Countertops, page 209
Drywall, page 241
Flooring, page 359



Concrete

If you've ever worked with concrete, you've probably experienced that familiar adrenaline rush as you hear the truck coming and know that you only have one chance to get it right. Contractors who occasionally use concrete, but aren't concrete specialists, tend to fall into one of two groups: they either know a lot about the product, or know just enough to order it and make the pour.

For the pour to be successful, the concrete must be placed accurately and cured carefully to create a durable product. If you're not already an expert, we'll give you the information you need to understand concrete and the conditions that provide the best chance for the result you want.

It's easy to think of concrete as a modern material, an innovation of the industrial age. In fact, the Romans used concrete as long ago as 100 BC. As the Roman Empire spread throughout Europe, they took concrete with them. Portland cement, which makes a more reliable and consistent concrete, was developed in England and patented in 1824.

The words *cement* and *concrete* are often used interchangeably, especially by those outside the trade — but sometimes within the trade as well. I once saw a truck with a company name followed by the description "cement contractors." Judging by the equipment in their truck, they looked like flatworkers. In their area, so many people must use "cement" for "concrete" that they now identify themselves in that way, even though they're contractors and should know the difference.

The Ingredients in Concrete

Concrete is the result of a chemical reaction among a combination of ingredients, resulting in a strong structural material. The basic ingredients are cement, aggregates of various sizes, and water. Other products, called *admixtures*, may also be added to the mix. Admixtures help to control set times, workability and durability. The difference between mortar and concrete is the aggregate used. A concrete mix includes a combination of coarse aggregates and fines (fine aggregates). Mortar is a mix containing only fines, used in laying brick and block. (Find more information on mortar in the sections dealing with masonry.)

Cement

Today's portland cement is made by various cement plants that use different raw materials. But the cements all contain the same basic components of lime, silica, iron oxide and alumina. These materials are heated until they fuse. Then they're ground into the cement we're all familiar with.

Portland cements are classified into five types:

Type I: The standard portland cement.

Type II: Alkali-resistant cement. Because of its superior resistance to sulfates, it's often used for foundations and flatwork where soils present a problem.

Type III: High-early-strength portland cement. Type III is particularly useful in cold conditions when you want an earlier cure to shorten the time that protection is needed. It generates higher heat as it sets and reaches its strength earlier than Type I or II.

Type IV: Low-heat portland cement, which sets slowly and generates very little heat as it sets. It's useful on large projects where the heat generated by the large mass could be a problem.

Type V: Similar to Type II except that it's intended for more severe sulfate and alkali exposure. As with Type II, it sets more slowly than Type I.

Aggregates

Aggregates make up 60 to 80 percent of the concrete volume, which reduces the cost, since aggregates are relatively inexpensive. They also control shrinkage and provide compression strength. Aggregates range from fine (sand) to coarse (rock). Any aggregate that will pass through a #4 sieve is considered *fine*. Any aggregate too large to pass through is classified as *coarse*. The aggregate you use affects the water and cement ratio you'll use during mixing, the strength of the finished product, and the finishing properties. As a chain is no stronger than its weakest link, concrete is no stronger than its weakest ingredient. That's why the aggregate mix is extremely important.

A cubic foot of concrete mixed with standard aggregate weighs 135 to 160 pounds. But concrete with lightweight aggregates is also available, and weighs less. Lightweight aggregates, composed of shale or slag, can produce concrete weighing 100 to 150 pounds per cubic foot. Very lightweight concrete mixed with aggregates such as pumice and mica can produce weights as low as 50 pounds per cubic foot.

As the aggregate can be the weak link, we don't recommend lightweight mixes for uses requiring high strength. Evaluate specialty aggregates carefully before using them where water resistance and abrasion are required.

Water

Water combines the aggregate with the cement to form a plastic mix ready to place and work, which soon begins the hardening process called *hydration*. Here's the basic rule for judging the water you'll be using in the concrete mix: If it's fit to drink, it's fit for mixing concrete. You may be able to get by with some impurities in water, if you compensate with additional cement following a design based on the water type. You'll have to have the water tested by your local water board or an independent laboratory and then have the cement manufacturer advise you on an adjustment to the mix. Otherwise, impurities can reduce the strength of the concrete and cause corrosion of the reinforcing.

The amount of water (the water ratio) in a given concrete mix affects the workability and the strength of the concrete. When the concrete dries, the evaporated water leaves small voids. The more water used, the more voids there will be. The more voids there are, the less strength the concrete will have. Anyone who has worked with concrete knows that wetter concrete is easier to work. So you make a trade-off between strength and workability. The unit of measurement to determine the wetness or workability of concrete is the *slump*. You test the slump by measuring the amount the concrete "slumps," or settles, under controlled conditions. A drop of 4 inches is considered a 4-inch slump. We'll cover slump tests and other tests at the end of this section.

Admixtures

In addition to the three basic ingredients of concrete, you can include admixtures that affect the concrete in a variety of ways. Admixtures accelerate or reduce the set time, improve workability, increase freeze/thaw resistance, and bolster durability. Common admixtures include air entrainment, chemicals and pozzolans.

Air Entrainment

Air entrainment in a liquid form is added during the mixing process. It's recommended for concrete that will be exposed to freezing and thawing. The entrained air creates microscopic air bubbles or voids when the concrete has set. They provide space for moisture to expand and contract without damaging the concrete.

The workability of concrete is affected somewhat by air-entraining because less water is used to achieve the desired slump. You may have to start finishing the concrete sooner than you would without it.

Chemical Admixtures

Water reducers, retardants, accelerators and pozzolans are all chemical admixtures.

Water Reducers **—** The ratio of water used in the concrete mix directly impacts the whole process, from placement to durability. On the site, wet (high-slump) concrete is easier to place, but has a lower cured strength than stiffer (low-slump) concrete. There are water-reducing chemical admixtures available that reduce the water but still achieve a workable slump. Because a mix with a water reducer has a higher strength than a mix of the same slump using only water, some batching plants will reduce the number of sacks of cement in the mix when a reducer is added. While the strength is the same, the flatworker may notice less *fat* in the concrete. When cement is finished, and the larger aggregates are worked down, the resulting mixture has very fine aggregates and cement at the surface. This surface mixture is sometimes called "fat."

Accelerants **—** Accelerants are used to speed up the set time of the concrete, most often during cold-weather pours. Calcium is commonly used as a setting accelerant, but you must use caution when working with it. Calcium is corrosive and can cause structural damage to steel reinforcement. One cold-weather advantage of calcium is a quick set time, which allows earlier finishing and form removal. A second benefit is its high-early heat generation during hydration, which helps prevent the concrete from freezing.

Retarders **—** Retarders are used to slow the setting time. Since they're the opposite of accelerants, as you can probably guess, they're commonly used in very warm weather. A retarder is used to slow the set time and allow more time for finishing when high heat or other factors may cause the mix to set too rapidly. Retarders are also useful for slow pours or pours that take place a long distance from the batching site. They allow the concrete to remain on the truck longer before discharge and placement.

Pozzolans **—** Pozzolans are siliceous or siliceous and aluminous materials which combine with calcium hydroxide to form compounds possessing cementitious properties. The properties of pozzolans and their effects on concrete vary. Before one is used, it should be tested in order to determine its suitability for the intended application.

The Mix Design

The mix of basic materials and admixtures creates concrete that can work for or against you. When ordering concrete, establish a mix design that will work in the conditions you'll encounter. The mix design should use a combination of water, cement, aggregates and admixtures to reach the psi (pounds per square inch) strength required for the project conditions.

The mix design will always specify a required strength in psi. This is a break strength test that the concrete must be able to pass. Many commercial projects require samples of the concrete to be taken while the concrete is being placed. These samples are broken in a laboratory after being cured in a controlled environment. The test breaks are usually made at seven and 28 days. Even though concrete will continue to gain strength, the 28-day break is considered a cured break and must meet the designed psi break strength.

To order concrete for a successful pour, take the following into consideration:

1. *Type of Project.* Is the concrete to be placed in forms for a wall or finished out as flatwork? What should be the aggregate size, slump, workability, durability and finish?
2. *Temperature.* Will the placement be done within an acceptable temperature range, or will you need to prepare for cold or hot weather conditions? Do you need accelerators or retardants, and air entrainment?
3. *Pour Time.* Will the concrete be in transit for an excessive time, or are there other factors that could make it a slow pour? Is a retarder required?

Curing Concrete

When cement and water are mixed, a chemical reaction known as *hydration* begins. It's hydration, *not* drying out, that makes concrete hard. Hydration will occur as long as conditions are right. Maintaining conditions conducive to hydration is known as curing the concrete.

Hydration continues as long as moisture is present. The object in curing is to maintain moisture and prevent premature drying from taking place. If the mix dries, hydration stops. That results in weakened, less durable concrete.

Curing Methods

Common curing methods include:

- Applying sealing compounds to the concrete to slow down the release of the moisture.
- Applying water to the surface of the concrete to prevent the concrete moisture from evaporating.
- Covering the concrete with a moistureproof barrier.

Sealing

Spray sealing compounds on the concrete as soon as it's exposed to drying conditions. Spray flatwork as soon as it's finished. For formed concrete, spray as soon as the forms are removed, before the concrete can begin to dry.

Both clear and pigmented sealants are available. Pigments are added for two purposes: to show that a curing compound was applied, and to provide a reflective surface that lowers surface temperatures during hot weather.

Projects specifying a curing compound will usually require a product labeled as C 309. This label is used by different manufacturers to signify that the product has been tested and conforms to ASTM C 309. By purchasing a labeled product, you can assure your client that proper curing is taking place.

Curing with Water

You can cure concrete with water by fogging it, building a dike around it and flooding it, or using curing mats that are saturated with water. Be careful when fogging or sprinkling. If you leave the concrete unattended, a change in wind direction, or workmen from another trade moving or shutting off your hoses, can leave spots or even cause the entire area to lose moisture too quickly.

Covering Concrete

Concrete is sometimes covered with impermeable barriers, including plastic, waterproof paper and insulating blankets. The most common are plastic and blankets.

If you choose plastic, it should be either clear or white, and a minimum of 4 mils thick. During hotter temperatures, choose white because it does a better job of reflecting heat. Make sure the plastic is as tight and flat as possible. Wrinkles and other irregularities can cause staining or marking on the concrete's surface.

Use blankets for curing in cold weather. Blankets prevent the concrete from freezing, while maintaining the moisture long enough for a proper cure. Blankets should overlap each other and cover all edges to protect all areas of the concrete.

Curing Time

Concrete continues to harden and gain strength as long as hydration continues. Perform strength tests at seven days and again at 28 days. Order your concrete based on the strength it should attain at 28 days. Under ideal conditions, concrete will be allowed to cure that long. But due to time and budget constraints, most projects can't be held up waiting on a 28-day cure. On most residential pours, concrete is only protected for three days. Sealants offer a double advantage: They protect the concrete from drying, and they allow the cure to continue even if work resumes after three days.

Planning a Foundation

There are some obvious and important steps you should take before you order concrete. These steps include inspecting the site, analyzing drainage, determining soil type, and getting or preparing a foundation design based on what you've found. We'll go through them shortly. But first, we should take a look at how important following proper procedures has become in recent years.

Today we live in a very litigious society. This has created an atmosphere where, by regulation or by choice, we often rely on consulting experts like engineers and architects, even for small jobs. Not so many years ago, any builder worth his salt could design and build with plans scratched out on a Big Chief tablet. These days many still could — but they're too smart to take the risk. So they inspect the site, take a soils test, and have a foundation designed for the conditions they find and the load of the building it will carry.

Following through on all these steps will assure that you've done a professional job and that your client will have a long-term foundation. They also allow you a degree of protection from litigation. If the foundation fails, it's the expert who advised you, not you as the builder, who's at fault.

The most important way you can protect yourself as a builder is to build as designed. If you see an error in the design, bring it to the attention of the designer. If you make changes on your own, you're shifting the liability from the designer to yourself. If there's a structural failure, you can be sure that you'll be involved. But you greatly reduce your liability if you can show that you built the project *as drawn*.

Site Inspection

Before ordering and placing concrete, you must first go through a great deal of analysis and preparation. This starts with an initial visit to the site to find out where to place the slab or foundation. Also, be sure to look at the drainage requirements.

Drainage

Poor drainage is one of the major reasons for concrete failure. Water undermining a slab or foundation causes voids to form or expansive soils to swell. Both can cause concrete failure. Make sure that the structure you're preparing to build can be drained properly.

Soils Analysis

Examine the soils that will support the concrete. You can get some idea of the type of soil conditions by looking at other structures nearby. Do they show signs of failure, or are they free of stress cracks? If you're building a permanent structure, a soils test is a must. Perform the test by drilling a sample hole and taking a sample for analysis. The report will detail the types of soils encountered and at what levels.

Foundation Design

A foundation design takes into consideration the loads of the structure and the capabilities of the soil it's placed on. It helps ensure that you're building a trouble-free structure. The soils report, site information, and building design are all taken into account. The design can include a standard foundation and footing, a foundation with no footing, caissons, or an overdig and recompaction with nonexpansive fills. The wide range of foundation costs reflect the complexities for the different types of foundation designs. More than one contractor has been short-changed by giving a firm price on a structure without investigating the soil conditions of the particular location. In some areas, soils, and therefore foundation designs, can change from lot to lot.

Foundation Types

Procedures for forming the foundation vary slightly depending on your foundation design. The first step is preparing the base that the foundation wall will be placed on. The preparation could include an overdig and recompaction, caissons, footings, or a footingless foundation on grade, with or without voids.

Overdig and Recompaction

An overdig is usually recommended for expansive or unstable soil on top of accessible stable soil. Remove the unstable soil and replace it with a stable fill material, carefully recompacted in lifts. Don't place more than 6 inches of fill before you compact it with a compaction machine. The type of compactor and the type of fill you use determine the depth of the lift that's needed.

The lifts (layers of fill material) are normally outlined and specified in your soils and foundation report. But these are just recommendations about how you can achieve the percentage of compaction required. A soils engineer can take samples of the materials you've compacted and test them to determine if you've achieved the recommended percentage of compaction.

Once the overdig is accomplished and you're back to grade with compacted new material, you can continue as if you'd encountered soil with acceptable bearing capacity.

Caissons

If the soil is inadequate to a depth that makes an overdig impractical, a caisson may be recommended. A caisson is a concrete pier created by drilling a hole in the ground to a predetermined depth, placing a steel cage for reinforcement, and filling it with concrete. The caisson penetrates the unstable soils so the structure can bear on stable materials below. This provides a structurally-sound base for the foundation in an area where shifting and damage would occur with another type of foundation system.

You can calculate the diameter and number of caissons from the load of the structure. The depth depends on the location of good bearing materials. If expansive soils could create a lifting force capable of raising the structure and the caissons, the engineer or local code may require you to add shear rings to the caisson. The purpose of the shear ring is to provide a gripping force on the solid bearing material to counter the lifting force of the unstable materials above.

To make a shear ring, place an attachment on the auger of the drilling rig after the hole is drilled to the proper depth. Then reinsert the auger into the hole, spin at the required depth, lift and spin again to create the required number of rings. See Figure 1.

In metropolitan areas, you can find caisson drillers through the yellow pages under *Caissons*. In outlying or more remote areas, you may have to make contact through concrete suppliers, architects or engineers in the closest city. Some drilling companies have traveling rigs and specialize in drilling in remote areas.

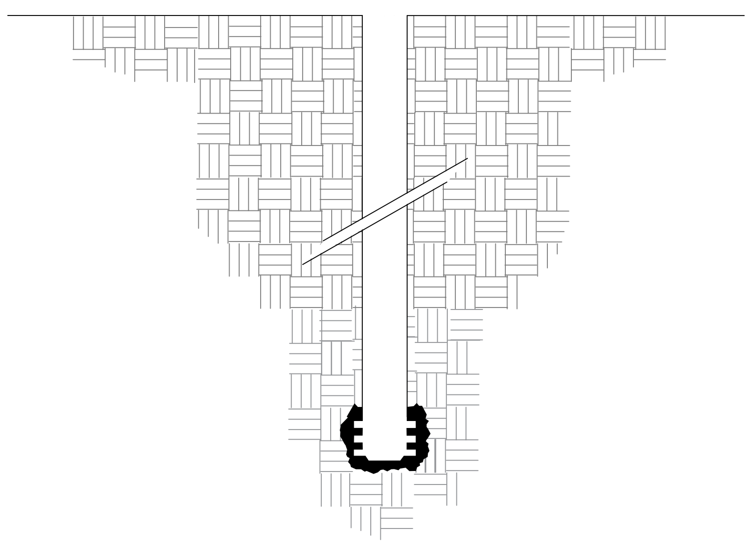


Figure 1
Caisson with shear rings

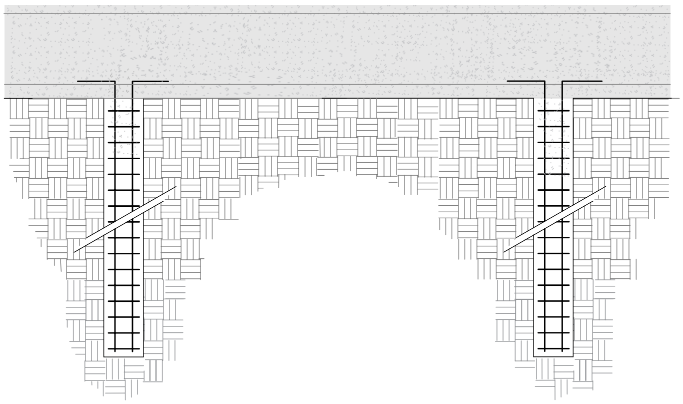


Figure 2
Foundation stem wall placed over caissons

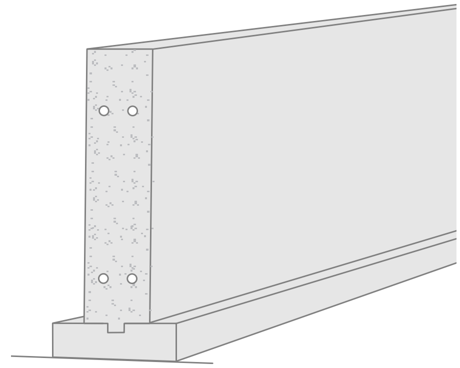


Figure 3
Footing with keyway

After the caissons are poured, you can form the concrete stem wall directly over them. Tie the reinforcing in the stem wall to the reinforcing that extends above the caisson for this purpose. Then set the stem wall as you normally would without a footing, as shown in Figure 2.

Footings

A stem wall placed on a spread footing (or simply *footing*) has long been considered the standard foundation. The spread footing distributes the weight of the structure over a larger area. A residential footing is usually 18 inches wide and 8 inches deep. It's normally reinforced with two horizontal bars of #4 grade 60 or #5 grade 40 steel reinforcement. You attach the spread footing to the stem wall with a keyway and/or steel rebar dowel uprights.

Create a keyway by placing a 2-by on edge in the wet concrete after you pour the footing. This leaves a $1^1/_2$- × $1^1/_2$-inch impression in the footing for the stem wall to attach to, as shown in Figure 3. The keyway helps keep the stem wall from sliding on the footing as it encounters outside forces created by expansion or shrinking of the fill.

A dowel is a piece of rebar with a bend at the bottom. The purpose of the dowel is basically the same as the keyway. But dowels provide a stronger connection because they penetrate the stem wall as well as hook into the footing. You should place dowels in the footing while the concrete is still wet. If the dowels are forced into concrete that's too far into its set, they may be loose at completion. Place and "jiggle" the dowels so the concrete is vibrated tightly around the dowel for a firm connection. Figure 4 shows a footing with doweled uprights.

You can also place dowels by wiring them in position before the concrete pour. This has two advantages: First, you can place the dowels more precisely, and second, it eliminates the risk of the dowels being loose because the concrete started to set before they were placed. Of course there are also some disadvantages. It's more labor intensive to place them ahead of time since it requires temporary supports to hold them in place during the pour. It's also more difficult to strike off the concrete when you have to work around uprights.

There are two basic methods of forming up spread footings: You can dig them in, or you can use forms. Unless your labor is cheap and your soil conditions are ideal for digging, forming them is best. Almost all footings are formed with 2 × 8 material. While it's important that the footings are formed as precisely as possible, you can overlap the form material. That way, you don't have to cut reusable forming material.

The footing width will be specified in the foundation design. In almost all cases, you center the foundation wall on the footing.

Footingless Foundations

A footingless foundation like the one in Figure 5 is one of the easiest and least expensive systems to put together. You can form the stem wall off of grade just as you would off of a footing. The difference is that you don't have the expense of putting in a footing. In setting up a footingless foundation, set the bottom plate directly on the site material. The site material can be the native soils or recompacted fill materials, as in the case of an overdig. Use stakes to hold the forming system in place. Most contractors prefer steel stakes because they're easier to place and they're reusable.

Footingless Foundation with Voids

Voids are engineered spaces at the bottom of the foundation designed to compensate for expansive soil. You can create these spaces by placing manufactured voids along the base of the forms before the pour.

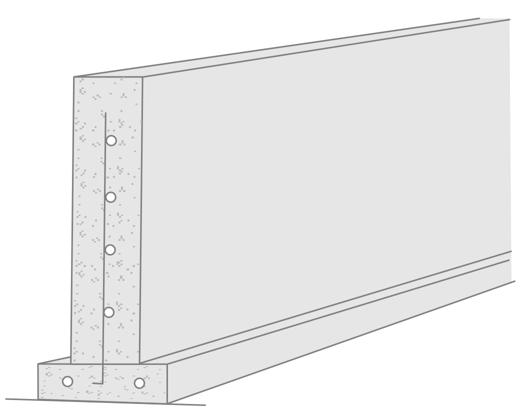


Figure 4
Footing with doweled upright

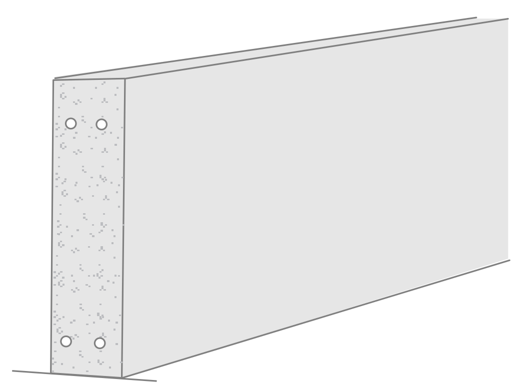


Figure 5
Foundation without a footing

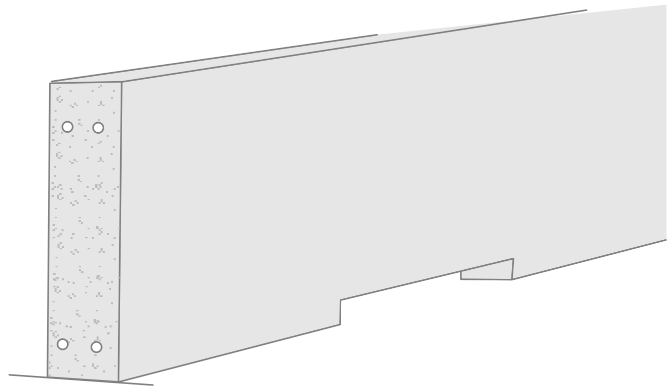


Figure 6
Foundation wall with void

The voids are cardboard devices designed for this purpose. They're strong enough to withstand the weight of the concrete as it's being placed, but they eventually rot away, leaving open spaces in the concrete. See Figure 6.

The voids create space for expansive materials to swell into. If the spaces weren't there, the force of the expansion could lift or break the foundation system. During wet conditions, expanded soil fills the voids. As the soil dries out, it shrinks back, opening up the spaces again. If properly designed and placed, a foundation with voids will remain in place and stable, and be unaffected by these changing conditions.

In designing a foundation with voids, the engineer must create a balance between the bearing capacity of the soil and the load, or weight, of the structure it'll be carrying. The voids should have a very specific layout, varying in length depending on the exact loads of each location. There's no such thing as a "standard" voided foundation. The thickness and the location of the voids for each specific project will be specified in the design. As the builder, it's imperative that you follow the design as closely as possible.

Forming the Foundation

Once you have the foundation design in hand and the footing excavation done, you should be ready to form up the wall. There are a number of forming systems you can choose from. While all of the systems are unique in design, they all involve the same basic concept. The steps involved in setting up a foundation also remain the same. All systems involve panels held together with some type of tie system.

The most important part of assembling any form system is to carefully follow the instructions for the system you're using. It's usually not that difficult. If there's a hole or a slot in your form for a tie, put one in. Most blowouts or other unpleasant experiences that occur during a pour can be traced to someone on the job who thought he knew more about the system than the person who designed it. Leaving out any tie is asking for trouble. I witnessed the aftermath of one pour where an inexperienced crew decided to leave out every other row of ties. The plywood and the ties weren't strong enough for the span. Several ties snapped, putting more stress on the plywood, which then broke. The result was broken forms, lost hardware, lost concrete, and the generous use of a jackhammer and a lot of wasted time to get the mess cleaned up.

Here are four basic rules that you can use as a guide when setting up forms:

1. Square up the layout. The first step in setting up the forms is to make sure you're setting up a square foundation.
2. Working off of the batterboards that were set up before excavation, reset your strings. Next, recheck for square to make sure the batterboards weren't knocked out during excavation.
3. Using a plumb bob, drop the corner points to the excavated grade (or crawl space or basement floor) as in Figure 7. Set at least a 16d nail at these points if you're dropping to a soil base, and make a pencil mark if you're dropping to a footing.
4. Recheck for square one more time.

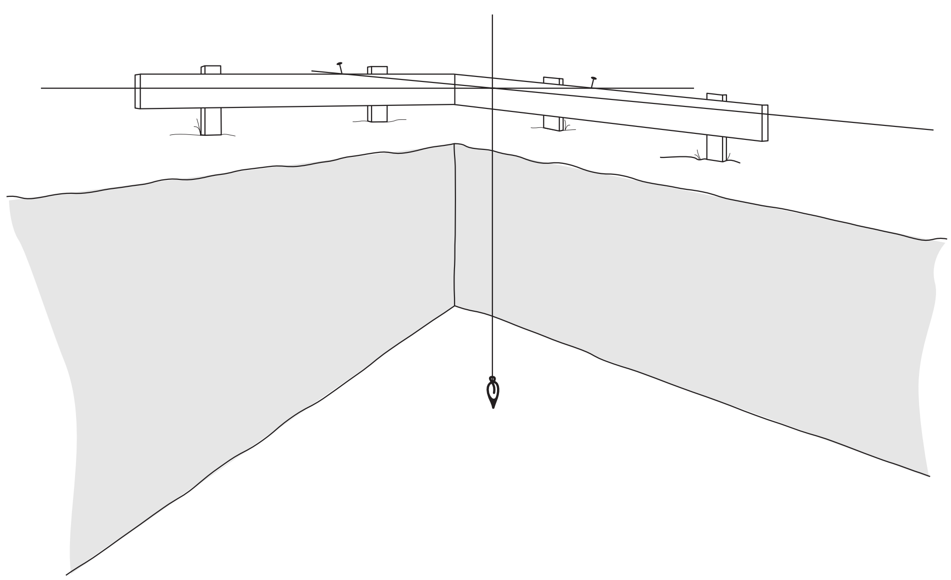


Figure 7
Dropping the squared corners to the bottom of the excavation

This may seem like overkill, but you don't want to get your forms set and then discover you're not quite on. If your layout allows you to take diagonals, this is one of the surest methods of checking. See Figure 8. If this isn't practical, use the 3-4-5 method shown in Figure 9, then pull the other corners off of the one you squared.

Setting the Plates

Snap chalk lines using the points you've set. Do this on either the footing or directly on the dirt if you're not using a footing. Remember, you're chalking for your bottom plate. You need to allow for your forming material. In the case of $^3/_4$-inch plywood, the plate line should be $^3/_4$ inch outside of the outside corner points you set.

Once you've chalked the plate lines and confirmed that they're square, you're ready to set the plates. The plates should be 2 × 4s that are either straight or have gentle bows that can be straightened by staking or nailing. A crooked plate makes a crooked wall.

Setting Plates on a Footing

Figure 10 shows the bottom plate being set on the footing. When you set the plates on the footing, lay them out and cut them to length. Because you'll be nailing them to the footing with 16d duplex nails, you can't overlap the plates because the nails won't reach. You can only use 16d duplex if you set the plate while the concrete is still green enough to allow them to penetrate. If the concrete has set too long and the duplex nails bend when you try to drive them in, you'll have to use concrete nails. Figure 11 shows the bottom plate nailed to the concrete footing.

Setting Plates in Dirt

Use stakes as shown in Figure 12 to place plates set in dirt. The plates may be overlapped if you stake them. The stakes are long enough to allow reasonable security without the plate being tight to the ground. When you have overlapping plates, whether at the corners or at a splice, fasten them with 16d duplex nails. The corner overlaps should have one nail, and the splices should have at least two. Overlap splices by at least 1 foot.

Start the plates in the corner with the longest run going out of it. Always run the panels out of a corner. Once you've set a corner with the plates, you can go ahead and set the first wall corner. Have someone continue on with the plating while the others start with the form panels.

Setting the Form Panels

Form panels are available in a variety of materials and configurations. The most common material for forming is plywood. While almost any $^3/_4$-inch plywood will do for one pour, for repetitive use you're better

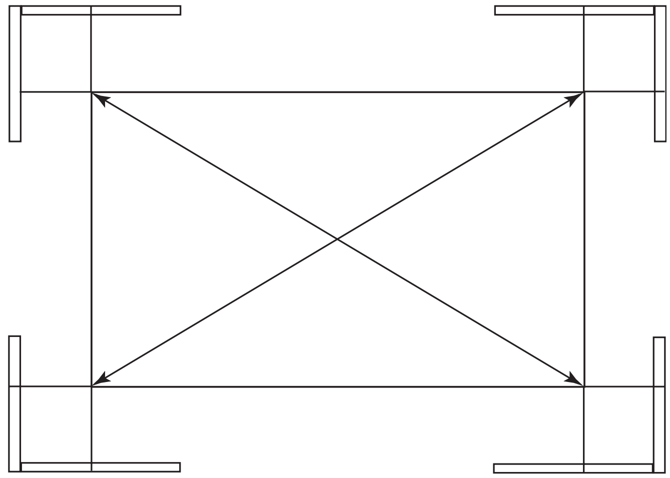


Figure 8
Squaring a foundation using equal diagonals

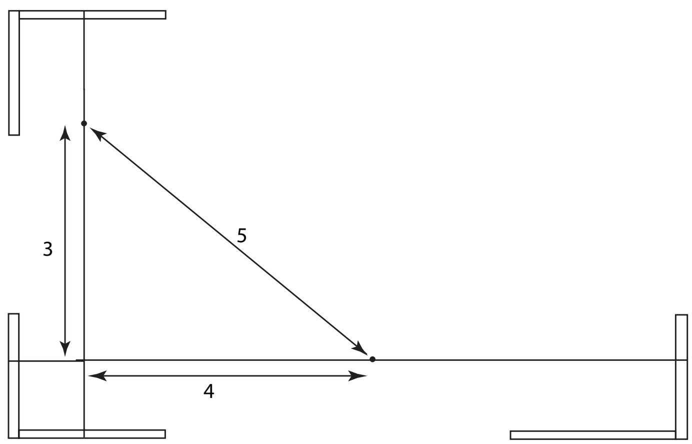


Figure 9
Squaring a foundation layout using the 3-4-5 method

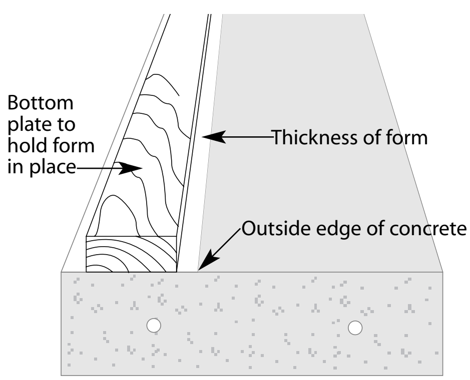


Figure 10
Setting the bottom plate on the footing

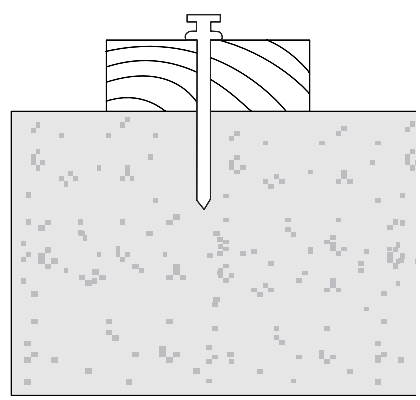


Figure 11
Setting bottom plate in concrete footing

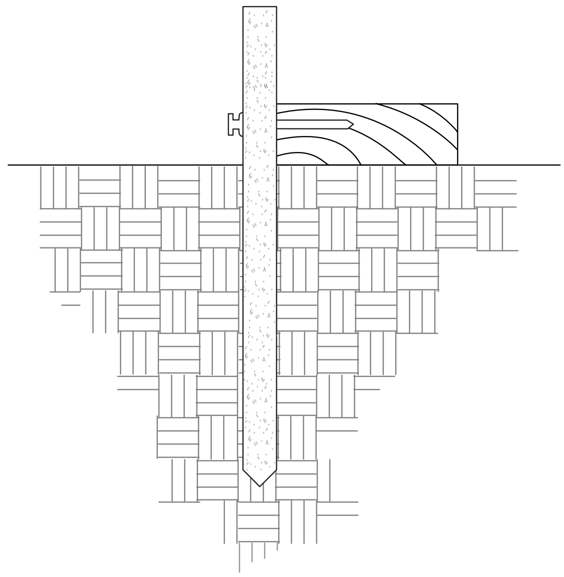


Figure 12
Setting bottom plate in soil

off with plyform that's manufactured specifically for form use. It's smooth on both sides and pretreated with a releasing agent. It's available through many lumberyards as well as forming system suppliers. You can get plywood precut and predrilled for specific forming systems from the suppliers for those systems.

For durability and smoothness, you can't beat metal forms. While the initial cost of metal forms is much higher than plywood forms, they'll pay for themselves eventually if you're able to take advantage of the number of uses you can get out of them. Because of their higher cost, metal forms are more frequently used by foundation contractors who can keep them in full-time use.

Setting the outside corner panels correctly is the key to setting the foundation properly. You must set the corner panels plumb so the top of the foundation will be directly over the bottom where you set your corner pins. Make sure all of the additional panels are set tight and secure against the corner panels. If you discover later that you're out of plumb in the corner, you'll have to loosen and reset all of the panels tying into that corner so you can move the corner panels. Because they're so important in maintaining a square and plumb foundation, take your time in the corners and save your speed for the straight runs.

To set a corner, set braces on the corner running off of each edge as shown in Figure 13. Set a stake for the brace. Plumb each vertical edge on the corner and fasten the corresponding brace and stake.

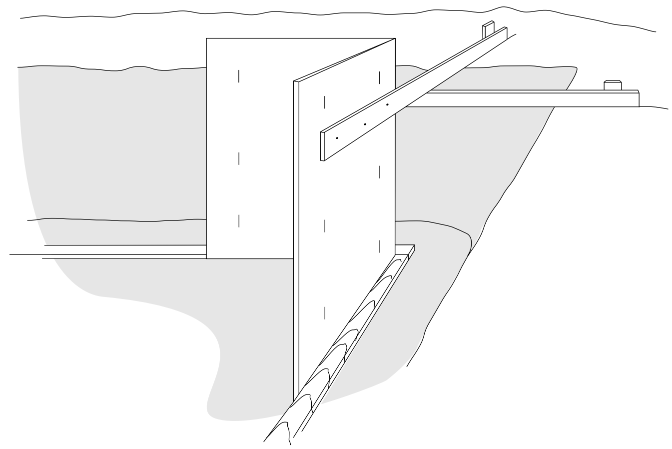


Figure 13
Setting the first corner form

Once the corner is plumb and braced securely, you're ready for the easy part — setting the corner panels. Prepare a top plate to hold the tops of the panels tightly together. See Figure 14. As you set each panel, push it tightly against the previous panel. When the bottom of the panel is tight, drive a 6d nail through the corner of the panel into the bottom plate. Nail the top of the panel to the top plate in the same way. Then nail the outside edge. Figure 15 shows the panels being fastened to the bracing.

The panels will stay plumb if you take care to install them as tightly as possible against the previous panel. But in long runs, you'll have to check the leading edge for plumb occasionally, and make adjustments if necessary.

When you reach the next corner, you can almost be assured that you won't have a panel that'll fit. Since you have form panels in a variety of sizes, use one that leaves the smallest gap, and finish it off with a filler strip. Use $^{3}/_{4}$-inch lumber to make the filler strip. That should work once you've narrowed the gap down to several inches. Don't try to use plywood; it's too flexible when ripped into small strips. Have 1-by material on the job to rip down for this purpose.

Ties and Walers

When you have all the outside panels erected, you're ready to set the ties and walers. The ties keep the forms rigid during the pour by connecting them together and keeping them from spreading. Depending on the system, ties may be twisted wire, a single wire rod, or a metal strap. Figure 16 shows a typical form tie. The tie protrudes through the form or between two forms and is held in place with a rod or wedge. When the forms are stripped after the pour, the metal ties remain with their ends protruding from the concrete wall.

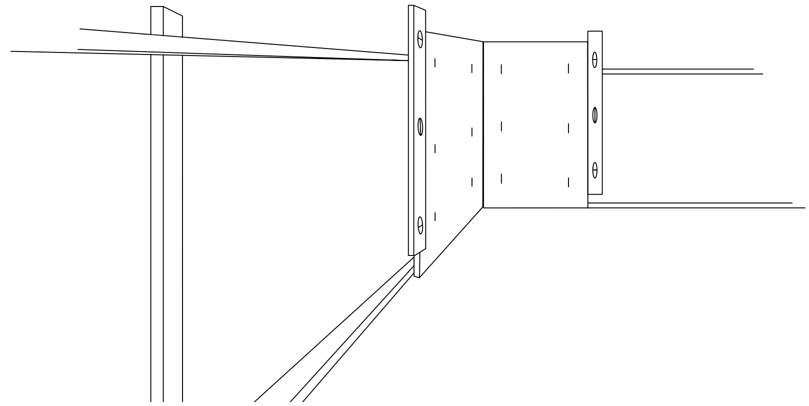


Figure 14
Start form set from a corner, with the panels braced plumb

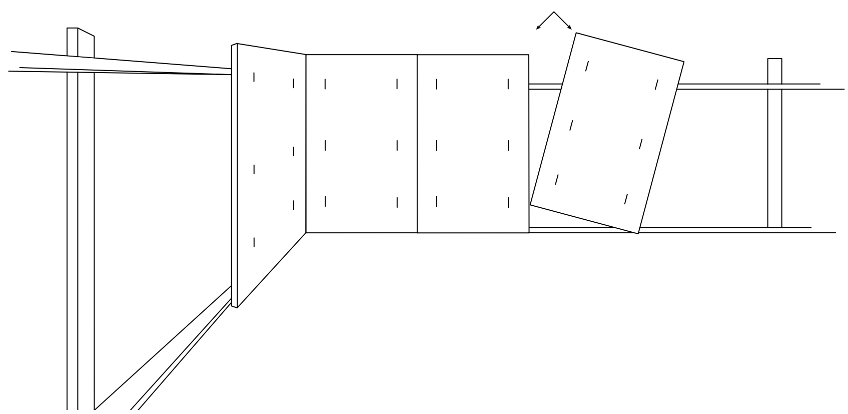


Figure 15
Pull the forms tight, and plumb, before nailing to 2 x 4 bracing or walers

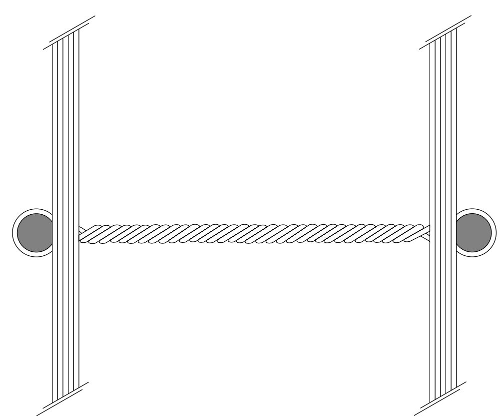


Figure 16
Form tie

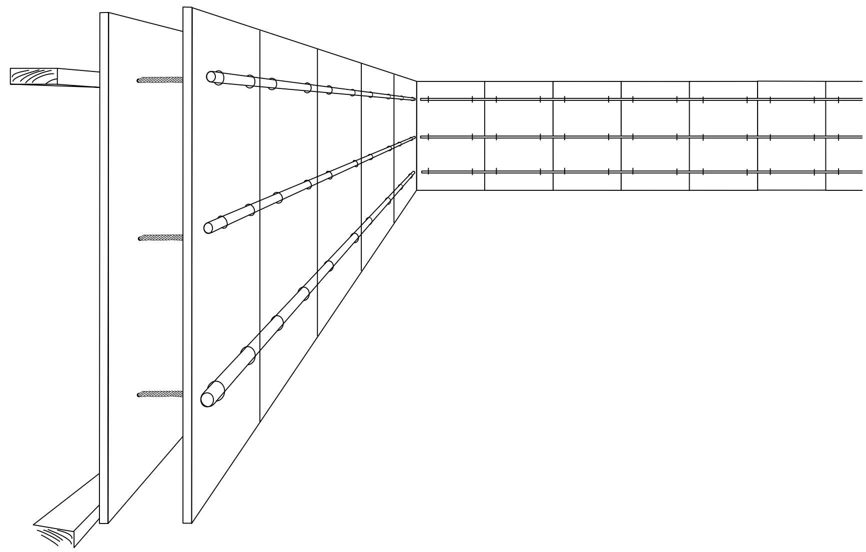


Figure 17
Forms held in place with rod-type walers

Most ties are designed to snap off flush with the concrete if they're bent back and forth once or twice or hit with a hammer. This type of tie is adequate for most applications. But with decorative concrete or in other special situations, an architect may specify *cone ties*. They leave an indentation that you can fill in to cover the ends of the ties. That way there's no metal exposed when the wall is done.

In some systems, like Jahn and Simplex, the walers are 2 × 4s that lock into the tie system. In others, such as Gates, they're a rod that slips through the tie. Figure 17 shows forms being held in place using the rod-type walers. Whatever system you use, be sure to place *all* of the ties and secure them with the walers.

Setting Grade Lines

With the forms up and the ties in place, you're ready to set the grade line. Set up your transit and use the benchmark you've established to shoot in the finished elevation. Mark each corner of your forms, then chalk between the marks.

If you're using a brick ledge as part of the footing to support a brick veneer exterior wall, find its elevation off of this line. If there's no brick ledge, nail a $^1/_2$- × $^3/_4$-inch strip under the line so you can use the top of the strip as the grade line to finish off the foundation. Or you can nail 3d or 4d nails into the grade line every 12 inches with the heads protruding about $^1/_2$ inch. The finisher can feel them with the trowel and use them to level the top of the foundation wall.

Windows and Blockouts

Any work you need to complete on the outside wall, including blockouts and filler strips, must be done before you can move on to reinforcement and setting the inside panels. Use the grade line to establish the location of windows and other blockouts. When you set window bucks for a basement pour, make sure they're braced well. A steel buck has holes drilled around the perimeter of the frame to nail it to the forms. In addition to these nails, cross brace the frames to prevent them from bowing in.

Reinforcement

With the blockouts in place, you can now place the reinforcement. Take care to place the reinforcement according to the foundation plan. The top row of reinforcement, especially on a 4-foot wall, is often set after placing the inside panels.

Setting the Inside Form Panels

Like the outside panels, you erect the inside panels starting with the corners. Set and align the inside corners using a spacer at the top and bottom. The inside is more difficult than the outside panels since the ties hanging from the outside forms need to be aligned and inserted into the holes on the inside panels. As you erect the panels, secure the ties temporarily to prevent the forms from shifting and the ties from falling out until you have enough forms up to place the rods or 2 × 4s.

When the inside panels are in place, complete the walers and make sure the ties are secured on both sides. Brace all walls, paying special attention to corners and jogs. Place enough braces on the straight runs so that you'll have minimal movement during the pour. Some longtime form setters use minimal bracing and then bounce and jiggle the forms straight once they're filled and have enough weight to remain in position. We don't recommend this for the inexperienced; poor timing with this type of procedure can damage setting concrete. And, if you do it too late and you have a curved wall, it may just stay that way.

Once all the formwork and bracing is in place and you've rechecked the foundation for square, you're ready to pour the foundation.

Ordering the Concrete

Experienced production formworkers have their concrete order on "will call" for a couple of days, depending on the work load of their supplier. With larger concrete batching plants, placing a will call order is a way of reserving a time for your pour. With smaller operations, you may only need to stop by and let them know you think you'll be ready to pour on Wednesday. In most areas, having an order on will call is especially important if you want a prime early morning pour time. To place a will call order, you'll need to provide the supplier with the following information:

- Rough estimate of yardage
- Day and time of pour
- Mix requirements
- Special requests for particular trucks your batching plant may have available, such as front end loaders.

Most batching plants will reserve a time for you, but it isn't considered an order until you call and confirm the exact requirements.

Figuring Yardage

To place an order you'll need an accurate estimate of your yardage requirement. The formula for figuring yardage is really very simple:

Linear feet of wall × width of wall × height of wall × 27 = cubic yards

To make the calculations easier, convert the length, width, and height to feet or fractions of feet for clearer calculations. Combining inches, feet and/or yards in one calculation just creates the opportunity for errors. Also, convert any fractions to decimals for easier calculations.

Multiplying the length times the width times the height gives you the cubic *feet* of concrete needed. There are 27 cubic feet (3 × 3 × 3) in 1 cubic yard. So you divide the cubic feet by 27 to get the cubic yards. Consider the following example:

You're pouring a foundation wall for a garage that's 14 by 24 feet. It's a standard 8-inch thick foundation wall, $3\frac{1}{2}$ feet high. First, convert from inches to decimal feet for the wall dimensions:

8 inches = .66 feet

$3\frac{1}{2}$ feet = 3.5 feet

Now find the total linear feet of wall:

14 + 14 + 24 + 24 = 76 linear feet

Finally, multiply length × thickness × height of the wall and divide by 27 to convert the answer to cubic feet:

76 × .66 × 3.5 = 175.56 ÷ 27 = 6.502 cubic yards

Always start by determining the overall cubic feet. If you have blockouts or windows, figure their cubic feet and subtract that amount from the total cubic feet before converting to cubic yards.

To make accurate yardage estimates, remember these two rules:

- Always convert inches to the decimal equivalent in feet.
- Avoid the common error of dividing the total cubic feet by square yards (9) rather than cubic yards (27).

Mix Requirements

A typical foundation uses a 3000 psi mix. For a poured wall, most batching plants use a mix with $^3/_4$-inch rock. Specify Type II cement because of its alkali. A 4-inch slump provides a mix that's workable in the forms without honeycombing. To order this hypothetical mix, you would give the following information.

- Location of job site:
- Requested delivery time:
- Type of pour:
- Foundation yardage: as required
- Psi: 3000
- Slump: 4 inch
- Cement type: II
- Aggregate: $^3/_4$ inch
- Admixtures: as required

Some batching plants refer to their mixes by the number of sacks of cement in a yard of concrete instead of by the pounds per square inch. Instead of ordering a 3000-pound mix, they would call it a five-sack mix. But considering that admixtures have a direct effect on the strength of the finished product, it's much more precise to place the order based on your required psi.

There's one more thing to remember: The amount of water also has a direct bearing on the final strength of the concrete. If you add water to the concrete in the field, you'll change the slump — and reduce the strength of the concrete you've ordered.

Choosing a Concrete Supplier

Most contractors make price the greatest consideration in choosing a concrete supplier. If everyone provided the same quality of mix, that would make sense. But how do you know if the quality is the same? To get a true comparison, ask for the mix design of the mix that you're ordering. Visit the facility and take a good look around.

Check the quality and source of aggregates. Are they kept separated and clean? What quality of rock do they use? On hot days is the aggregate kept cool to prevent too quick a set?

Check the condition of the equipment. Does the entire batching plant appear to be well organized and in a condition that indicates they can accurately put together the mix?

Check the condition of the trucks. Are they well-maintained mechanically? A broken-down truck on your site becomes a problem for you as well as for the supplier. Are the drums free from build-up? If there's build-up in the chutes, the fins are probably built-up as well. You can't get adequate agitation with dirty fins, especially if you're using air entrainment.

Check the number of trucks. Are there enough for your pour? If you have to wait for one truck to cycle between your job and the batching plant, you may end up with cold joints. A cold joint is the result of fresh concrete being poured over concrete that has already set.

In metropolitan areas, there are usually several concrete suppliers to choose from. And because of competition, they probably all produce a good product in well-maintained trucks. In that case, price will usually be the determining factor. Unfortunately, in many rural areas there isn't much choice in concrete suppliers. It's difficult to support the overhead of more than one batching plant in an area with relatively low demand. It's rare to be in a situation where you need to choose between a poor product and a good one. Most of the time the supplier with the poor product will be put out of business by the one offering the better quality, unless there's a big difference in their price.

Site Access for Equipment

The site should be cleared so you have adequate access available for any equipment you need during the pour. The equipment will almost always include a concrete delivery truck. You may also need a pump truck or a crane and bucket.

Sometimes, because of unfavorable terrain, existing structures or other complications, you can't use a concrete truck to make a direct pour at the site. In these situations, you may have to consider additional methods of transporting the concrete from the truck to the forms. Several alternatives are available depending on the size of the pour.

Small Pours

For very small pours, if you have adequate labor available, you can merely ramp the forms and transport the concrete by wheelbarrow. If you have ample room, you can use the bucket of a small tractor or skid loader. If the concrete truck can be elevated to allow the concrete to flow without changing the slump, you may be able to rent long extension chutes to carry the concrete to the forms. While all of these methods work well for small jobs, you need a faster rate of pour on larger jobs to prevent cold joints.

Pump Trucks

You can get pump trucks in a wide variety of sizes and capacities. They range from trailer-mounted units pulled behind pickups, to large truck-mounted boom units. Each type of unit has a capacity based on its optimum operating conditions. Some units are rated at over 150 cubic yards per hour.

Pumping units consist of a pump, hopper, and hoses, with the pumps either piston or pneumatic driven. The concrete is discharged from the delivery truck into the hopper of the pumping unit. It passes through the pump and into a combination of metal piping and flexible hoses for placement.

The pumping ability of any pump varies with the mix. The aggregate size and slump, along with other mix factors, have a direct effect on a unit's pumping performance. The amount of lift and the curves in the line also affect performance. While a variety of factors are involved in your pumping rig selection, always keep the following rule in mind: you choose the pump to fit the mix specifications, you *don't* change the mix to fit the pump. This rule is especially true in regard to slump. In situations where the only available pump can't handle your mix specifications, you should consult the original mix designer before adjusting the mix. Have the pumping company indicate the mixes that will work with their pumps, or have them work with the mix designers directly, if possible, to obtain a workable solution.

Concrete comes out of the hoses at a lower slump after pumping than when it's placed in the hopper. As the concrete is placed under pressure in the hoses, water is forced into the aggregate, lowering the slump of the mix. The loss of slump varies depending on the porosity of the aggregate. When you adjust for this loss of slump, you must remember that the water will be slowly released from the aggregate when the concrete is no longer under pressure. This may make the mix wetter than it appears when it's discharged from the pump.

There are a variety of pumps available for applications ranging from small residential projects to large commercial jobs. They're ideal for tight job sites. Once set up, pumps with a boom can reach over most obstacles. However, you still need to have adequate access to the site for the concrete trucks to be able to discharge into the hopper of the pump truck.

Crane and Bucket

Using a crane and bucket is another alternative you can consider for placing concrete in forms that aren't accessible to a concrete truck. As with pump units, cranes and buckets are available in many sizes. Crane types range from portable units, which can be brought to the site just for concrete placement, to the tower cranes that have a variety of functions. The bucket capacities are as small as $^1/_4$ yard or as large as 12 yards.

In general, most contractors prefer pumps to cranes and buckets for placing concrete in forms. They have a better range and more precise point of placement.

Concrete Trucks

There are two basic types of concrete mixers, the front discharge and rear discharge. Rear discharge trucks are the most common. The concrete mixing drum is carried on a conventional truck chassis with the concrete discharged from the rear. A drum can be placed on virtually any make of truck in this manner, providing endless combinations. Because of their versatility, a ready-mix operator can buy this type of truck for much less money than a front-discharge truck.

Front-discharge trucks have the concrete mixing drum positioned so that the concrete is discharged to the front, over the cab of the truck. To make this possible, the drum must be placed on a truck chassis designed specifically for this application. Because of its unique design, these trucks are much more expensive and create higher overhead for the ready-mix operator. But they offer a real advantage. With the weight in the rear and the discharge in the front, the operator can get into positions for discharge that would tip a rear-discharge truck. In addition, the operator can monitor the pour from the cab, ready to swing the chutes, move the truck, or adjust the flow as required. A good operator in a front-discharge truck can eliminate one person from the placement crew.

Placing the Concrete

Before starting any pour, make sure that you have adequate tools available, even though tools needed to pour a wall are minimal. The tools required include:

- Shovels for directing the flow from the truck discharge chute to the forms.
- A concrete vibrator to consolidate the concrete and ensure the rebar is fully encased with no honeycombing around blockouts.
- A trowel, usually a float, to finish off the concrete.

In addition to these tools, make sure you have plenty of the anchor bolts or other fasteners you'll need to place in the concrete. You need enough anchor bolts to place a minimum of every 6 feet on center or closer, depending on your local code or foundation design. For residential construction, $^1/_2$- × 10-inch anchor bolts are usually called out, but always rely on your foundation design and local code for these details.

Filling the Forms

When the truck is in place and the operator is ready, ask him to discharge a small amount of concrete into the chute to check the slump and mix. If it's acceptable, the operator can begin filling the forms. You should always have someone in a position to see the concrete as it's discharged into the forms, to divert any overflow into the forms with a shovel. Choose an experienced crew member who can:

- Monitor and direct the pour from this position.
- React to the rate at which the forms are filling.
- Coordinate the speed of discharge with the truck operator.

Consolidate the concrete with a vibrator during the fill. This not only prevents honeycombing, but also promotes the flow of the concrete and cuts down on the effort of moving the concrete in the forms.

As the forms are filled, check to make sure there are no failures in the formwork. If the forms are properly set and in good condition, this requires minimal effort. At the same time, clear away any spills or leakage on the plates or against the forms. If these spills are left to harden, stripping the forms becomes much more difficult, and more likely to cause damage.

The forms need to be "floated" level during the fill and topped out using your established grade line. A float is your best choice to finish off the top of a formed foundation wall. A retaining or decorative wall will need to be floated, edged, and steel troweled. We'll have more information on this a little later.

After the concrete is floated level using the grade line, you need to place the anchor bolts.

Setting Anchor Bolts

Set the anchor bolts by jiggling each one into position. The jiggling movement ensures that the concrete will fully encase the bolt as shown in Figure 18. Center them on the sill plate, spaced according to the plans. That's usually a maximum of 6 feet on center with at least two bolts per sill plate.

When the anchor bolts must be set precisely, such as for steel columns, making a template greatly increases the accuracy of your placement. Make the template from plywood using the dimensions from the drill pattern of the column. Cut the plywood so that you can set it tight to one side of the forms. If you mark a centerline on the template, as well as a centerline on the form, setting the anchor bolt grouping during the pour becomes a simple task of lining up the centerlines, placing the template tight against the side of the form, and jiggling the bolts into position. Figure 19 shows an anchor bolt placement template with the center lines marked.

Flatwork

Flatwork is a term that refers to horizontal concrete pours for items such as patios, driveways, and sidewalks. You can give flatwork a variety of finishes ranging from functional to decorative. As with foundations, placing concrete slabs starts with the layout and formwork.

Forming for Flatwork

You can begin forming for flatwork when the site is rough graded to within 1 or 2 inches. First, set stakes to determine the line, or edge, of the slab. Next, place a string on the stakes at an elevation showing the grade, as in Figure 20. With the string showing the line and grade of the slab in place, you can accurately position the edge forms. Figure 21 shows typical flatwork forms in place. You can use a builder's level or transit for this task, though in many situations a 4-foot hand level with a straightedge or a string level may be all you need.

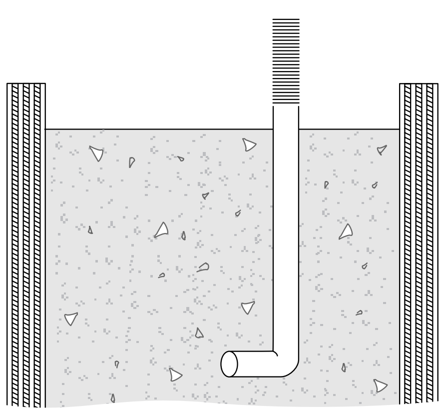


Figure 18
Fully-set anchor bolt

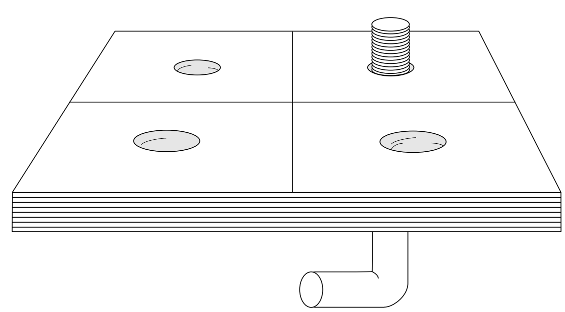


Figure 19
Template used for anchor bolt pattern

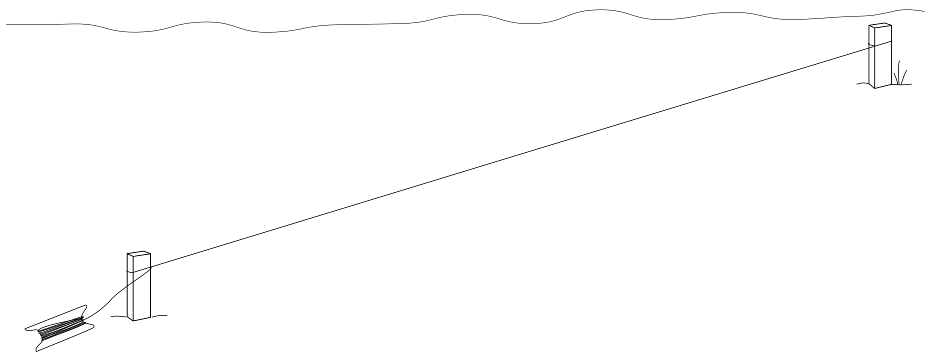


Figure 20
Setting form line with string

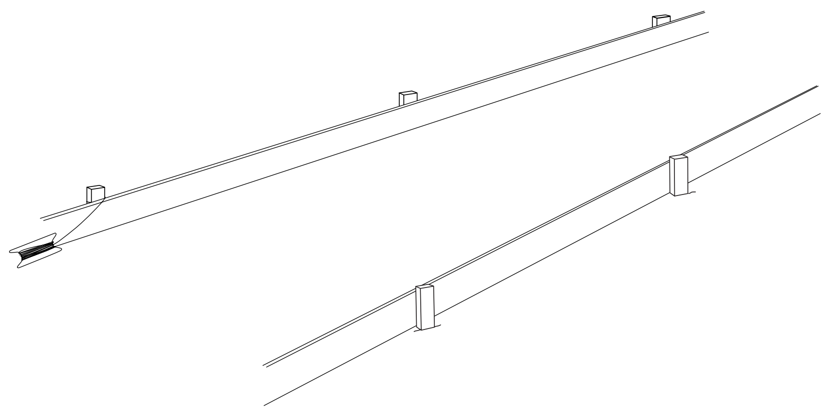


Figure 21
Flatwork forms

Usually, 2 × 4s are used for edge forms, but you may need wider 2-by material depending on the thickness of the slab. Set the 2-bys in place with the string on the inside and the stakes on the outside. Drive the stakes so that the tops are below the top edge of the 2-by. This will keep them out of the way when you're striking off the concrete. Two edge forms are all you need to strike off the concrete on a narrow slab such as the sidewalk in Figure 22.

Using a Screed Pipe to Strike Off

There are two methods you can use to strike off the concrete on a wider placement, like a driveway or basement slab. With the first (and probably the most common) method, you set an intermediate screed. Stretch a string across the edge forms and set the screed supports the depth of the screed below the string. This is best done by first setting the two end supports, and then stretching a string between these two supports to set the remainder.

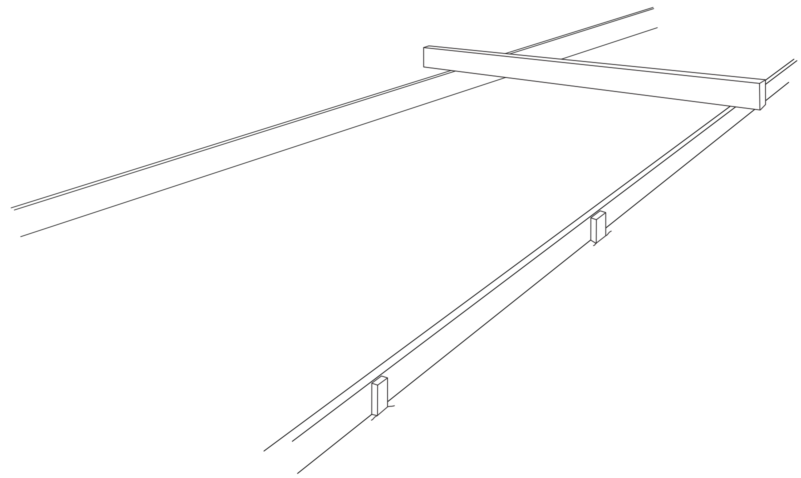


Figure 22
Straight edge used to check depth and screed concrete

With the edge forms and any necessary screeds in place, you can fine grade the base. The first step in fine grading is to bring the base up to or above the final grade level after compaction. (If the base is compacted after final grading, the process will have to be repeated as compaction will lower the base once again.) Establish the grade using the strike-off board and a scraper the depth of the slab (use a 4-inch scraper for a 4-inch slab). With the top of the scraper brushing the bottom of the strike off, remove any base that may be too high. This may seem like a simple job, but accurately estimating the right amount of concrete will be impossible if it's not done well. Unless you need to place reinforcement, the forms are now ready for the concrete.

When using a screed, you need two people to work the strike off, and a third to direct the concrete chute and rake away the excess concrete. Pull the screed straight down the path of the placement in short strokes, lifting the front edge first for each stroke. Don't use a see-saw motion (this is a common problem) as it can cause excess concrete to work up behind the strike off and produce an uneven floor.

Striking Off with Screed Points

The second method of striking off concrete involves a system of point stakes that you lay out in grids approximately 6 feet square (see Figure 23). When you place concrete in this manner, one person works from the middle of the strike-off board and pulls the concrete toward him.

Use Step 1 for placing concrete in an area with perimeter walls, such as a basement. If you're using edge forms, begin at Step 2.

1. Start by placing about 6 inches of concrete along a grade chalk line on the perimeter wall of the first square. Strike it level using your strike-off board (Figure 24).
2. Place about 6 inches of concrete between the wall and stake "A." Going off of the top of stake "A" and the perimeter line, strike this row level (Figure 25).
3. Fill in the area between, using the concrete you just laid as screeds when striking off.
4. Continue to fill the additional squares in this manner, building on each other. This system works well if you don't have a lot of labor, but you need a strong, skilled worker to do it right. A competent worker can place, strike off, and finish slabs, such as garage floors, single-handedly using this method.

When both sides of the screed pipe or the concrete around the screed points have been placed, remove the pipe, or move it forward along with the concrete, or remove the points. Remove the screed supports, and carry concrete in to fill the voids left by the supports and the pipe. After screeding, you may want to use a Roller Bug or Jitter Bug to push the large aggregate down. Leaving only the paste on top makes finishing the surface easier. However, some people discourage this practice because the lack of large aggregate at the top can weaken the surface.

Floating the Surface

Float the concrete as soon after screeding as possible. Besides shaping and smoothing the surface, floating further consolidates the concrete. On slabs, use a bull float first. A bull float is a 3- to 4-foot-wide float with extension handles that you can use to work the surface from the sides while the concrete is still too wet to support a finisher.

Hand float large areas that are too wide to be reached with a bull float. You can hand float the surface off of knee boards as soon as the concrete is firm enough to support both the knee boards and the weight of a concrete finisher.

Hand floats are rigid trowels made from magnesium, wood, or a laminated fiber composite that's thick and ridged. Each material has a slightly different feel, and most concrete finishers develop an individual preference for one type or another. The basic function of the hand float is to "shape" rather than to "finish" the concrete. Use it to flatten any ridges or humps resulting from screeding and bull floating, as well as to create any required ramping or drainage.

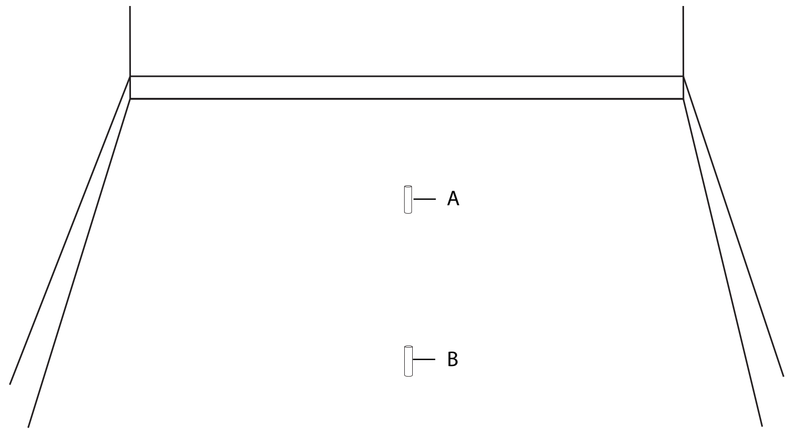


Figure 23
Striking off flatwork using screed points — setup

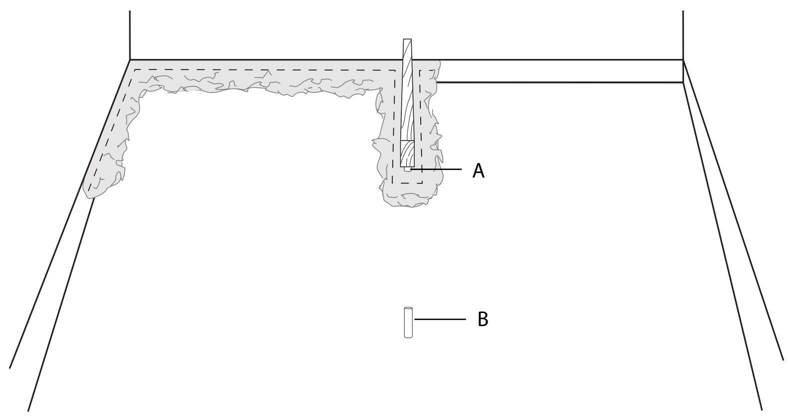


Figure 24
Leveling concrete using screed points

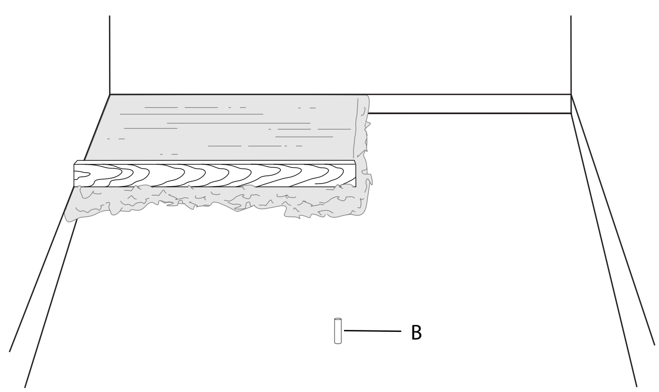


Figure 25
Leveling concrete using screed points

Power Trowel

A power trowel is controlled by raising or lowering the control handle. Raising the handle results in the trowel moving to the left, while lowering the handle results in the trowel moving to the right. This is caused by the counter clockwise rotation of the trowel. Neutral pressure causes the trowel to remain stationary.

Work the hand float in a sweeping half-circle motion. As you move it, it should be at such a low angle that it appears to be flat. Put less pressure on the leading edge than the rear to prevent it from catching and digging in. You can best achieve the float's purpose of leveling, smoothing and consolidating the concrete with this very low angle. If you hold it at a higher angle, it may cause the float to skip, pop up aggregate, or generally make the surface rougher, rather than smoother.

Finishing the Concrete

The final step in finishing a smooth slab is troweling the surface with a steel trowel. The steel trowel is thin, flexible and useful only for providing the final finish on the surface paste of the concrete. To use a steel trowel effectively, the concrete must be "set" to the extent that the paste is still workable when pressure is applied, but firm enough so that the pressure doesn't distort it.

The most important aspect of using a steel trowel is understanding and getting a feel for the most effective angle of the trowel. There are two things to keep in mind: You need to hold the trowel at the lowest angle that produces the desired finish, and the harder the concrete is, the steeper that angle will need to be.

Finishing Concrete with a Power Trowel

You can use a power trowel to finish larger projects, or to reduce labor. Power trowels operate on the same principal of blade angles that you use with steel hand trowels, except you can use the same blade for both floating and final finishing. The blades work as floats when placed in a near flat position. As the concrete hardens, you raise the angle to give a slicker finish. The disadvantage of a power trowel is that if you get on the concrete too early or raise the angle of the blade prematurely, it will cause ripples in the concrete.

Begin power troweling as soon as the concrete is hard enough to support the weight of a person without leaving footprints that are too deep to be covered easily when the trowel is passed over them. Move the trowel back and forth in front of you while you walk backward. That way, you trowel out your foot tracks as you go.

Functional and Decorative Finishes

In addition to the steel-troweled smooth finish already discussed, there are many other finishes that you can apply for either decoration, function, or both.

Functional Finishes

Most functional finishes are textures that create a non-slip surface. The "broomed" finish is a common example of these.

You can vary a broomed finish from rough to fine to suit the use of the slab or flatwork. For a rough finish, you would screed, bull float, and then broom the concrete. You can refine the finish by hand or power floating before brooming. Go over the slab once with a steel trowel before brooming to create an even more refined broom finish. With any concrete finishing method, timing is all important. The further the concrete hardens, the less impact brooming will have on the finish.

A swirl design is another popular and functional finish. You can create a swirl design by first floating to shape the concrete, and then following up with a finish floating using a small circular motion. The result is a decorative finish with a very good non-slip surface.

Exposed aggregate makes another decorative non-slip surface. After the concrete is set, brush the surface with a stiff brush and then wash it with water until you remove enough paste to expose the aggregate.

Decorative Finishes

Decorative finishes include some of those that we've already covered, as well as others whose primary purpose may be decorative even though they're still very functional. You know how easily you can make permanent impression in concrete if you've ever been surprised by a misplaced shoe print or a vandal's initials. By using molds, mats, and stamps, you can give concrete the appearance of a wide variety of stones, bricks, tile, and cobble. Just remember that your timing is critical when using patterns.

Concrete Damage Control

The first and most important step in controlling concrete damage is following proper placing and curing procedures. Maintaining proper slump, using enough reinforcement, removing all surface water before troweling, and following up with careful curing are all important steps in providing a sound slab. Even if you use all these procedures, cracking can and will still occur. But you can control the cracking through the use of control joints and expansion joints.

Control Joints

Control joints are grooves that you make in the surface of the slab to intentionally create weak points in the concrete. When the slab contracts, the cracking takes place along these prearranged weak spots rather than in random patterns in the middle of the slab.

You can make control joints using a concrete groover while you're finishing the concrete or by sawing them into the concrete within 24 hours of placing the slab. Cut the joints to a depth equal to $^1/_4$ of the thickness of the slab. Space sidewalk joints about every 4 or 5 feet. For larger slabs, space the joints from 12 to 25 feet apart, depending on the temperature variations in the area where you're working and the hardness of the aggregates you use. The greater the temperature variations or the softer the aggregate, the closer together the control joints need to be. The spacing should be called out on your project construction documents.

Isolation Joints

Use isolation joints, or expansion joints, whenever a slab comes in contact with existing concrete or where you may have concern about vertical and horizontal movement. This includes basement walls, concrete steps, columns, and joints between the curb and gutter and sidewalks.

Isolation joints are expansion strips typically made of bitumen-saturated materials resembling asphalt-impregnated composition sheathing. Set them into position before you place the concrete. Strips are sold in widths corresponding to common slab thicknesses, with non-bitumen saturated strips available for use in areas that aren't directly exposed to weather. Figure 26 shows a sidewalk with expansion joints.

Protecting Concrete Pours

The ideal temperature for placing concrete is 55 degrees Fahrenheit. At this temperature it cures to its highest strength. Because you'll rarely be working under ideal weather conditions, you'll need to make

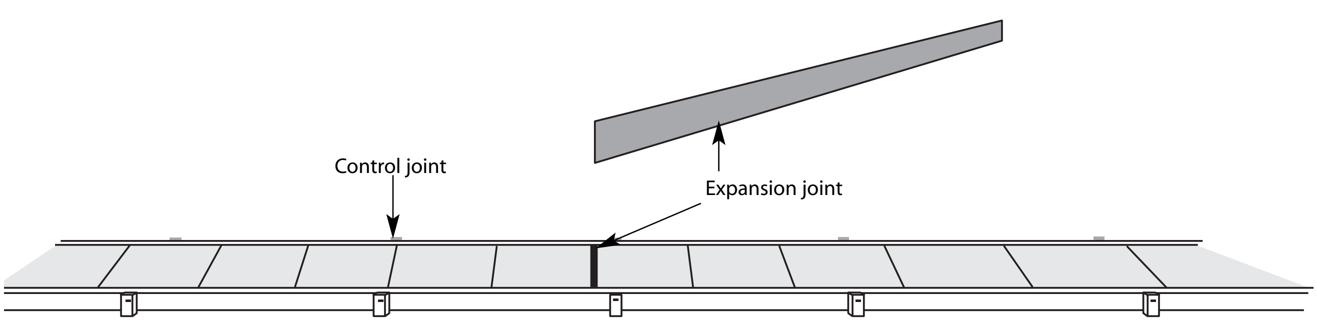


Figure 26
Expansion joint in sidewalk

preparations for cold or hot weather pours, as well as for other factors such as humidity and wind, that influence the workability and set time of concrete.

Cold Weather Pours

For placing concrete, cold weather is usually considered to be anything below 40 degrees Fahrenheit. The problems associated with cold weather placement include slow setting and curing times and greater labor expense due to the efforts required to prevent the concrete from freezing.

A slow set time is an aggravation because it delays finishing. However, if you can keep the concrete from freezing, slow curing in cool weather appears to actually boost the strength and durability of the concrete. Although its early strength is degraded from the cold, after 28 days concrete placed in cold weather is found to have higher strength than concrete placed in warm (over 70 degree) weather. The danger lies in freezing, which is disastrous to new concrete.

Once it's frozen, no matter how hard it freezes or how long it remains frozen, you'll have to replace the concrete. You can test concrete to see if it has frozen by pouring hot water over it after it has cured. If the concrete has cured properly, the hot water will have no effect. But if the concrete has frozen when setting, it will soften up on the surface.

Concrete should *never* be placed in contact with snow, ice, or frost. Always protect your forms and reinforcement from frost and make sure you clear away any frost if it does occur.

During the fall, in periods of warm days and cold nights, you can keep frost out by covering the ground or the top of the forms during the night. Once you place the concrete, cover both the concrete and formwork for at least three days. You can cover the concrete and formwork with:

1. *Plastic sheeting.* Cover the ground and newly poured concrete with plastic (or visqueen) during periods of light frost.
2. *Blankets.* Concrete blankets are the next step in protection. They have an insulating foam liner and are available with varying R-values.
3. *Tenting.* In continuously cold weather, you may have to tent the project, usually with visqueen, and maintain the temperature inside the covered areas with space heaters. You have to be careful when using space heaters. They can start fires, or overheat sections of the concrete and cause premature drying.

Cold Weather Concrete Mix

Another method of protecting your concrete pour during cold weather is to adjust the concrete mix. There are several ways you can do this.

- Using *heated water* is the most practical method of raising the temperature of the concrete mix, as well as the most cost effective.
- *Admixtures* are available which will accelerate the concrete set time as well as its early strength gain. Avoid using calcium chloride with reinforcing steel.
- *Type III high-early-strength portland cement* generates high heat as it cures as well as curing faster; both are advantages in cold weather.
- *Air entrainment* improves the freeze-thaw resistance of hardened concrete. As the water in concrete freezes, it expands, causing pressure that can rupture the concrete. The entrained air voids act as reservoirs for excess water, thus relieving pressure and preventing damage to the concrete.

Placing concrete in cold weather requires the normal equipment for placement plus special equipment to deal with the cold. Use a thermometer to verify the temperatures and help you determine the amount of protection you need. You may also need protective materials, such as plastic sheeting, blankets, tenting equipment and heaters. You should have everything you need on hand, for whatever the stage of protection required, before you begin the placement.

Cold Weather Curing

Curing concrete in cold weather presents a unique set of problems. You must keep moisture in the concrete for proper hydration to continue, but as long as moisture remains in the concrete, it's susceptible to freezing. Because evaporation is slower during cold weather, keeping the moisture in during the curing period is usually not a problem. Covering or tenting usually provides adequate moisture protection during the curing time. But if you're supplying artificial heat in a tented situation, be sure to protect the concrete from direct heat that would cause premature drying in isolated areas.

Hot Weather Pours

You can begin to experience hot weather concrete placement problems as temperatures reach about 90 degrees F. In addition to the temperature, humidity is also an important consideration. For example, low relative humidity (below 25 percent) and high temperatures create a placement situation that can only be made more difficult with the presence of wind.

Problems associated with hot weather placement include quick setting, surface drying while finishing, surface cracking, and strength loss. And if you add low humidity and wind, all these problems happen faster.

The key to a successful hot weather pour, as with any concrete placement, is careful preparation. You can counteract the effects of the heat through the mixing and delivery process, site preparation, and the curing process.

Mixing Hot Weather Concrete

Using cold water is one of the easiest methods of keeping the concrete mix temperature down. In extreme cases, you can even add crushed ice. You should keep the aggregates cool by shading them whenever possible, and sprinkle them frequently with enough water to promote cooling through evaporation. Be careful, however, not to saturate them to the point that they absorb and store the moisture. That would cause the mix proportions to be off.

Ready-mix plants located in hot weather areas can keep mixes cooler in transit by using white mixing drums. They've found that white drums keep the mix temperatures as much as 25 degrees lower than dark drums that absorb heat. They can also keep temperatures down by draping the drums with wet canvas or misting them with water to promote evaporative cooling.

Cooling the Site

Flatwork is at higher risk during hot weather than concrete placed in formwork. Concrete placed in formwork normally requires less finishing, has less exposure to the wind, and consequently is at less risk of being damaged. However, you should prepare both flatwork and formwork sites for hot weather pours to help lower the risks. To cool the sites:

1. Spray water on the forms and reinforcing to cool them down.
2. Spray water on the subsurface base to prevent premature loss of water from the concrete.
3. Shade the entire site if possible, especially the flatwork areas. This helps prevent sun exposed portions from setting faster than protected or shaded areas. Uneven setting creates finishing headaches; one portion may be ready for finishing while another in the same area may not be.
4. Have hoses and nozzles available to fog the site. Fogging lowers the temperature and raises the humidity, which slows the evaporation of the moisture from the mix.

Hot Weather Curing

The primary focus in hot weather curing is to prevent premature drying caused by high temperatures and/or wind. We know that concrete cured at high temperatures doesn't cure to the same strength as concrete cured at the ideal temperature of 55 degrees. We also know that premature drying also inhibits curing. While on most jobs it's difficult, if not impossible, to control the temperature, you *can* control the moisture.

There are hot weather curing methods that prevent the moisture from evaporating prematurely. The ideal hot weather cure is a water cure, which not only retains the moisture during the curing period, but also helps keep the concrete temperature down. You can either apply the water by spraying as shown in Figure 27 or by ponding.

Another way you can prevent moisture loss is to apply a sealing compound as soon as possible to trap the moisture in the concrete. A white sealant is best, applied by hand or with spray equipment. White reflects the sun and lowers the surface temperature of the concrete.

Whichever method you prefer, keep in mind that you can't neglect proper curing during high temperature periods.

Moisture Protection for Finished Concrete

Protecting a foundation from excess moisture is necessary to protect the habitable spaces as well as to protect the foundation itself from failure. You can provide moisture protection by applying a dampproofing or waterproofing coating to the concrete, or by diverting water and excess moisture away from the foundation with surface or subsurface drainage.

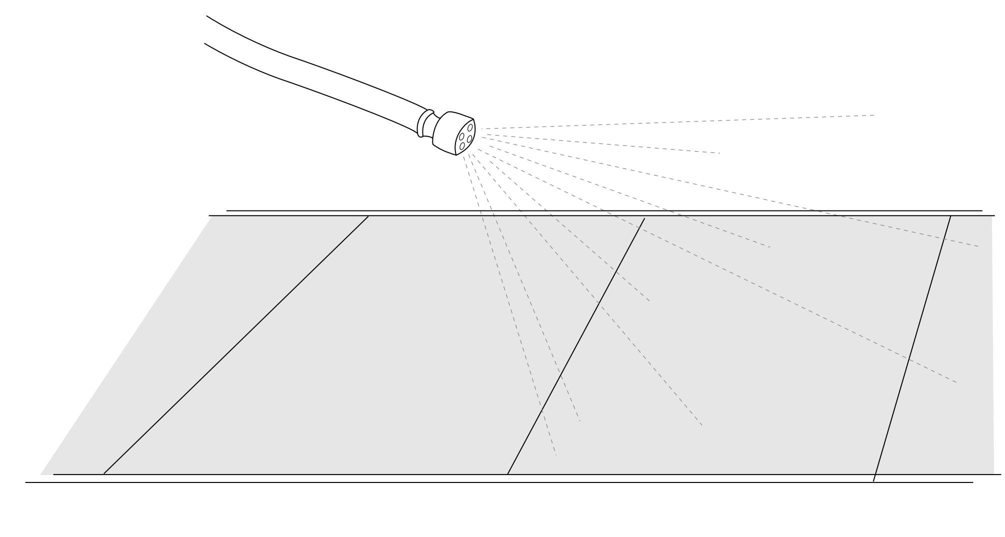


Figure 27
Use fogging nozzle on hose to add moisture to new concrete

The first step in providing a dry environment below grade is to build a tight foundation free of voids or honeycombing, especially around joints where leaking is most likely to occur. A foundation designed for the structure and soil conditions, properly placed and reinforced, will greatly reduce if not eliminate cracking, which is a common source of leaks.

The next step in providing a dry environment is dampproofing or waterproofing. Those terms are frequently used interchangeably. While they are very similar, and their object is the same, they are different in the type of moisture they work against. Waterproofing blocks all water, even water that's under pressure (water under pressure is often referred to as a hydrostatic head). Dampproofing blocks water that isn't under pressure (capillary moisture). Figure 28 lists types of dampproofing and waterproofing systems and their applications.

While waterproofing and dampproofing are different concepts, both are designed to produce a dry environment. The way you'll provide a dry environment for any project is generally based on the potential for hydrostatic pressure. Usually the project architect or engineer specifies the type of moisture protection you'll need after reviewing the

System	Application	Types	Purpose
Liquid membranes	Single or multiple coats; trowel, brush, roll or spray	Asphalt, coal tar, elastomeric (neoprene, urethane and PVC), vinyl acrylic, crystalline formations and other patented formulas	To resist or block water penetration under capillary and/or hydrostatic pressure. Apply liquid membranes with total coverage, including the top of the footing. If pinholes appear, apply a second coat whether or not the system requires it. Cover all bubbles or other irregularities in the concrete.
Sheet membranes	Single or multiple layers, as per manufacturer's guidelines	Asphalt or coal tar saturated fabric, bitumen, PVC, polyurethane, bentonite and other patented products	To block moisture under hydrostatic pressure. Lap sheet membranes as specified by the manufacturer. Patch any tears or punctures occurring in the membrane. Any break in the surface may allow water to pass through, damaging the protective ability of the system.
Hydrostatic pressure relief systems	Per manufacturer's guidelines	Proprietary drain boards	To reduce or eliminate hydrostatic pressure.

Figure 28
Common dampproofing and waterproofing systems

results of the soils report. On projects not involving an architect or engineer, and where ground moisture wasn't encountered during the excavation, most contractors will choose to dampproof.

Dampproofing

Basic dampproofing consists of a liquid or emulsion, based on asphalt or tar, that's sprayed, brushed, or rolled onto the foundation. You can apply some dampproofing products in one step, while others are two-step systems with a primer coat and seal coat. Depending on local conditions, you can add a few other items for insurance, such as a 6-mil polyethylene sheet applied over the coating, and a seal placed at the joint where the foundation wall meets the footing.

Waterproofing

Waterproofing systems are usually all-inclusive systems designed by manufacturers for installation with particular materials. The materials and guidelines for installation vary from manufacturer to manufacturer. Many of these systems are similar to built-up roofing, involving multiple layers of either matting and emulsion, sheeting or liquid membranes. The deeper the foundation, the greater the potential water pressure, and the more elaborate waterproofing system you may need.

You must install any of the proprietary waterproofing systems in strict accordance with the manufacturer's guidelines. However, a number of general guidelines apply to nearly every situation.

- Almost all systems require a smooth surface.
- Any honeycombing, joints, voids or other irregularities should be filled.
- Some systems can be applied to green concrete; others require the concrete to be cured and dried. You must know and follow the system's requirement.
- Protect the coating or membrane during backfill to prevent opening the surface to water penetration.

Water Diversion

Keeping water away from the foundation is imperative, both to protect a foundation from failure and provide a dry environment inside. With proper surface drainage, you ensure that water is carried away from the structure, preventing the soil next to the structure from becoming saturated. Subsurface drainage collects and carries water away from the base of the foundation before it can saturate any supporting soils and weaken the foundation.

Surface Drainage

All foundation protection should include draining surface water away from the structure. You need to maintain positive drainage for a minimum of 10 feet from the structure. See Figure 29. There should be a minimum 2 percent gradient in paved areas and a 10 percent gradient in landscaped areas. Make sure that lawn sprinklers are installed at least 5 feet away from the structure.

Subsurface Drainage

Drainage at the base of the foundation, which in most cases is the footing, is important for protecting the total integrity of the foundation. If the supporting soils become saturated, soften, and lose their supporting capacities, the foundation will fail. Place perimeter drain tiles in the footing to collect and carry off subsurface water and prevent saturation.

You can use 4-inch clay tile or perforated plastic pipe for the perimeter drain. Figure 30 shows a subsurface perimeter drain using perforated pipe. It's usually placed at the base of the footing, encased in gravel and filter fabric. If the terrain has a suitable slope, you can run the drain to daylight. Where this isn't possible, collect the water in a sump well and pump it to the surface with a sump pump.

Cutting, Coring, and Drilling Concrete

You may need to make alterations in new or existing concrete to accommodate errors, changes in plans, or for remodeling work. You can cut, saw, core and drill concrete to allow for electrical conduit runs, plumbing runs or other materials if blockouts were missed during the pour, or not made during the original concrete placement.

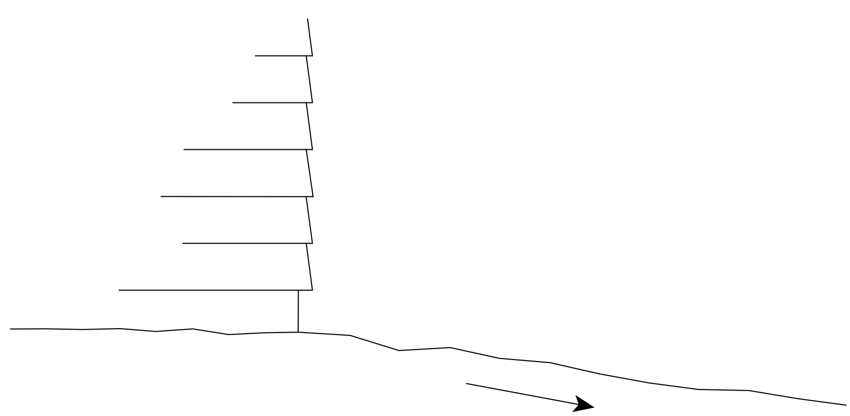


Figure 29
Maintain positive surface drainage

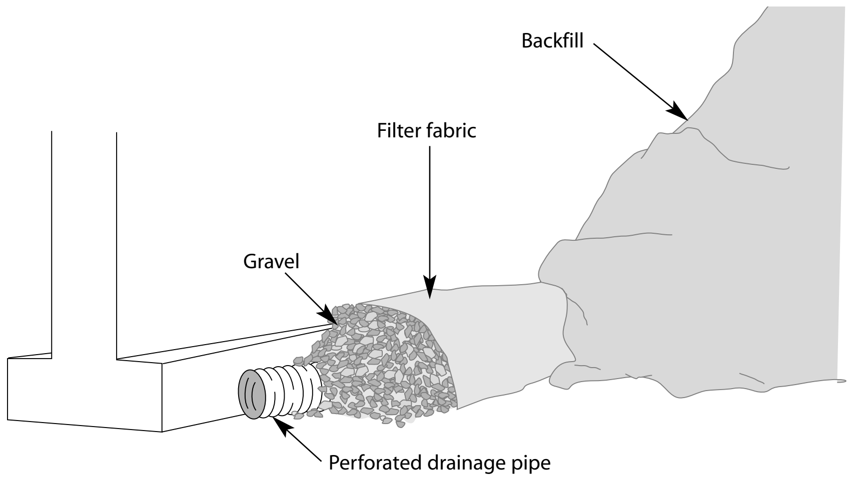


Figure 30
Subsurface drainage system

Cutting

There are a variety of tools that you can use to cut concrete. Jackhammers, both electric and pneumatic, will cut concrete. The usual jackhammer points are best suited to demolition and penetration. Chisel points, from narrow to wide, provide better control for cutting.

Sawing concrete gives you greater control and cleaner results for concrete removal than using a jackhammer. Use saws for tasks such as cutting control joints in slabs, or cutting a doorway or window in an existing concrete wall. Both gasoline and electric concrete saws are suitable for light duty sawing. You can get carborundum or industrial diamond concrete cutting blades for them. Diamond blades are considerably more expensive, but their cost is offset by their longer wear.

"Demo" saws with 14-inch blades are good for cutting through wall sections. Since you make most vertical cuts without water, these cuts create a large amount of dust. Wear goggles and a particle mask to protect your eyes and lungs from dust, and provide dust protection for the surrounding areas as well.

Gasoline-powered walk-behind saws with water to cool the blade are your best choice for cutting flatwork. They have good stability and can produce nice deep cuts, or long straight cuts like those used for control joints, with only a chalk line as a guide.

Drilling and Coring

Drilling and coring concrete are similar processes, and for all practical purposes, they accomplish the same task. Concrete drill bits are generally only available in sizes up to 2 inches in diameter, but core bits are available in much larger diameters. Your choice of drilling or coring will usually be made based on the size of hole that you need. However, in some cases it's the core you need, not the hole. A core bit saws a circular plug in concrete in the same manner that a hole saw does in wood. You can use a core bit to obtain the core samples needed to test existing concrete.

Testing and Inspecting Concrete

Testing and inspecting concrete begins before the concrete is mixed and is completed a month after it's placed. The tests and inspections range from none, on residential projects in some rural areas, to full-time inspectors with on-site labs on large commercial and industrial projects.

Typically, most placements include an inspection of the footing and foundation wall by a local building official. Their primary focus is to ensure that you adhere to the local engineering requirements. Inspections and tests can be done before, during, and after placement, and may involve off-site inspections of proposed materials as well as on-site inspections of the materials in place.

Prior to Placement

Off-site inspections prior to placing the concrete involve documenting the mix designs and the inspection, sampling, and testing of the proposed materials. Samples are taken to verify the quality of these materials. Aggregate samples are the most common taken, which are sampled for size ratio, hardness, and porosity. Water samples may also be taken if the purity of the water seems questionable. The tests and samples are made or monitored by the project's supervising engineer.

On some projects, the concrete supplier needs to submit documentation of the mix design and contents to the supervising engineer. Cement and admixture vendors have engineering reports from independent labs that verify the contents of their products, as do the larger aggregate suppliers. Your concrete supplier should make these reports available to the engineer.

On-site inspections prior to placing concrete center around the formwork, with the main focus on the placement of reinforcing. The inspector needs to verify that you place the reinforcement in accordance with the project's engineering requirements.

Inspections and Testing During Placement

Slump testing is the most common test done on concrete. It's also one of the first and most important tests for the concrete worker or contractor to understand. The design strength of a given mix will be lost if the slump is exceeded. The slump is determined using a numerical grading system; the higher the number grade of the slump, the more liquid the mix. A concrete mix that's too liquid won't be as strong as the same mix with less water. When it dries, the wetter concrete will be less dense, and therefore weaker.

Proper testing follows a very exacting procedure. The slump is measured by placing concrete in a 12-inch-high metal cone that has an 8-inch diameter at the base and a 4-inch diameter at the top. A rod is placed over the top of the concrete cone. When the metal cone is removed, the distance the concrete "slumps" or settles below the rod is measured (Figure 31). That measurement is referred to as the concrete's slump. As you can easily guess, the wetter the concrete, the more it will settle, and the greater the slump. The dryer the concrete, the less it will settle. A 2-inch slump is considered dry concrete; a 6-inch slump is wet concrete; and a 4-inch slump is considered standard.

For projects without a slump specified by a project engineer, 4 inches is the expected slump. It's helpful if you become familiar with what a 4-inch slump looks like coming out of a chute.

Project engineers often require test cylinders for testing the compressive strength of the concrete. You should take the samples in sets of two; the compressive strength will be the average of the two cylinders. The 1997 *Uniform Building Code*, in section 1905.6.1, outlines the frequency of testing as follows:

1905.6.1.1 Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, or not less than once for each 150 cubic yards of concrete, or not less than once for each 5,000 square feet of surface area for slabs or walls.

1905.6.1.2 On a given project, if the total volume of concrete is such that frequency of testing required by Section 1905.6.1.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

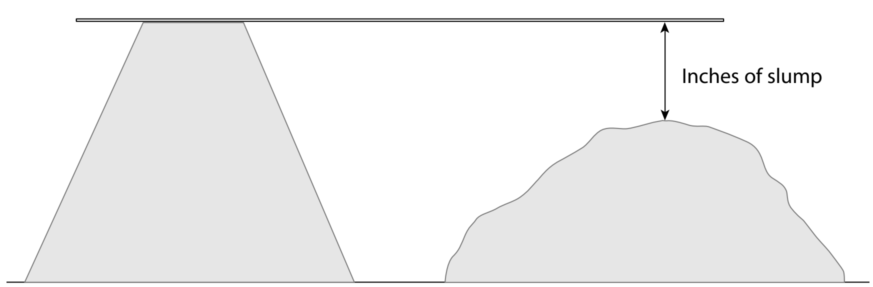


Figure 31
Measuring slump

1905.6.1.3 When total quantity of a given class of concrete is less than 50 cubic yards, strength tests are not required when evidence of satisfactory strength is submitted to and approved by the building official.

1905.6.1.4 A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of f'_c. (f'_c is the specified compressive strength of concrete, given in psi.)

You can also find information on the evaluation of concrete in the 2003 *International Building Code* under section 1905.6.

The test cylinders are 12 inches long and 6 inches in diameter. They can be made of a variety of different materials as long as they conform to ASTM C 470. The cylinders are filled with concrete, cured, and then compressed until they break to determine the concrete's compressive strength. The standard cure time before breaking is 28 days, though tests may be made on additional samples before that time to monitor the strength gain over time.

Testing Existing Concrete

When new concrete is being batched, its individual ingredients can be tested or verified and cylinders filled in preparation for compression tests. Occasionally, existing concrete also needs to be tested to verify the strength of an existing foundation, or more likely, to verify the concrete strength of a foundation that has failed. There are a few different tests used to determine the strength of existing concrete.

Coring. You can test existing concrete for compressive strength by breaking a test cylinder, in the same manner a sample is broken during new construction. The difference is in the manner the sample is taken. The samples of existing concrete are created by coring sample cylinders from the concrete in question (refer back to Drilling and Coring).

Swiss hammer. A Swiss hammer is designed to give a strength reading for existing concrete without leaving any visible effects. It's a spring-loaded device that strikes the concrete with a steel plunger. It measures the rebound of the plunger to determine the strength of the concrete. While a Swiss hammer can be helpful, it isn't as accurate as a cylinder break. You need to make multiple tests and then come up with an average for the results. Fifteen tests with a Swiss hammer are recommended, with the top ten being averaged.

Windsor probe. A Windsor probe works in much the same manner as a Swiss hammer. A powder-actuated probe is shot into the concrete leaving a measurable indentation, rather than bouncing off the surface like the spring-loaded probe.

Manhours

Manhours to Place Ready-Mix Concrete, per CY		
Job Type	**Manhours**	**Suggested Crew**
Footings & foundations (no forms, finishing or reinforcing included)		
Direct from chute	.564	1 laborer
By pump (trailer-mounted, 30 CY/hr)	.125	1 carpenter, 2 laborers
With buggy	.701	1 laborer
Slabs on grade (no forms, finishing or reinforcing included)		
Direct from chute	.430	1 laborer
By crane (60 ton crawler crane)	.594	1 carpenter, 3 laborers, 1 crane operator, 1 truck driver
By pump (mounted-mounted, 20 CY/hr)	.188	1 carpenter, 2 laborers
With buggy	.543	1 laborer
Slab finishing		
Float finish	.009	1 cement mason
Trowel finishing		
Steel, machine work	.014	1 cement mason
Steel, hand work	.017	1 cement mason
Broom finish	.012	1 cement mason
Scoring concrete finish, hand work	.005	1 cement mason
Driveway aprons (includes forms & finishing, but no site preparation)		
4″ thick (80 SF per CY)	.024	1 carpenter, 1 laborer, 1 cement mason
6″ thick (54 SF per CY)	.032	1 carpenter, 1 cement mason, 1 laborer
Walkways (placed by chute from truck, broom finish, scoring, no forms or reinforcing)		
4″ thick (80 SF per CY)	.013	1 cement mason, 1 laborer
Add for steel trowel or aggregate finish	.011	1 cement mason
Steps on grade, 6″ rise & 12″ tread (placed by chute from truck, includes forms and reinforcing)	5.43	1 carpenter, 1 laborer

Manhours for Forming			
Type	**Unit**	**Manhours**	**Suggested Crew**
Footings (4 uses) 2″ x 6″ 2″ x 8″ 2″ x 12″	LF LF LF LF	 .116 .130 .145	2 carpenters, 1 laborer 2 carpenters, 1 laborer 2 carpenters, 1 laborer
Wreck & clean 2″ x 6″ 2″ x 8″ 2″ x 12″	LF LF LF LF	 .051 .056 .061	 1 laborer 1 laborer 1 laborer
Foundations, 8″ or 12″ thick (12 uses) 4′ high, make, erect & coat Wreck & clean 8′ high, make, erect & coat Wreck & clean 12′ high, make, erect & coat Wreck & clean	 SF SF SF SF SF SF	 .169 .048 .194 .058 .215 .068	 4 carpenters, 1 laborer 2 laborers 4 carpenters, 1 laborer 2 laborers 4 carpenters, 1 laborer 2 laborers
Slab on grade (4 uses) 2″ x 4″ (4″ thick slab) 2″ x 6″ (5″ or 6″ thick slab) Wreck & clean 2″ x 4″ 2″ x 6″	 LF LF LF LF	 .045 .045 .025 .026	 2 cement masons, 1 laborer 2 cement masons, 1 laborer 1 laborer 1 laborer
Walkways, per side 2″ x 4″ or 2″ x 6″ edgeform 2″ x 8″, 2″ x 10″ or 2″ x 12″ edgeform	 LF LF	 .050 .055	 2 carpenters, 1 laborer 2 carpenters, 1 laborer

For more information on related topics, see:

Brick Masonry, page 51
Concrete Block, page 189
Concrete Reinforcement, page 201
Flooring, page 359
Porches and Decks, page 485
Stone Masonry, page 655

Concrete Block

Concrete block is the workhorse of masonry. Nearly two-thirds of all masonry walls built today are made of concrete block. And for good reason. It's cheaper to buy and faster to lay than either brick or stone masonry. It also offers several attractive alternative surfaces: smooth like tile, rough to imitate stone, color and texture to simulate adobe, and patterned to dress up an otherwise inexpensive, utilitarian wall.

Concrete block is just what its name implies: blocks of concrete, or more specifically, portland cement and one of a variety of aggregates. The aggregate used to make the block determines the finished texture, color and weight.

Size and Grades of Block

Hollow, standard block comes in two weight sizes. The heavier block, or structural block, is made with a heavy aggregate such as sand, gravel, or crushed stone. They weigh between 40 and 50 pounds each and have a compressive strength from 1,800 psi up to 3,000 psi.

Lightweight blocks only weigh between 25 and 35 pounds each because they're made from lighter weight aggregates such as clay, volcanic cinder, or pumice. Their compressive strength is lower as well, in the range of 700 to 1,800 psi. Although both are very durable, you shouldn't use lightweight block for walls over 9 feet high.

Even if lightweight block is initially more expensive than standard block, it may be cheaper in the long run because you can lay it about 10 percent faster. The larger the job, the more labor savings you can achieve with the lighter block.

Block Dimensions

As with brick, the measurements are always given in the same sequence: width, height, then length. They are generally in nominal sizes rather than specified sizes. Nominal size includes an allowance for a $^3/_8$-inch mortar joint; specified size is actual block size without mortar.

Although concrete block comes in a variety of sizes, the most basic unit, appropriately called standard block, is 8 × 8 × 16 inches. Its size makes estimating and laying standard block faster and easier than brick. For every concrete block you lay in a single-wythe wall that's the same width as brick, you'd have to lay almost 12 bricks.

Grades

There are only two grades of concrete block, Grade N and Grade S. Use Grade N for exterior walls, both above and below grade. It can tolerate exposure to moisture and freezing. Grade S is designed for interior walls and above grade exterior walls that have weather-protective coatings.

Estimating Concrete Block

Block is conveniently manufactured in multiples of 2 or 4 inches. Widths are 4, 6, 8, 10 and 12 inches; heights are 4 and 8 inches; and lengths are 8, 12 and 16 inches.

Knowing this, it's easy to estimate the exact number of blocks you'll need for a given project. First, determine the length and height of the wall. If you're using standard brick (8 × 8 × 16), use the following steps.

1. Multiply the height by 1.5 to find out the number of courses you'll lay.
2. Multiply the length by .75 to determine the number of blocks per course.
3. Multiply A times B to find out the number of blocks for the wall.

If you're using standard block (8 × 8 × 16) to build a wall that's 10 feet high and 10 feet long, your figures will look like this:

10 × 1.5 = 15 (courses)

10 × .75 = 7.5 (blocks per course)

15 × 7.5 = 112.5 blocks

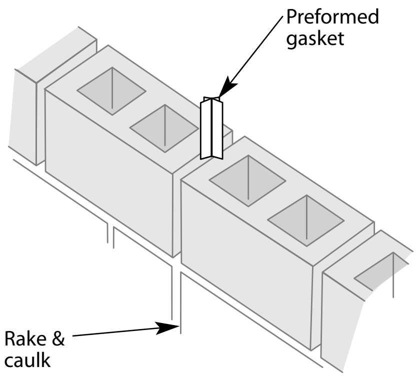


Figure 1
Typical control joint

Rather than spend time cutting blocks in half, you can buy half blocks (8 × 8 × 8). Of course, you'll also need to deduct for any openings and allow about 5 percent for breakage, but this formula will get you as close to the exact number as you can get.

Mortar for Concrete Block

You mix mortar for block in the same way as for brick (refer back to Brick Mortar on page 58). However, concrete block doesn't absorb water like a fired clay brick does. Make your mortar mixture with less water than for brick masonry; the mortar should be slightly stiffer, about the consistency of stiff butter.

Refer to Brick Mortar Types on page 60 to determine whether to use Type M, Type S, or Type O mortar mix. If you're building a reinforced block structure, use either Type M or Type S. Use either masonry cement or Type I or Type II portland cement in the mix.

Control Joints

Because temperature changes cause concrete to shrink and then expand again, use control joints to compensate for these changes. A control joint is a vertical separation in a wall that prevents the wall from cracking or breaking apart. You can use something as simple as a 1- × 6-inch redwood board, or you can buy special gaskets or preformed blocks to use for control joints. There are special notched half- and full-length blocks that you can use so that the vertical joints can run the full height of the wall without interruption. Whatever you use, place the control joints every 16 feet. Also, rake the mortar out of the vertical joint and caulk it. Figure 1 shows a typical control joint using a preformed gasket.

Laying Concrete Block

Laying concrete block is very similar to laying brick. However, there are a couple of important differences. First, concrete block should be dry when laid. The block will still absorb moisture from the mortar, but unlike brick, the rate of absorption isn't enough to affect the bond between the mortar and block. Lightweight blocks absorb 7 to 16 pounds of water per cubic foot of cement. Structural blocks absorb less, around 4 to 5 pounds per cubic foot. If you have trouble getting the mortar to stick to a block, wetting the block before buttering it should help, but it isn't necessary for the whole batch of blocks. Another difference between laying concrete block and brick is the need for reinforcement from the foundation up.

Tools and Materials

- *Chalk line*
- *Mason's line*
- *Level*
- *Story pole*
- *Rubber mallet*
- *Corner block holders*
- *Rebar, vertical and horizontal*
- *Joint reinforcement*
- *Control joints*
- *Metal lath*
- *Concrete block*
- *Mortar*
- *Trowel*

As with any masonry, a solid foundation is essential. Even with lightweight block, 100 square feet of 8-inch block weighs at least 2,500 pounds. Your foundation should extend below the frost line and be at least twice as wide as the wall. Allow the footer to cure for several days before building on it.

1. Snap a chalk line on the footer to mark the front of the wall. Slip the corner blocks over the foundation rebar. Dry lay the rest of the first course of blocks, allowing $^3/_8$ inches between blocks for the mortar joints. Use your finger or a piece of plywood to quickly and evenly space the brick. After you've spaced the blocks to fit, use a wax crayon to mark the position of the corner blocks.
2. Remove all of the blocks except for the corner ones.
3. Mix a small amount of mortar and bed the corner blocks so that the mortar is no more than 1 inch thick under the blocks.
4. Attach corner block holders from one outside corner to the other with a mason's line between them. Hang a line level on the string. Using your level and mallet, tap the blocks into place so that they're level in all directions. The mortar under the blocks shouldn't be less than $^3/_8$ inch or more than 1 inch at this point.
5. Trim the excess mortar, and strike the joint with a convex or V-jointer. Let the blocks set up for an hour or more.
6. Next, mix enough mortar to lay the first course of block. Working from both ends toward the center, spread and furrow a 1-inch thick, 3-inch long mortar bed. Butter the flange (the U end) of a block, and lower it over the rebar. Butt it up against the first block by slightly lifting the buttered end and shoving it against the end. Use your level with each block to make sure that it's plumb in every direction and in line with your string.
7. Allow the first course to set for an hour or more. Begin the next course in the least conspicuous corner or end. Step back the end by starting the next course with a half block, followed by two full blocks. If you're using horizontal joint reinforcement, bed it in mortar. Begin the next course with a full block. Continue to level each block and check it against your story pole. Your story pole should be marked at 8-inch intervals; the standard height for one course of block plus mortar (see Figure 2).
8. Build up a lead at the other end in the same manner. Move up the corner block holders and lay the next course. Continue with the horizontal joint reinforcement on every other course.
9. Scrape off excess mortar as you work. When the mortar is thumbprint hard, tool the joint with a convex or V-jointer.

Finishing Off the Wall

How you finish off a concrete block wall depends on the type of wall you're building.

Garden Wall

1. For the top course, lay channel, or bond beam, blocks with the U side up. Cut the vertical rebar to about 1 inch below the top of the channel. Wire $^1/_2$-inch horizontal rebar to the vertical rebar the entire length of the wall.
2. Grout all the cores that hold vertical rebar. Then grout the channel blocks.
3. Mix a fresh batch of mortar and lay cap blocks over the channel blocks.

Foundation Top

1. Before laying the top course, grout all the cores that hold vertical rebar.
2. Place metal lath on this course in a bed of mortar. Then lay the final course and grout all of the cores.

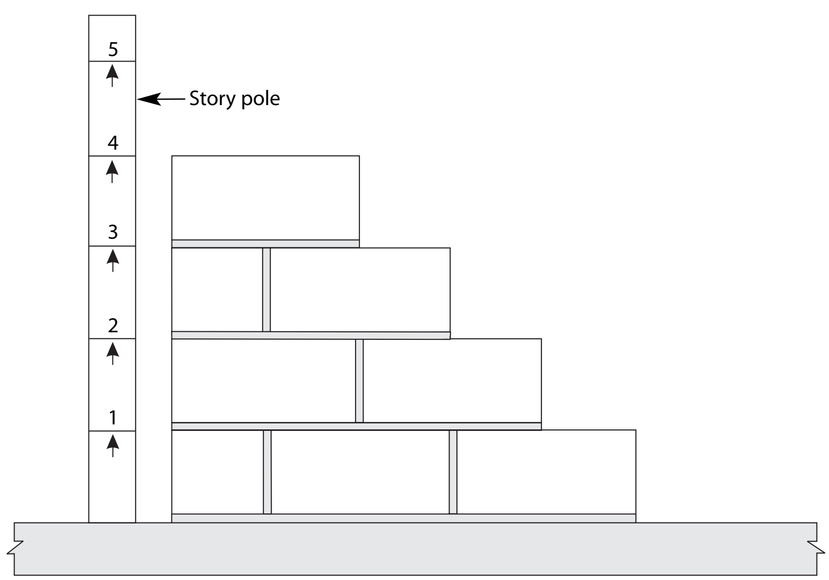


Figure 2
Check each course against story pole

Sill Plates

1. Two courses from the top, grout all the cores that hold vertical rebar.
2. Place metal lath on this course in a bed of mortar.
3. Lay two more courses of block. Place 18-inch long, $^{1}/_{2}$-inch diameter anchor bolts in the top two courses. Grout the cores that hold the anchor bolts and the vertical rebar.

Concrete Block Reinforcement

Depending on your geographical region and the kind of structure you're building, your concrete block may need reinforcement. This is particularly true of earthquake zones and high wind areas. Check with your local building department for requirements.

Although rebar comes in 20-foot lengths, no one wants to have to place a concrete block over 20 feet of steel. The solution is to cut the steel into manageable lengths and splice pieces together. To splice, the pieces must overlap by 30 times their diameter. So two pieces of $^{1}/_{2}$-inch rebar will need to overlap 15 inches. Tie these pieces at a minimum of three points along the overlap, and wrap each tie at least three times around the bars.

The steel must also have a minimum mortar coverage: at least $^{3}/_{4}$ inch or the diameter of the steel, whichever is greater. Set joint reinforcements in at least $^{5}/_{8}$ inches mortar.

Placing Reinforcement

Reinforcing concrete block is really a two-step process. Place steel rebar vertically in the foundation when it's poured (see *Concrete Reinforcement*) and in the concrete block cores of every other block as you lay the blocks (Figure 3).

In some structures, you'll also need to place rebar horizontally using specially-formed blocks with hollow channels called *bond beam blocks*. Lay a course of reinforced bond beam blocks at the top of the wall to give it added strength. Another kind of horizontal joint reinforcement uses special girder-type ties, such as a ladder or truss joint reinforcement. Use this kind of reinforcement every other course, overlapping the wires by the length of one block.

Reinforcing Decorative Block

For decorative blocks like screen blocks, you'll need a different kind of reinforcement. Screen block is hollow front to back, rather than top to bottom, so there's no core in which to place the reinforcement.

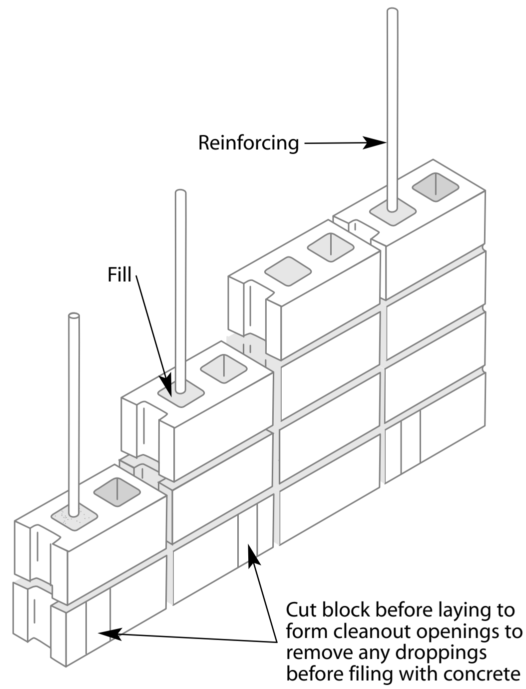


Figure 3
Concrete block wall with steel reinforcement

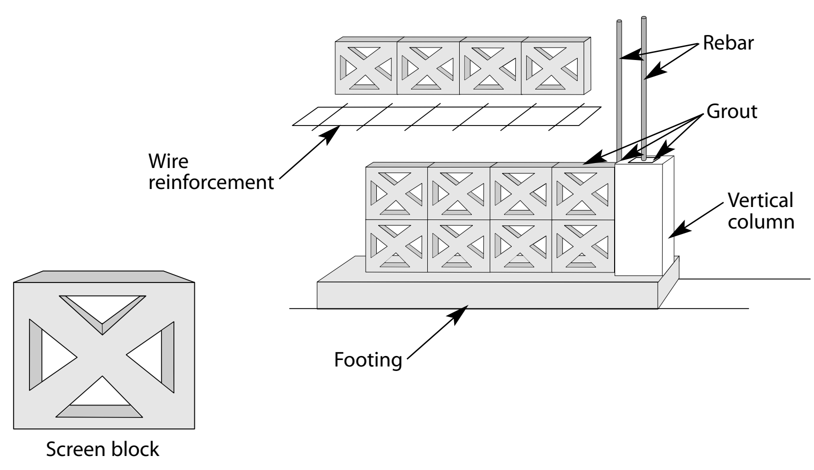


Figure 4
Reinforcing a decorative block wall

Instead, some have channels along the horizontal surface to accept rebar or wire reinforcement. The wire reinforcement must be placed at least every second course, along with the grout mix that is placed between each course and joint. Set vertical, hollow columns every 10 feet or closer. These are placed over rebar running the height of the wall that has been installed in the footer. Fill the columns with grout. Some column blocks have a channel on the sides to receive the screen block. Rebar and grout are installed in the channel in the same way as inside the column void. See Figure 4.

This system of block, rebar, and grout provides both strength and flexibility for the block structure. It literally allows a 6-foot high, 4-inch-thick wall to flex up to 2 inches without causing the wall to fail.

Cutting Concrete Block

Tools and Materials

- *Safety goggles*
- *Leather gloves*
- *Pencil*
- *Straightedge*
- *Brick or stone chisel*
- *Small sledgehammer*

You need the same materials, and use about the same methods, to cut brick, concrete block or stone.

Here's the basic method for cutting any masonry unit:

1. Draw a line where you want to cut the brick, block, or stone. For stone, try to find the stone's natural grain. Place the masonry on dirt or sand.
2. Wearing goggles and gloves, gently score along the lines by tapping the chisel with a sledgehammer.
3. After scoring all four sides, put the chisel into the etched line, blade facing toward the waste end. Hit the chisel with the sledgehammer in one hard, clean move. The masonry unit should break neatly in two. For fieldstone, after scoring on both sides, place a 2 × 4 under the stone about an inch before the line. Use a sledgehammer to knock off the waste.

You can also cut masonry with a power saw and a masonry blade. Use either a diamond tipped or carbide masonry blade. Wearing goggles and gloves, make several cuts. Start with a shallow one, and make each successive pass deeper than the last until the cut is complete.

Waterproofing Concrete Block

Waterproofing is particularly important when you lay concrete block below grade. But even when you lay it above grade, exterior block walls usually need some kind of protective coating, even if it's just paint.

For below-grade walls, good drainage is essential. If everything else has been done correctly, but the drainage pattern allows water to flow toward the foundation and sit next to the block, eventually you'll have water problems. (Refer to *Concrete*, *Waterproofing* on page 180.)

You can waterproof by parging, coating with a commercial sealer, or both.

Tools and Materials

- *Plaster*
- *Steel trowel*
- *Scarifier*
- *Water*

Parging

Parging is a thin cement-sand plaster that you apply to the block. Allow the block to cure at least three days before parging.

Use the following guidelines for your parging application:

1. Mix the plaster with a ratio of 1 part cement to $2\frac{1}{2}$ parts sand.
2. Dampen the block. With a steel trowel, spread a thin layer of plaster over the block. This first layer is called a *scratch coat* because when it has set slightly, you "scratch" it with a scarifier (a comb-like tool that leaves little grooves in the plaster) to rough up the surface and improve the bond with the final coat.
3. Keep the scratch coat damp and allow it to set for two days. Apply the final coat of plaster so that the total thickness of the two layers is at least $\frac{3}{8}$ inch.

Commercial Seal Coat

Waterproofing with a commercial coating is considerably less work. However, the wide variety of available options can be confusing. Waterproofing products fall into two broad categories: those that form a protective skin on the block and those that repel the water. In addition, you can choose from water-based or solvent-based solutions. The best products to use are solvent-based solutions that repel. Ultimately, though, no coating will be truly effective unless it completely covers the exposed area. If you miss spots, you leave a place for water to seep in.

Cleaning Masonry

The real beauty of masonry is that it requires so little maintenance. However, new masonry, and occasionally existing masonry, needs some cleaning to look its best. (See *Cleaning Brick Masonry* on page 76 for guidelines on cleaning masonry.)

Manhours

Manhours to Lay Concrete Block Walls, per SF		
Block	**Manhours**	**Suggested Crew**
8″ x 16″ blocks laid in bond		
4″ thick wall	.090	1 bricklayer, 1 helper
6″ thick wall	.100	1 bricklayer, 1 helper
8″ thick wall	.120	1 bricklayer, 1 helper
12″ thick wall	.150	1 bricklayer, 1 helper
Add for grouting cores at 36″ intervals	.07	1 bricklayer, 1 helper
Decorative block, 8″ x 16″, 3/8″ joints		
Split face hollow block		
4″ wide	.110	1 bricklayer, 1 helper
6″ wide	.121	1 bricklayer, 1 helper
8″ wide	.133	1 bricklayer, 1 helper
10″ wide	.140	1 bricklayer, 1 helper
12″ wide	.153	1 bricklayer, 1 helper
Split rib (combed) hollow block		
4″ wide	.107	1 bricklayer, 1 helper
6″ wide	.115	1 bricklayer, 1 helper
8″ wide	.121	1 bricklayer, 1 helper
10″ wide	.130	1 bricklayer, 1 helper
12″ wide	.146	1 bricklayer, 1 helper
Screen block		
6″ x 6″ x 4″ wide	.210	1 bricklayer, 1 helper
8″ x 8″ x 4″ wide (2.25 per SF)	.140	1 bricklayer, 1 helper
12″ x 12″ x 4″ wide (1 per SF)	.127	1 bricklayer, 1 helper
8″ x 16″ x 8″ wide (1.11 per SF)	.115	1 bricklayer, 1 helper

Manhours to Reinforce Concrete Block Walls, per LF		
Type	**Manhours**	**Suggested Crew**
Placed horizontally		
#3 bars (3/8", 5,319 LF per ton)	.005	1 bricklayer, 1 helper
#4 bars (1/2", 2,994 LF per ton)	.100	1 bricklayer, 1 helper
#5 bars (5/8", 1,918 LF per ton)	.009	1 bricklayer, 1 helper
#6 bars (3/4", 1,332 LF per ton)	.010	1 bricklayer, 1 helper
#6 galvanized bars	.014	1 bricklayer, 1 helper
Placed vertically		
#3 bars (3/8", 5,319 LF per ton)	.006	1 bricklayer, 1 helper
#4 bars (1/2", 2,994 LF per ton)	.010	1 bricklayer, 1 helper
#5 bars (5/8", 1,918 LF per ton)	.012	1 bricklayer, 1 helper
#6 bars (3/4", 1,332 LF per ton)	.013	1 bricklayer, 1 helper
#6 galvanized bars	.014	1 bricklayer, 1 helper

For more information on related topics, see:

Brick Masonry, page 51

Concrete, page 141

Concrete Reinforcement, page 201

Porches and Decks, page 485

Concrete Reinforcement

Concrete reinforcement recommendations are part of the foundation design and vary with the type of foundation being installed. The recommendations outline the size, strength and location of the reinforcing steel. Concrete's strong point is its compressive strength, but without steel reinforcement, its use would be greatly limited.

Steel bars and welded-wire fabric are the most common forms of steel reinforcement used in concrete work. Steel bars are used for walls, columns, and heavily reinforced flatwork, and welded-wire fabric is used for average flatwork.

Steel Bars

Reinforcing steel bars are deformed, which means they are formed with ridges on them, as shown in Figure 1. The ridges help them bond with the cement in the concrete. Each bar is also stamped with markings that identify their size and strength. Figure 2 shows a typical grade or identification stamp.

The stamps indicate:

1. The mill by the use of a letter (A through Z)
2. The bar size, #3 through #18, with the number representing the number of 8ths of an inch in the diameter (#3 is a $^{3}/_{8}$ inch diameter bar)
3. The type of steel. The UBC specifies bars must conform to four standards:

A 615	S	(billets)
A 616	I	(rail)
A 617	A	(axle)
A 706	W	(low-alloy)

4. The bar grade: 40, 50, 60 and 75

   Grade 40 and 50 are unmarked

   Grade 60 is marked "60" or has a single grade line

   Grade 75 is marked "75" or has a double grade line

The grade markings signify the minimum yield strength of the bar. For example, 40 indicates 40,000 psi.

Placement of Steel Bars

The foundation design calls out how the reinforcing should be placed, how many bars to use (if bars are required), and the size and strength of the required reinforcement.

You can place steel bar reinforcing in a number of ways:

- As single bars (Figure 3)
- In mats for flatwork, created by laying bars horizontally and vertically across one another (Figure 4)
- In curtains for vertical applications such as walls (Figure 5)
- As cages, for use in columns (Figure 6)

You must overlap connecting bars a minimum of 30 bar diameters. In other words, a #4 bar, which is $^{1}/_{2}$ inch in diameter, must overlap a minimum of 15 inches. When you bend a bar on the site, the bar must always be bent cold so you don't compromise its strength by heating the steel. Figure 7 illustrates a length of rebar being bent.

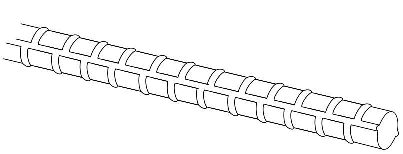


Figure 1
Rebar is ridged for bonding

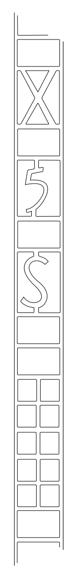


Figure 2
Typical rebar grade stamp

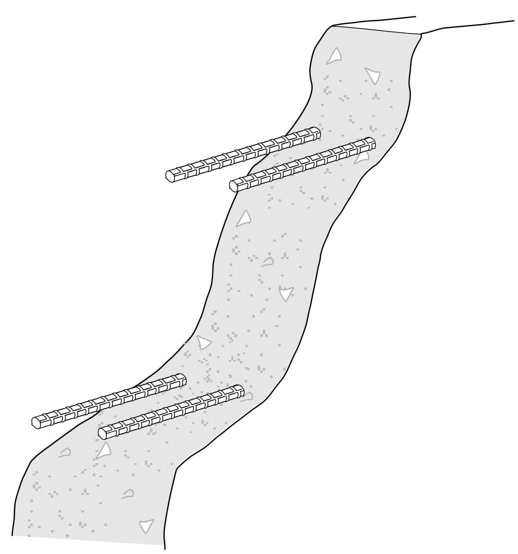


Figure 3
Single bars placed in pairs

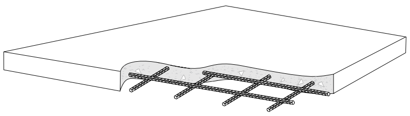


Figure 4
Rebar layed as a mat in flatwork

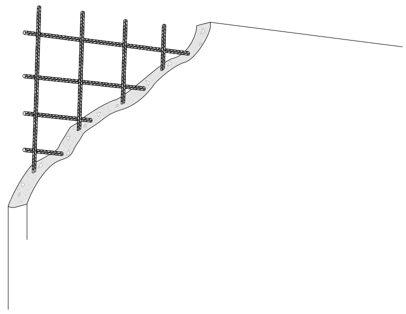


Figure 5
Rebar placed as a vertical curtain

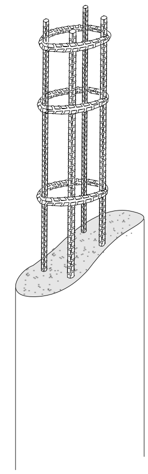


Figure 6
Rebar cage used for caisson reinforcement

Vertical Bars

When vertical bars are specified for a foundation, place them when you pour the footer with a "J" hook set into the footer. If you're using curtain type reinforcement, attach the horizontal bars to the vertical as shown in Figure 8 to create the curtain. Tie the bars together using wire ties. They're available in either bulk wire (cal wire) which is dispensed from a reel (Figure 9), clipped and tied with a wire cutter, or in looped tie wire which is placed around the bars then twisted tight using a wire twister as shown in Figure 10.

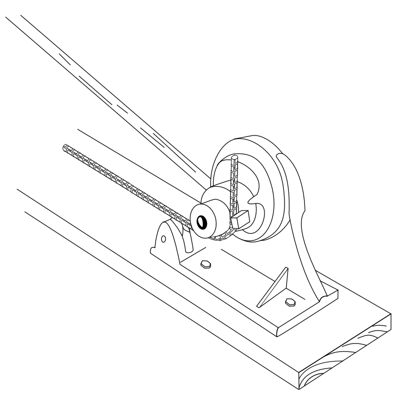


Figure 7
Bending rebar

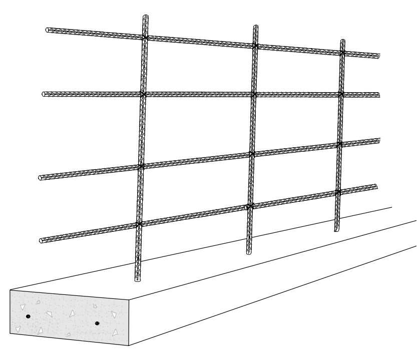


Figure 8
Tie horizontal rebar to vertical rebar to create a curtain

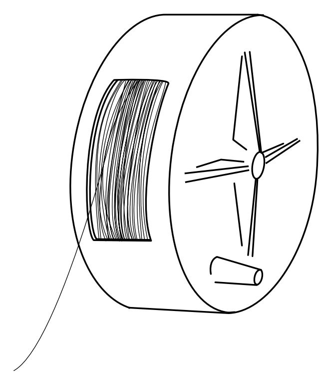


Figure 9
Tie wire in a reel holder

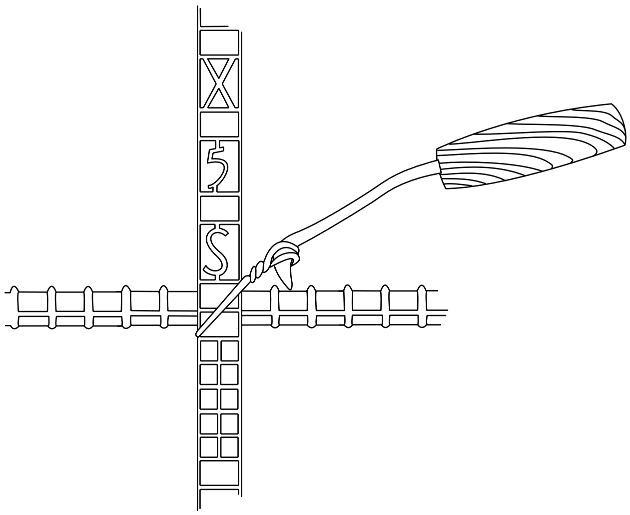


Figure 10
Connecting rebar using a wire twister

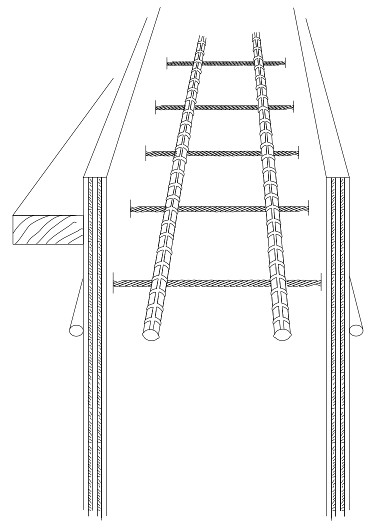


Figure 11
Rebar placed horizontally on form ties

Horizontal Bars

When the foundation design specifies horizontal bars only, you would normally position the bars by attaching them to the form ties. Figure 11 shows rebar placed horizontally. In this situation, you'll need to protect the ties from direct exposure to corrosion that could eventually break the integrity of the reinforcing. You can achieve this protection by using a cone-type tie if the concrete will be exposed, or by using waterproofing if the tie ends will be below grade or in an area where they won't be visible.

Cages, Mats, Curtains and Individual Bars

You can bend bars into rings, triangles or squares and attach them to straight bars to assemble reinforcement cages. While vertical and horizontal bars are usually assembled in the forms as you set them up (normally with the outside forms set, but before the inside has gone up), you assemble the cages for piers or caissons outside the form and then lower them into their permanent location. With columns, where access is better, you can usually assemble the cages in place as you assemble the forms.

Whether you're placing bars as cages, mats, curtains or individual horizontals and verticals, as with any other aspect of construction, workmanship is a key element. Take care to ensure that you place the steel in the manner it was designed to be used. In the event that you're working on a project where no specific design work was done, follow the building code adopted by your area.

Importance of Reinforcement

In too many cases, the importance of placing steel reinforcement is misunderstood by workers who view it as a task involving all brawn and no brains or finesse. Make sure that anyone placing reinforcement understands that it's there for a very important reason. It's not just something that they have to get out of the way and cover with concrete before they can get on with the real building. Everyone involved in reinforcement placement should be aware that it's a crucial element of the job. Without the right reinforcement, the job will eventually fail.

Tools

- *Rebar cutter / bender*
- *Wire twister*
- *Tape measure*

In general, when working with reinforcement, make sure that:

- At splices, the bars lap the minimum of 30 bar diameters
- The steel is covered by at least 3 inches of concrete
- The ties are snugged tight, but not twisted so tight that they're ready to pop when hit with the weight of the concrete
- The steel runs are uniform, with clean tight bends and no contact with the formwork

There are a number of manufacturers that make rebar cutters, although each has their own design. You can cut steel with hacksaws and cutoff saws, but it's difficult to get a good clean bend without a bender.

On small jobs, you'll usually receive your steel in 20-foot lengths, and you'll be cutting and bending it on site. Have it dropped in a location where you'll have good access to your project as well as adequate room to maneuver the lengths you're dealing with. If the foundation or basement is big enough, have your equipment and materials in those areas, close to your work.

On larger jobs, you may have a reinforcing plan, usually prepared by your supplier, which calls out shop-bent pieces for corners as well as cut-to-length straight pieces. For these jobs, the steel is available in lengths up to 40 feet, but they'll be fabricated to your specific needs. When installing steel on projects using shop-fabricated steel, your assembly will involve tying the steel in place using the shop drawings and the prefabricated pieces that are numbered to determine their location.

Welded Wire Fabric

Welded wire fabric, or wire mesh as it's also called, is the standard slab reinforcement. Welded wire in gauges suitable for residential slabs and walks is ordered by the roll, in dimensions determined by the size of the squares and the gauge of the wire. The rolls are 5 feet wide; the length depends on the gauge of wire. W2.9 × W2.9 × 6 × 6 rolls are 150 feet long, while W1.4 × W1.4 × 6 × 6 rolls are 200 feet long. Heavier gauge wires are available in flat sheets.

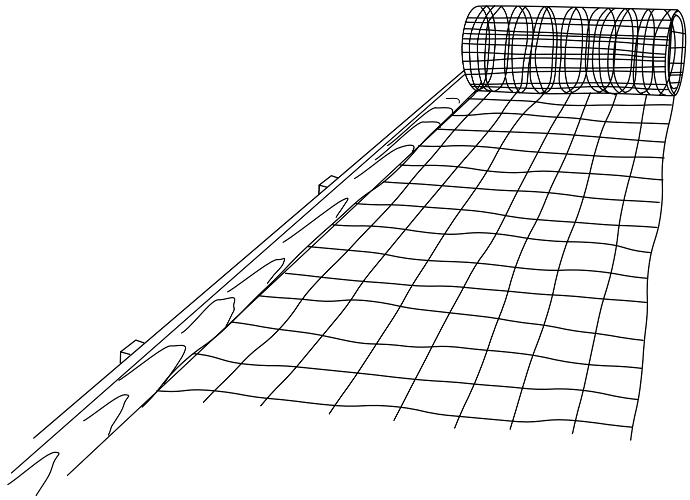


Figure 12
Rolling out welded wire fabric

When you unroll the mesh, you'll need to flatten it as much as possible. You can do this by rolling out the length, cutting it, and flipping it over. Once it's flipped, you can further flatten it by pulling up on the ends, giving it a reverse bend. Figure 12 shows welded wire mesh being unrolled.

Placement of Wire Mesh

Place and lap the mesh according to local codes. As a rule of thumb, mesh should overlap at least one square. The most difficult aspect of placing wire mesh is locating it properly in the slab. Since it will be walked on during the concrete placement, you must take care to keep it in place.

One way to place wire mesh is by laying it on the ground and then pulling it up into position as the concrete is distributed. It takes an extremely conscientious crew to ensure that this is done uniformly. Another alternative involves placing the mesh on stands, called bridges, but this only works if nobody walks on the mesh before or during concrete placement. You can also place the concrete in two layers, with the mesh sandwiched between them. With this method, you place one layer of concrete and roughly level it with the wire in place, then place the second layer of concrete on top.

Fiber Mesh

There are various types of fiber mesh products that have been tried as concrete reinforcement. Fiberglass mesh is the one that appears to be the most useful. Fiber mesh has the advantage of producing an even distribution of reinforcement in flatwork. It also eliminates the concern of being forced down to the bottom of the slab if it's walked on during concrete placement. Because the mesh is fine, the larger aggregate can't move through the holes, so the mesh remains suspended in the concrete. Fiber mesh also works to stop cracks from forming as the result of plastic shrinkage. Always consult with your architect or engineer before using fiber mesh. You can't assume that it's interchangeable with welded wire mesh in all situations.

Manhours

Manhours to Place Reinforcing Steel Bars, per LF		
Reinforcement, Placed & Tied	**Manhours**	**Suggested Crew**
Footing & grade beams		
1/4" diameter, #2 rebar	.003	1 reinforcing iron worker
3/8" diameter, #3 rebar	.004	1 reinforcing iron worker
1/2" diameter, #4 rebar	.007	1 reinforcing iron worker
5/8" diameter, #5 rebar	.009	1 reinforcing iron worker
3/4" diameter, #6 rebar	.012	1 reinforcing iron worker
7/8" diameter, #7 rebar	.016	1 reinforcing iron worker
1" diameter, #8 rebar	.021	1 reinforcing iron worker
Structural slabs		
1/4" diameter, #2 rebar	.002	1 reinforcing iron worker
3/8" diameter, #3 rebar	.004	1 reinforcing iron worker
1/2" diameter, #4 rebar	.006	1 reinforcing iron worker
5/8" diameter, #5 rebar	.008	1 reinforcing iron worker
3/4" diameter, #6 rebar	.011	1 reinforcing iron worker
7/8" diameter, #7 rebar	.014	1 reinforcing iron worker
1" diameter, #8 rebar	.019	1 reinforcing iron worker
Walls		
1/4" diameter, #2 rebar	.003	1 reinforcing iron worker
3/8" diameter, #3 rebar	.005	1 reinforcing iron worker
1/2" diameter, #4 rebar	.007	1 reinforcing iron worker
5/8" diameter, #5 rebar	.010	1 reinforcing iron worker
3/4" diameter, #6 rebar	.014	1 reinforcing iron worker
7/8" diameter, #7 rebar	.018	1 reinforcing iron worker
1" diameter, #8 rebar	.024	1 reinforcing iron worker

Manhours to Place Vertical Steel Bars, per VLF		
Spiral Caissons and Round Columns	**Manhours**	**Suggested Crew**
Hot rolled steel spirals with main vertical bars		
16" diameter with 6 #6 bars	.041	1 reinforcing iron worker
24" diameter with 6 #6 bars	.085	1 reinforcing iron worker
36" diameter with 6 #6 bars	.216	1 reinforcing iron worker

Manhours to Place Wire Mesh, per SF		
Type	**Manhours**	**Suggested Crew**
Beams and columns		
2" × 2" W.9 × W.9 (#12 × #12)	.020	1 reinforcing iron worker
Slabs		
2" × 2" W.9 × W.9 (#12 × #12)	.004	1 reinforcing iron worker
4" × 4" W1.4 × W1.4 (#10 × #10)	.003	1 reinforcing iron worker
4" × 4" W2.0 × W2.0 (#8 × #8)	.004	1 reinforcing iron worker
4" × 4" W2.9 × W2.9 (#6 × #6)	.005	1 reinforcing iron worker
4" × 4" W4.0 × W4.0 (#4 × #4)	.006	1 reinforcing iron worker
6" × 6" W1.4 × W1.4 (#10 × #10)	.003	1 reinforcing iron worker
6" × 6" W2.0 × W2.0 (#8 × #8)	.004	1 reinforcing iron worker
6" × 6" W2.9 × W2.9 (#6 × #6)	.004	1 reinforcing iron worker
6" × 6" W4.0 × W4.0 (#4 × #4)	.005	1 reinforcing iron worker

For information on related topics, see:

Brick Masonry, page 51

Concrete, page 141

Concrete Block, page 189

Countertops

The most common coverings for countertops are tile and plastic laminate, although Corian, synthetic or cultured marble, faux granite and marble are also widely used.

Countertop Materials

These materials vary considerably in durability, cost, versatility, and difficulty of installation. We'll touch on all of them here. But we'll concentrate on plastic laminate, with detailed information on its characteristics, as well as its installation and repair.

Plastic Laminate

Plastic laminate is the least expensive of the options, but it's also the least durable. Still, for standard usage, plastic laminate can last 20 to 30 years or more, making it a logical choice for many homeowners. Plastic laminate, usually referred to by the trade names Formica or Wilsonart, is actually made of layers of paper sandwiched in resin. The layers are pressed together, usually to $^{1}/_{8}$ inch thick, and then set at a high temperature. It's available in widths of 24, 30, 36, 48, and 60 inches and in lengths of 5 to 12 feet.

You can have a countertop of plastic laminate over particleboard or plywood built in a specialty shop, or you can build it yourself on site using contact cement and standard tools. Two carpenters can install approximately 2 linear feet of laminate countertop per hour.

One of the real advantages of plastic laminate is that it's the most flexible of all the coverings. You can bend it into curves, while other coverings must be molded to the desired shape. Of course, this flexibility can also be a disadvantage. You must glue the laminate to a perfectly-even surface. The flexibility that allows the laminate to bend also makes it adhere to every dip and bump, highlighting each flaw in the surface.

Corian (Methyl Methacrylate Binder)

Most likely, methyl methacrylate binder isn't a familiar term to you. You're probably more familiar with its trade name, *Corian*. Corian is a solid, nonporous material, with the color and pattern running through its entire thickness. Because of this, it has a significant advantage over materials whose colors and patterns are only in the surface layer. You can buff out scratches and rub off burns, including cigarette burns, with abrasive household cleaners without losing the color or pattern of the material.

Corian comes in sheets $^1/_4$, $^1/_2$, and $^3/_4$ inches thick, up to 30 inches wide and 12 feet long. It also comes molded for integral vanity tops and bowls, kitchen countertops and sinks, and drop-in or undermount lavatories and sinks. Like plastic laminates, you can have Corian countertops built in a specialty shop, or you can put them together on site. You can cut, shape, route, and sand the material like fine hardwood.

The biggest drawback to Corian is its expense, which can run up to ten times higher than plastic laminate. For most customers, price is a more significant factor than durability.

Ceramic Tile

Ceramic tile comes in an endless variety of patterns, textures, colors, and sizes. In addition to being decorative, tile is also versatile and durable. It's installed at the job site, which allows a good installer to fit small spaces and work around odd shapes in a way that other materials can't match. Ceramic tile countertops are very popular and make an attractive addition to almost any style kitchen. But ceramic tile also has several drawbacks that for some make it a less attractive option than plastic laminate.

First, although it ranges considerably in price, even the cheapest tile is more expensive than plastic laminate — usually two to three times as much. Second, the hardness of tile works both for and against it. Although it can take some abuse, it also has very little give. As a result, if a heavy dish is dropped on a tile countertop, both the dish and the tile may break. Replacing a broken tile in the middle of a countertop is a major job – if you can find a match. (If you do tile a countertop, be sure to order quite a few extra tiles, especially the edge ones, which are the most frequently broken.) A tile countertop is also more difficult to maintain than plastic laminate. Cleaning the grout can be a big job, and replacing loose or stained grout is an even bigger job.

From the homeowner's point of view, while tile may well be the most attractive countertop material, not having a smooth surface to just wipe down or to swoosh spills into the sink can be quite a nuisance. You have to wipe out every row of grout.

For information on installation, see *Ceramic Tile*.

Synthetic and Cultured Marble

Synthetic marble is a manufactured product that closely resembles the color and veining of natural marble. Made of catalyzed polyester resin and fiberglass, the color and pattern run through its entire thickness. Like Corian, this gives it more durability than plastic laminate. Synthetic marble handles like an extra-dense hardwood; you can cut, shape, and sand it. Generally, synthetic marble countertops are built in specialty shops, but the material is manageable enough for you to do some building with it on site.

Cultured marble (sometimes called synthetic marble) consists of up to 75 percent real marble. That makes it more difficult to handle than synthetic marble. It's often sold slightly larger than the necessary job site dimensions and then cut to size with a masonry blade on a circular saw.

While synthetic and cultured marble are inexpensive alternatives to real marble, they still cost two to three times as much as plastic laminate. However, because they're very durable and don't absorb water, they're often used for bathroom vanities and shower and tub enclosures. Also, you can buy vanity tops with the sink molded in, which saves money over buying a laminate top and separate sink.

Marble and Granite

Marble and granite are by far the most durable — and the most expensive — of all the countertop materials. The very thing that makes them durable, though, are sometimes their drawback. Not everyone wants a surface that's as hard and unforgiving. Still, they have a natural beauty that makes them a popular choice for kitchen counters and bathroom vanities in the more expensive homes. Marble and granite countertops are never built on site because the material is difficult to cut — and mistakes can be extremely expensive.

Countertop Design

Regardless of the countertop material you choose, some basic design details are typical of all of them. Figure 1 shows standard countertop dimensions.

Here are the countertop terms you'll need to know:

Backsplash: A vertical member of the countertop that's connected to and rises above the back edge of the deck (Figure 2).

Backsplash height: The dimension from the countertop deck to the top of the backsplash.

Build down strip: The additional material that's applied to the underside of the deck to establish countertop thickness.

	Height (in)	Depth (in)	Width (in)
Kitchen			
Standard counter	34-36	21-24	--
Wheelchair counter	32-34	21-24	--
High counter (bar)	40-42	21-24	--
Backsplash height	2-4	--	--
Knee well under high counter	--	20-24	24-28
Bathroom			
Standard lavatory	32-34	--	--
Wheelchair lavatory	26-34	17-19	--

Figure 1
Standard countertop dimensions

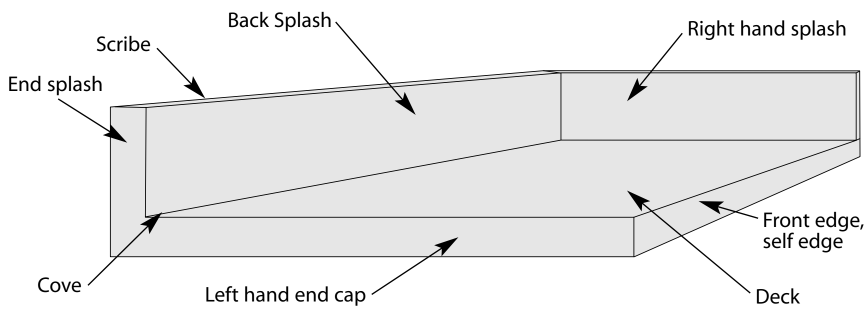


Figure 2
Countertop components

Cove: The junction of the deck and the backsplash (Figure 2).

Cove stick: The support material at the cove area.

Cutouts: The openings cut through the countertop or the backsplash (for sink, range top, electrical fixtures, etc.)

Deck: The work surface of the countertop (Figure 2).

Deck width: The measurement from the front edge of the countertop to the face of the backsplash.

End cap: The finished end of the countertop (Figure 2).

End splash: The vertical component similar to the backsplash at an end of the countertop (Figure 2).

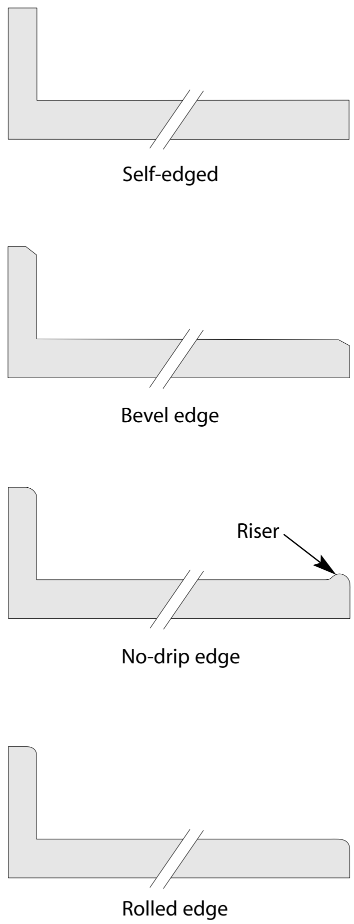


Figure 3
Four standard profiles

Front edge: The vertical edge of the front of the countertop. Figure 3 shows the four types.

- *Self-edged* — A front edge at a 90-degree angle to the work surface.
- *Bevel* — An edge with a 45-degree angle to the work surface and a 45-degree angle to the rest of the front edge.
- *No-drip* — A front edge that's raised slightly.
- *Rolled leading edge* — The curved front edge of the deck without a riser.

Joints: Figure 4 shows the two common types of joints.

- *Butt* — The machined ends of two countertop sections for assembly to each other.
- *Miter* — The matching machined ends of two sections of countertop cut at an angle to change the direction of the countertop.

Joint assembled, butt and miter types: The machined components are drawn tight and assembled with water-resistant material and mechanical fasteners as required. They can be site- or factory-built.

Nose: The leading edge of a typical countertop including the side edges of a peninsular top.

Postformed countertop: A one-piece seamless countertop that includes the backsplash and the front edge.

Riser: The raised area at the front edge of the countertop that produces the no-drip feature (see Figure 3).

Riser height: The dimension measured from the top of the riser to the deck surface.

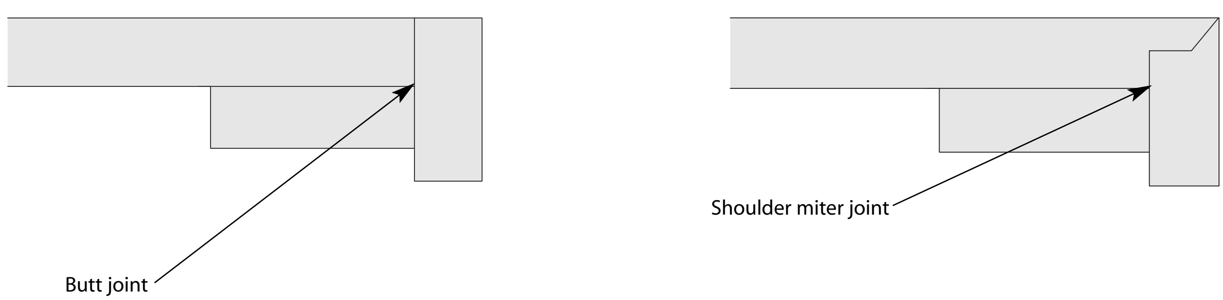


Figure 4
Types of edge joints

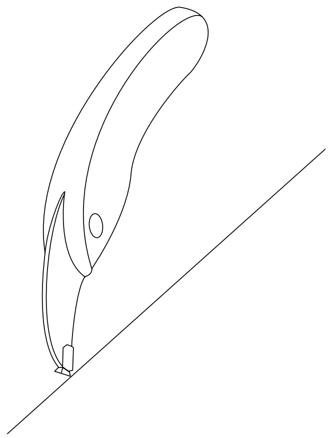


Figure 5
Carbide-tipped knife used to score plastic laminate

Scribe: The material at the top rear edge of the backsplash that allows for a closer fit to the wall (Figure 2).

Scribe width or depth: The dimension from the back of the backsplash to the extreme edge of the scribe area.

Self edge: A strip of laminate that's applied to an edge of the countertop (Figure 2).

Substrate: The supporting material for laminate, usually particleboard or grade A through D plywood. Particleboard is used most often because it's less expensive. Use plywood when strength is important. Both are easy to work with, but particleboard absorbs up to twice as much adhesive as plywood and may require two coats.

Cutting Plastic Laminates

The first step in installing a plastic-laminate countertop is to measure and cut the pieces you'll need. Some laminates may chip, so it's wise to practice cutting on scraps before diving into the real thing. If the laminate you're using comes with a protective covering, wait until you trim the countertop before removing it.

You can use a carbide-tipped utility knife, like the one shown in Figure 5, or a hacksaw to cut small pieces. When using a utility knife, place the laminate decorative side up and score the face a couple of times. Then turn it over and do the same to the back side along the same line. Using a table edge as a hard line, bend the piece at the cut line and snap it off.

If you use a hacksaw or shears for cutting, hold the piece firmly by clamping it, decorative side up, between a board and your workbench. Mark your line and cut it, keeping the hacksaw almost flat against the laminate as you saw. There are special carbide shears that you can use for cutting irregular shapes, notches, or small pieces. Cut with the decorative side up.

Use a circular, saber, or even a table saw for larger cuts. But don't even try using these without a carbide-tipped blade, because a regular blade will start to dull immediately, making it hard to cut a straight line. For odd-shaped pieces, make a jig for a pattern. Clamp the laminate in place, again between a board and the workbench, and cut it with a router and carbide bit.

Always cut so that the blade enters — *never exits* — on the decorative side. In other words, place the decorative side up when using a circular or table saw; and place the decorative side down with a saber or radial saw. The only exception is when you're using the special plastic laminate blade that's available for saber saws. These allow you to cut from the top.

Cut all the pieces about $^1/_8$ inch larger than you need. When the surfaces are set, you can trim up the edges with a router. There are special laminate carbide bits that have a roller bearing that protects the laminate surface from getting scratched or burned. The best router to use for countertops is an offset laminate router. It allows you to rout off the edges of backsplashes that are already in place.

Adhesives

Use either a solvent-, chlorinated-, or water-base contact adhesive. (See *Adhesives*.) Figure 6 is a chart describing the characteristics of the three types of adhesive. Whichever type you use, apply it to both surfaces and allow it to dry until it's no longer tacky.

When applying a solvent-base adhesive, use extreme caution. It's highly flammable, and the vapors may be highly toxic. Always work in a well-ventilated area away from all open flames, pilot lights, and even static electrical sparks. Wear a protective mask.

Instructions for contact adhesives vary depending on their base and their manufacturer. So read the label carefully and follow the directions. Contact adhesives work best in temperatures above 65 degrees with the humidity between 35 and 80 percent.

Adhesive Chart					
Base	**Drying time**	**Application**	***Green strength**	**Flammability**	**Coverage**
Solvent	Tack-free in 5 to 10 minutes	Spray, brush, (brush grade may be troweled or rolled)	Extremely high	Extremely high; vapors may be toxic	1 gallon at 4 mils covers up to 200 square feet
Chlorinated	Tack-free in 5 to 10 minutes	Spray, brush, fine-toothed trowel, roller	High	Nonflammable	1 gallon at 6 mils covers 250 to 300 square feet
Water (neoprene)	Up to an hour	Spray, brush, fine-toothed trowel, carpet stipple roller	High	Nonflammable	1 gallon at 4 mils covers up to 400 square feet

*Green strength refers to the bonding strength of the adhesive on contact

Figure 6
Adhesives for plastic-laminate countertops

Here are some general rules of thumb you can follow:

- Generously spread the adhesive evenly on both the laminate and the substrate. Too much adhesive might result in lumps to the finished surface. Too little will prevent a good bond between the two surfaces. You're looking for a consistent color, with no voids.
- Particleboard may absorb so much adhesive that you need to apply a second coat.
- When the adhesive is no longer tacky, the surfaces should still look wet. Dry spots mean the material absorbed the adhesive; apply another coat to these areas and wherever the adhesive film looks uneven.

There are four methods for applying the adhesive:

1. *Brush* — Use a 2- to 4-inch natural bristle or sponge brush for small areas.
2. *Roller* — For large areas, use a carpet stipple or short-nap paint roller. Cover the paint tray with foil or use a disposable tray liner for quick cleanup.
3. *Trowel* — Use a fine-toothed trowel, smoothing out any adhesive ridges as you go.
4. *Spray* — Check the guidelines for the equipment, but generally you can use 60 psi for line pressure and 20 to 30 pounds psi for cup pressure. You may need to double-spray to get full, even coverage.

Installing a Plastic Laminate Surface

When using any adhesive, the surfaces to be coated must be smooth, dry, and thoroughly clean. Any dips, bumps, or other flaws will show. Use wood putty to fill in surface holes, then sand it smooth and vacuum up the dust. If necessary, clean the particleboard with a solvent, letting the wood dry completely before you apply the adhesive.

Laminate pieces are usually applied in a specific order. Typically, the last piece laid should hide the other joints as much as possible. On a countertop, this means that you put the front band on first, then the horizontal workspace, followed by the vertical portion of the backsplash (ends, then face), and finally the horizontal strip on the backsplash. For drawer fronts, put the outer strips on first, including the top one, and then apply the front.

When the substrate surface is clean, dry, and smooth, and your pieces are cut, you're ready to start.

***Tip**: One difficulty in placing plastic laminate is that the coated surfaces bond immediately on contact. This is just what you want if you have the laminate and the substrate lined up perfectly. However, this can be more than a little tricky if you're trying to place a 2- x 10-foot piece of laminate. To make it easier, test to see if the pieces are "tack dry" by touching the surfaces with clean kraft paper. When the adhesive no longer sticks to the paper, the pieces are ready to put together. To give yourself a safety net when positioning the laminate, first cover the substrate with a sheet or series of sheets of clean kraft paper. Or place dowel rods or clean slats of old venetian blinds on the tack-dry substrate. Position the laminate on top, then carefully pull out the paper, dowel rods, or slats, firmly pressing the pieces together as you remove them.*

1. Apply the adhesive to both the substrate and the back of the plastic laminate (Figure 7a). Allow to dry until tack dry.
2. Spread the kraft paper, dowels or Venetian blind slats to prevent immediate contact, and position the laminate (Figures 7b and 7c). As you pull out the paper, dowels or slats, firmly press the laminate to the substrate.
3. Apply quick, heavy pressure to the entire surface. Start from the center and work towards the edges to force out any air bubbles. Use a hammer and a block of hardwood to apply more pressure. Or use a laminate roller or a rolling pin to smooth laminate (see Figure 7d). Pay particular attention to edge joints to make sure they are solidly sealed. Be careful not to chip or break unrouted edges.

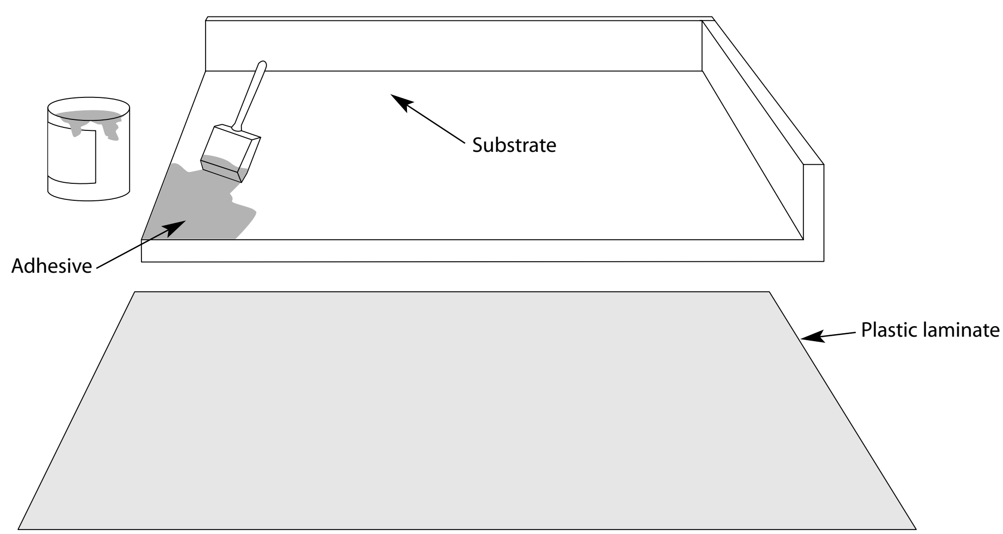


Figure 7a
Apply contact adhesive to back of plastic laminate and the substrate

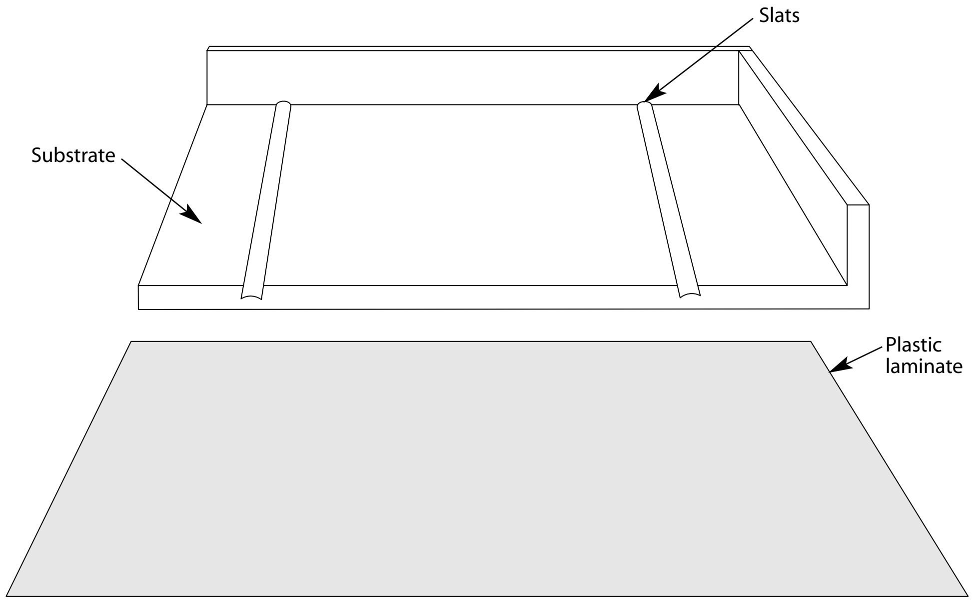


Figure 7b
Place venetian blind slats to prevent contact while positioning the plastic laminate

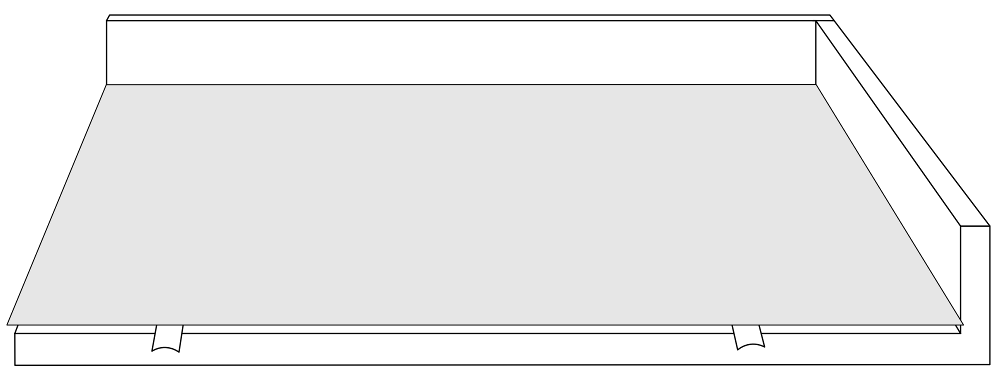


Figure 7c
Carefully position the countertop over the slats

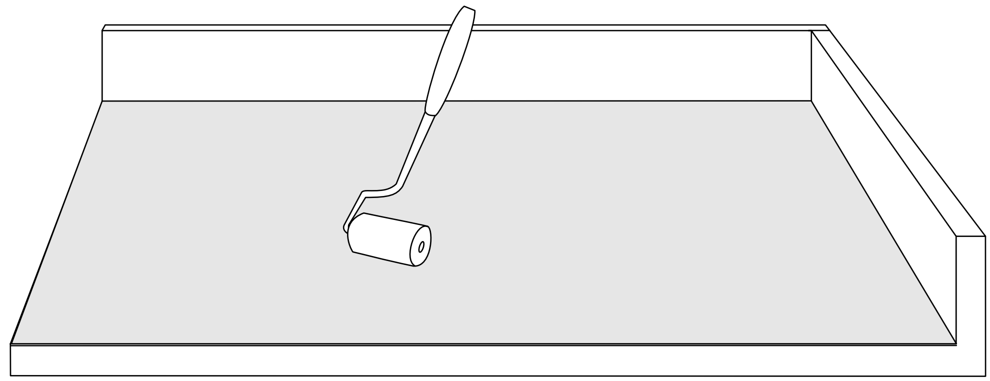


Figure 7d
Remove slats and roll plastic laminate to ensure good adhesion

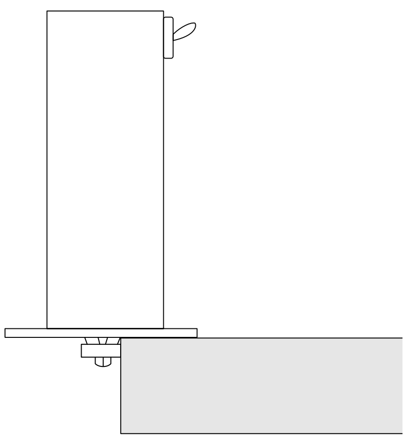


Figure 8
Use a router to trim plastic laminate

4. Trim the overhanging edge with a router as shown in Figure 8. First, trim a 90-degree angle with a straight cutter. Then use a bevel cutter to angle the edge slightly, about 20 to 22 percent. If you don't have a laminate bit with a bearing roller, spread petroleum jelly over the surface to keep it from burning the laminate. *Caution:* Be sure to wear safety goggles to protect your eyes from the sharp laminate particles.

5. Repeat steps 1 through 4 with each piece.

6. Clean up excess contact cement by using a piece of plastic laminate to scrape off any adhesive that oozes out. Or use a rag and the contact cement solvent recommended on the label to wipe the surface.

Building a Backsplash

1. Build the backsplash as a piece separate from the countertop. Trim the ends first, then the face, and finally apply the top horizontal piece. Rout a 90-degree edge for the edges that butt up against a wall or another piece of laminate. Rout a bevel edge for the other.

2. If you're using a metal cove molding, place it between the deck and the backsplash. If not, run a bead of tub and tile caulk where you join the backsplash and deck. Clamp the two pieces together, and drill screw holes for wood screws. Attach the backsplash to the countertop from the underside.

Making the Sink Cutout

For prefabricated countertops, the countertop shop will do the sink cutout. Just give the make and model number of the sink you're using, and as long as it's a standard model, the shop should have a template for it. If it's an odd model, you'll have to take in the template provided by the sink manufacturer.

If you're making your own countertop, do the following:

1. Determine where to place the sink. Take the template provided by the sink manufacturer and trace around it.
2. Drill holes on the inside of the line at the four corners. Cut along the lines using a saber saw with a plastic blade (one with a partially-reversed or neutral kerf).

Repairing Plastic Laminate

Use the following suggestions for basic laminate repairs.

Blisters

Blisters are raised areas in the plastic laminate caused by delamination *within the laminate itself*. Unfortunately, the only way to repair this is by replacing the section where the blister appears. Check with the supplier to see if this is covered by their warranty.

Bubbles

Sometimes a raised area, or bubble, will appear. This can occur when the laminate and the substrate don't bond properly. You may be able to repair it by ironing it out. Cover the bubbled area with newspaper, then heat the area using the "silk" setting on the iron. Lower the setting slightly if the newspaper starts to scorch. When the heat from the iron has softened the adhesive, use a laminate roller or rolling pin to press the laminate to the substrate.

Burns

You generally can't repair a burned area. Remove the section by removing the screws from the bottom, and replace the entire section as in a new installation.

Loose Sections

Pull the laminate up and spread adhesive over the substrate with a putty knife. Press the laminate against the substrate in order to coat the underside of the laminate; then pull it up again. Prop the laminate up with toothpicks until the adhesive is tack dry. Press down and roll with a laminate roller or rolling pin.

Stains

Try cleaning the stain with a soft-bristle brush and a solution made up of 1 percent liquid dishwashing detergent in water. Don't use a scouring pad or abrasive cleaners because they'll leave fine scratches for dirt or stains to collect in. For more difficult stains, use household bleach or denatured alcohol and rinse immediately.

Manhours

Manhours to Install Countertops

Material	Unit	Manhours	Suggested Crew
Plastic laminate, solid colors, 25"-36" deep, 4" backsplash	LF	.181	1 carpenter, 1 laborer
Ceramic tile, 4 1/4" × 4 1/4" to 6" × 6" glazed, in conventional mortar bed, with grout	SF	.352	1 tile layer
Cultured marble vanity tops with integral backsplash and sink, 22" deep, 24" to 48" long	Each	2.60	1 carpenter, 1 laborer
Corian vanity tops with integral sink, 22" deep, 3/4" thick			
25" long	Each	.654	1 carpenter, 1 laborer
31" long	Each	.742	1 carpenter, 1 laborer
37" long	Each	.830	1 carpenter, 1 laborer
43" long	Each	.924	1 carpenter, 1 laborer
49" long	Each	1.02	1 carpenter, 1 laborer

For information on related topics, see:

Adhesives, page 25

Ceramic Tile, page 125

Doors

Exterior doors, today more than ever, are largely for security. But we also expect them to stop the infiltration of both hot and cold air. Interior doors, on the other hand, have privacy as their primary function. Although both kinds of doors have very practical functions, they're often selected because of their decorative value or character.

Door Unit Components

An interior door unit consists of a door, jamb and hardware, including hinges and locksets. Exterior units also include a sill, threshold and weatherstripping. Both interior and exterior doors are available as prehung units or as individual components that you assemble on site. Most of today's installers prefer prehung units for residential doors. Whether you choose a prehung unit or individual components, you'll need to understand the components to select the right unit for each situation.

Door Sizes

Door widths are given in feet and inches rather than just inches. A door measuring 32 inches is referred to as a 2-8 (two-eight). A door measuring 36 inches is referred to as a 3-0 (three-oh). Standard door widths are 2-0, 2-6, 2-8 and 3-0.

The standard door height is 6 feet 8 inches, or 6-8 (six-eight). If you require specialty heights, their sizes will also be given in feet and inches, with zero always pronounced as "oh."

Framed openings for doors should be 2 inches larger than the door size. A 3-0 × 6-8 door should have a framed opening of 3 feet 2 inches by 6 feet 10 inches.

Door Thickness

Doors are available in a variety of thicknesses, but $1\frac{3}{8}$ inch and $1\frac{3}{4}$ inch are the most common. Most residential interior doors are $1\frac{3}{8}$ inches thick. Residential exterior doors, as well as all commercial doors requiring a fire rating, are $1\frac{3}{4}$ inches thick. Other sizes available by special order are 2, $2\frac{1}{4}$, $2\frac{1}{2}$, and 3 inches.

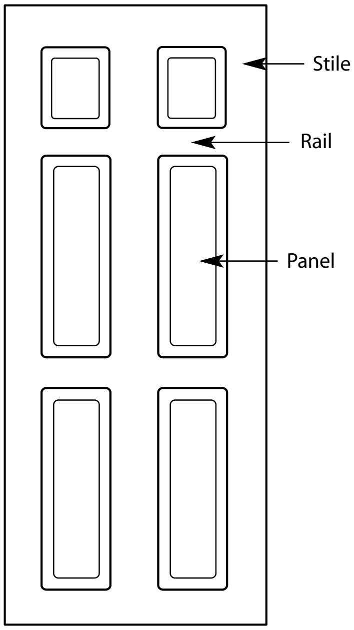


Figure 1
Parts of a panel door

Door Types

Traditional doors (the style that you see most often) are solid wood panel doors or copies of that type of door. Solid panel doors are built in several separate pieces, with stiles (solid vertical side members), rails (solid cross or horizontal members), and filler panels (see Figure 1). Panel doors are referred to by the number of panels, such as four panel, six panel, and so on. Figure 2 shows typical interior and exterior door designs.

Doors built of metal or man-made products use two different methods to simulate panel doors. The first is the embossed door, made by stamping the panel into the door. An embossed door most closely resembles, and in some cases is actually superior to, a true raised-panel door. There's a tendency for the panels of true raised-panel doors to move inside the rails and stiles, causing paint or stain lines. This annoyance is caused by changes in humidity and wood's natural tendency to swell and shrink as it loses or absorbs moisture. Because an embossed door is one unit, any swelling or shrinkage involves the entire unit rather than individual pieces, so there are never any shrink lines.

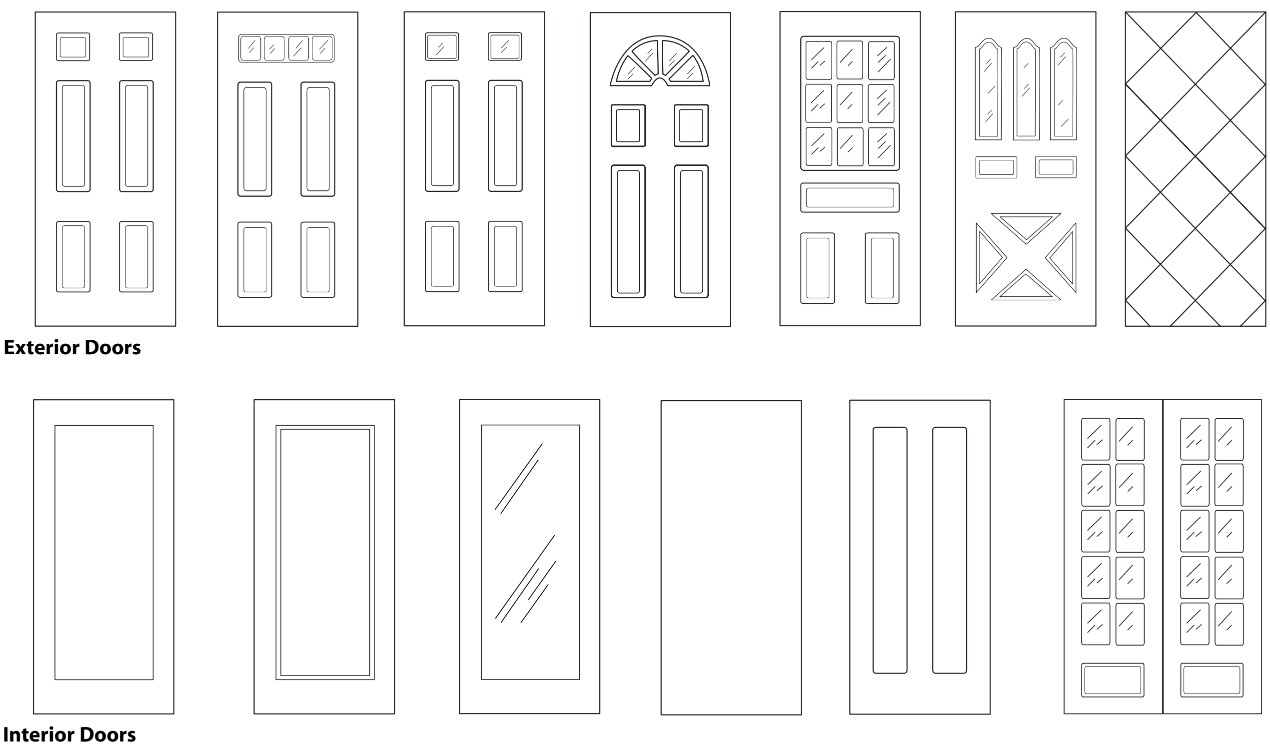


Figure 2
Typical door designs

The second method of simulating a panel door is by attaching moldings to a flush wood door. While this doesn't produce a panel door that's as authentic in appearance as one that's embossed, the moldings do add interest and improve the look of an ordinary flush door.

Veneer Doors

Many doors are made with a veneer surface over a wood frame. The surface may be a hardwood veneer such as an oak veneer, a man-made product such as hardboard, or steel. Veneered doors may be either hollow core or solid core. A hollow-core door has a wood-framed perimeter with an interior of cardboard in a "honeycombed" configuration that provides support throughout the center. Solid-core doors are also built with a solid wood perimeter. The core, however, is filled with a solid material, usually particleboard. Fire-rated solid-core doors have a gypsum core.

Steel veneered doors have become popular as residential entry doors because of their weather resistance. A residential steel veneered door has a wood perimeter, unlike commercial steel doors. The core of a steel door can be insulated, providing a weathertight unit. You usually set residential steel doors in wood jambs, unless fire resistive requirements dictate a steel jamb.

Jambs

Door jambs consist of two legs and a head piece. Most jambs come precut and ready to assemble as a package that includes the legs and header. If packages aren't available, you can easily cut the headers on site. An extra leg will make two head pieces.

Jambs are available in several configurations. Traditionally, solid wood jambs are made from the same wood species as the door. Veneered jambs are also available with a core of either particleboard or finger-jointed material. Some carpenters prefer the veneered jambs because they believe they're less likely to cup or warp.

You can get steel jambs to meet fire resistive standards. At first glance, all steel jambs look alike, but there are options available. A standard steel jamb comes as a "knock-down" unit. That's three separate pieces that you assemble on the job site. Knock-down units are useful when replacing an existing door because you can install them after the drywall. Or, you can request welded units as an option. Welded units come with the legs welded to the header, with the weld ground down and primed for a smooth finish. You must install welded units before the drywall goes up.

If you'll be using an automatic door closer, you'll need an additional steel support piece welded into the header. The steel jamb isn't heavy enough to hold the screws for the closer without the backing piece. If you need a deadbolt or other specialty hardware, the cutout and backing for both the jamb and the door should be done at the supplier's shop. A chisel just won't do the job later. Most steel door and frame suppliers have a shop where they make these modifications.

Sills, Thresholds and Sweeps

On residential construction, sills and thresholds are, with few exceptions, limited to entry doors. Most door units use a combination sill and threshold. Several manufacturers offer an adjustable threshold in this combination. This is a nice convenience for initial installation, as well as for later adjustments. Most thresholds and combination sill/thresholds are aluminum.

A sweep is attached to the bottom of the door to prevent air infiltration from under the door. Several types of sweeps are available. Use an adjustable sweep when you can't adjust the threshold, and stationary sweeps when you can adjust the threshold. Figure 3 shows a door sweep.

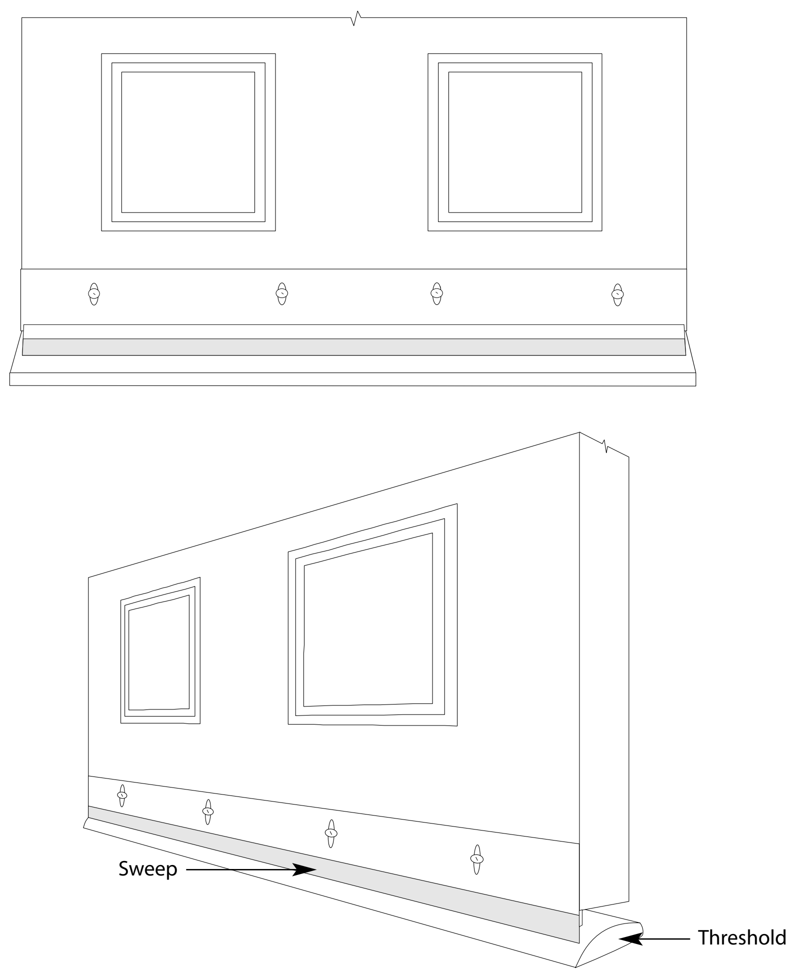


Figure 3
Door sweep

Door Hardware

Door hardware is available in a variety of qualities and finishes. In Figure 4, door hardware finishes are given as BHMA (Builders' Hardware Manufacturers Association) and the nearest U.S. equivalent.

Locksets and Deadbolts

To the layman, locksets are simply doorknobs. There are, however, several different types, each with a special purpose. They include passage, privacy and entry locksets.

Passage locksets only latch and provide no locking capability. Passage locksets are used for closets.

Door Hardware Finishes			
BHMA	**U.S. Equivalent**	**Finish Description**	**Base Material**
600	USP	Primed	Steel
601	US1B	Bright Japanned	Steel
602	US2C	Cadmium Plated	Steel
603	US2G	Zinc Plated	Steel
605	US3	Bright Brass/Clear Coat	Brass
606	US4	Satin Brass/Clear Coat	Brass
611	US9	Bright Bronze/Clear Coat	Bronze
612	US10	Satin Bronze/Clear Coat	Bronze
613	US10B	Oxidized Satin Bronze, Oil Rubbed	Bronze
618	US14	Bright Nickel Plated/Clear Coat	Brass, Bronze
619	US15	Satin Nickel Plated/Clear Coat	Brass, Bronze
622	US19	Flat Black Coated	Brass, Bronze
624	US20A	Dark Oxidized, Statuary Bronze/CC	Bronze
625	US26	Satin Chromium Plated	Brass, Bronze
626	US26D	Satin Chromium Plated	Brass, Bronze
627	US27	Satin Aluminum/Clear Coat	Aluminum
628	US28	Satin Aluminum/Clear Anodized	Aluminum
629	US32	Bright Stainless Steel	Stainless Steel 300 Series
630	US32D	Satin Stainless Steel	Stainless Steel 300 Series
684	----	Black Chrome, Bright	Brass, Bronze
685	----	Black Chrome, Satin	Brass, Bronze

Figure 4
Door hardware finishes

Privacy locksets are not keyed, but you can lock them from the inside. Privacy locksets have a small hole on the outside that allows the emergency "key" that comes with it (or even a nail or hairpin) to unlock the door from the outside. Privacy locksets are used for bathrooms, bedrooms, or any other location where you might want privacy but not true security.

Entry locksets are keyed. While they're normally used for entry doors, you can use these locksets wherever you want or need keyed security.

Deadbolts are usually used with a lockset as a secondary and more secure locking device. Deadbolts are available as either single- or double-cylinder units. The cylinder is the part of the lock into which you insert the key. With a single-cylinder deadbolt, you need a key to enter from the outside, but a thumb latch unlocks the bolt from the inside. Double-cylinder locks require a key on both sides. A double-cylinder lock prevents an intruder from breaking a window in or next to the door and reaching in for the thumb latch to gain entry. But in the event of a fire, the occupants have to find their key to get out, unless they negate the purpose of the double cylinder and leave the key in the cylinder. Warn any homeowner who requests a double-cylinder lock about the fire hazard. During the panic of a house fire, it's not always easy to remember the key.

Most manufacturers have several lines of locksets and deadbolts. The weight of the lockset or deadbolt is often an indicator of cost. The lower-cost units often have plastic or lightweight metal components.

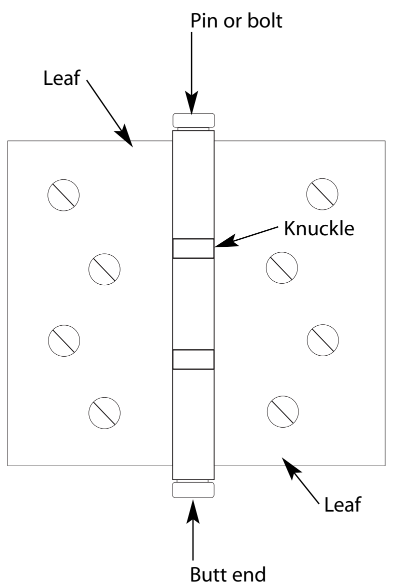


Figure 5
Hinge

Door Hinges

The basic function of a hinge is simple, yet there are hinges for almost every imaginable need. The primary consideration in selection is using a hinge that will structurally match the door. Lightweight $1^3/_8$-inch hollow-core doors can be supported with one pair of hinges. Heavy $1^3/_4$-inch solid-core doors will require one and a half pair of hinges – or three hinges. Hang high-use heavy doors with ball bearing hinges for both durability and ease of operation. The parts of a hinge are illustrated in Figure 5.

Automatic Door Closer

Automatic door closers may be desirable in some situations and required in others. In single-family residential construction, you generally only use door closers on the door between the garage and living space. The Uniform Building Code, and most local building departments, require a closer on doorways in fire-rated walls.

Ordering Doors

By now you should have an idea of the kind of information you need for ordering a door unit. But there's one last important detail to consider: Which way does the door swing? The placement of the hinge determines the door swing. Too often, there's confusion over door swings.

Door Swing

Door swings are designated as *left-hand*, *right-hand*, *left-hand reverse*, and *right-hand reverse*. To determine which swing you want, imagine yourself standing in front of the door ready to open it towards you. If you would reach for the latch with your left hand, it's a left-hand door. If you would reach for the latch with your right hand, it's a right-hand door. In the field, contractor's commonly use the "butt-to-butt" method to determine the door swing. Just stand in the doorway with your "butt" against the jamb where the hinge butts will be placed. Swing your arm out as the future door will swing. Which arm you use to represent the door determines the door swing. Even after reading this paragraph, you may need to confirm your supplier's method of determining door swing before you order any doors. Be real careful here. Chances of a misunderstanding are high.

When you're ordering doors, most door shops will send out a representative to check the door openings. If they don't volunteer this service, request it. This is especially important in multi-unit buildings where wall thicknesses may vary from doorway to doorway due to different drywall thicknesses. In addition to jamb widths, check framed opening widths and light switch locations that might conflict. Architects, framers, and superintendents can and do make mistakes. Order or install the wrong door and whether it's your fault or not, you're still going to get hurt.

Prehung or Not?

There are good reasons why you should use prehung doors. There are also good reasons why you shouldn't. Make your choice after determining whether there's a good door shop available and/or evaluating the skill level of your carpenters. A good door shop will be able to prehang custom door orders, with your choice of door, hardware, jamb and threshold. If you've got good carpenters available, but not a good door shop, go with site-installed doors. If a good door shop can supply your job, prehung units save money and require less skill from the carpenter.

When installed, a well-built prehung unit should be indistinguishable from a well-crafted site-installed unit. Experienced craftsmen can always cite examples of poor prehung units. But you don't need to look too far to find site-hung doors that fit poorly, either.

Check through your suppliers' catalogs and cut sheets for the available door styles and hardware after you've collected all the information you need to order your door units.

Tips for All Door Installations

- *When installing two doors side by side, set the door elevation off of the tops of the doors rather than the floor. If the floor is out of level, the tops won't match. Failure to have the tops match is a sign of poor workmanship and grounds for the rejection of the product by the client.*
- *If a jamb has a slight warp between shims, place a nail at the warped area and then adjust by pulling the jamb out with a pry bar or tap in with a hammer.*

After the door unit is installed, the ends of the shims will still be extending beyond the jambs. Cut these off with a fine-toothed saw or simply score them with a utility knife and pop them off. If you choose this second method, be sure you make the score deep enough. With a thick shim you might pull the jamb out of plumb.

Installing Prehung Doors

Interior and exterior doors are most often installed as prehung units. Interior door units include the jambs, hinges and door with drilling for locksets and strikes included to your specifications.

Exterior doors also include a combination sill and threshold and exterior casing.

Prehung Interior Doors

Use the following installation steps:

Tools and Materials

- *6-foot level*
- *Hammer or air nailer (most carpenters prefer an air nailer)*
- *8d or 10d finish nails*
- *Wood shims*
- *Pry bar (optional, but useful)*
- *Door unit*

1. Check the level of the floor. In new construction this shouldn't be as critical as in a door replacement or remodel, but still take time to do it. If the floor isn't level and the door is set with the first jamb leg tight, you can't get a good reveal without cutting the second jamb leg. A low jamb leg will need to be shimmed to level.
2. Set the door unit in the opening, hinge side first. If the floor was low on the hinge side, begin by placing a shim under the hinge side jamb leg.
3. Place shims slightly above the hinges so the jamb will be roughly centered in the doorway. Nail through the jamb and the shims into the trimmer. Place shims behind the bottom hinge and adjust them using a 6-foot level to plumb down from the first shim location. Before nailing the bottom, plumb the side of the jamb as well. Plumbing the sides of the jamb is as important as plumbing the face. If the side isn't plumb, the hinge line won't be plumb. That means that gravity will swing the door open or closed.

4. Finish setting the hinge side jamb leg by placing a 6-foot level spanning the first two shim locations. Now shim at a midway point so that the jamb will be tight on the level, and nail in place.
5. After you've set the hinge side jamb plumb on both the face and the sides, you can set the header and strike side using the reveal as a guide, but continue to cross-check with the level. Start at the top of the strike side jamb by checking the reveal of the header. Place a temporary shim beneath the jamb and adjust the height until the header shows an even reveal. Ideally, this will be a strong $^{1}/_{16}$ inch, but the actual reveal will be dictated by how the door was set at the shop.
6. After the elevation has been set for a good reveal at the header, set the strike side jamb using at least three shim-and-nail locations. Locate the center shim at the strike.
7. After the door unit is set plumb, with a good reveal, finish by adjusting the stop. To adjust the door for a snug fit, set the stop tight across the header and at the base of the strike side jamb and slightly looser through the strike. This will create a very slight spring when the door is closed, keeping the latch tight in the strike and preventing rattling.

Installing Individual Door Components

Even if you're a firm believer in prehung units, you'll occasionally encounter a situation where you've got to hang a door in an existing jamb, a steel jamb, or a specialty jamb where a prehung unit isn't feasible. A well-hung door is both a source of pride and an enjoyable task for most craftsmen.

Installing a Standard Wood Jamb

Use these guidelines to install a standard wood jamb:

Tools and Materials

- *6-foot level*
- *Hammer or air nailer*
- *8d or 10d finish nails*
- *6d box nails*
- *Framing square*
- *Tape measure*

1. Assemble the frame and prepare to place it in the doorway as a unit. Place four 6d box nails (finish nails will pull through too easily) through each jamb leg into the header.
2. Check the floor for level. If the floor is out of level and you start on the low side with the jamb leg tight to the floor, you won't be able to get the header level. If both jamb legs must be tight against the floor and the floor is out of level, measure the distance the floor is out and cut that amount from the leg on the high side.

3. Place the jamb in the doorway and center it in the framed opening. Shim the top of the first side and nail through the shim and into the trimmer.
4. Shim out the bottom of the first jamb leg using a 6-foot level to plumb from the top shim point.
5. Use the level as a straightedge and shim and nail the center of the jamb.
6. Before moving on to the header and second jamb leg, check the completed first jamb for overall plumb and straightness. Don't move on until you're satisfied that it's as good as you can possibly get it.
7. Shim the top of the second jamb leg snug in the opening. Be careful not to drive the shim too tight or the first leg may be pushed out of plumb by the header. Before nailing the top of the second jamb leg, use the framing square to check the header and the first leg (that you double-checked for plumb) for square. If the header is out of square, adjust the second leg to bring it into square, and then nail through the shim to secure the second leg.
8. Shim and nail the bottom of the second jamb leg by plumbing down from the top shim location. Before securing with a second nail, use the tape measure to check the opening width. The measurement should be the same at the bottom as at the header if your level is good and both sides are plumb.
9. Use a 6-foot level as a straightedge and shim out and nail the center of the second leg. Again, cross-check with a tape.

Tools and Materials

If you don't have a jig and a router, you'll need the following tools to hang a door:

- *Hammer*
- *Chisel*
- *Phillips screwdriver*
- *Pry bar*
- *Plane*
- *Utility knife*
- *Pencil*
- *Tape measure or folding carpenter's rule*
- *Two cordless drills (optional)*
- *Circular saw*
- *Belt sander*

Hanging a Door

There are three separate tasks associated with hanging most doors. First, you've got to fit the door to the frame. Second, set the hinges and install the door. And third, install the lockset.

Fitting the Door to the Frame

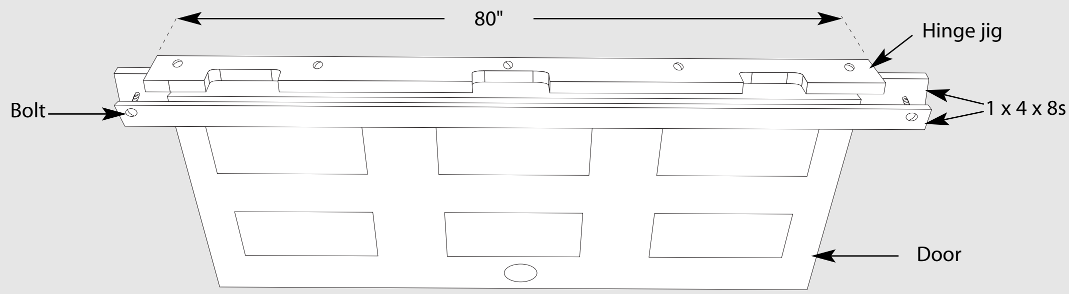
If the new jamb is installed properly, fitting the door should be a piece of cake. In a good jamb, you may only have to trim one side of the door, or if you're really lucky, there's no fitting at all. Fitting a door to an existing poorly-installed frame can be a chore requiring all of the following steps.

1. Measure the doorway and compare it to the new door. A 3-0 door should fit a 3-0 opening. If the door won't fit in the doorway, trim the minimum amount required for the door to fit.

Door Hanging Jigs

Several manufacturers offer hinge template jigs. These jigs are fully adjustable for hinge sizes and spacing. They're useful when hanging a wood door in a metal frame, or a wood jamb and door. If you install doors frequently, manufactured jigs are a worthwhile investment. They not only save time, but produce a crafted product difficult to match with a chisel. Each manufacturer provides detailed steps for their jigs. If you can't justify buying a jig, make your own or follow the manual steps.

Here is a simple jig that you can make using three pieces of 1 × 4 × 8 lumber.



1. *Begin by cutting the first piece of lumber to 80 inches in length. (This piece will be placed against the edge of the door.)*
2. *Measure 7 inches down from the top of the board and place the top of one hinge, butt side out, against the mark. Trace the hinge on the board.*
3. *Measure 11 inches up from the bottom of the board and place the bottom of a hinge, butt side out, against the mark. Again, trace the hinge on the board.*
4. *Center the third hinge in the space between the two traced on the board, and trace it onto the board.*
5. *Cut openings in the board along the traced lines for the three hinges and smooth any rough edges.*
6. *Attach this piece to the edge of one of the 1 × 4 × 8s so that the inside edges of the cut-out openings will be the same distance in from the door edge as the hinge setbacks on the door when the 1 × 4 × 8 is held against the back of the door.*
7. *Attach the second 1 × 4 × 8 to the first using bolts or clamps through the ends of both boards where they extend beyond the top and bottom of the door. The jig is now secured to the door.*
8. *Cut out the mortises in the door using a straight-out router bit. If your bit is too long, put spacers under the jig to lift it off the edge of the door so that the router doesn't cut the jig.*
9. *The recessed cuts you make for the hinges (often called gains) will be rounded on the inside edge. If you use squared hinges, cut the corners with a utility knife and chisel out the waste.*

2. Place the door in the doorway. Place the pry bar under the door with a block under the door so you can raise the door by pressing down on the pry bar with your foot.
3. With the pry bar, lift the door until the hinge side top is tight against the top and the hinge side is tight against the jamb. Check the fit of the door along both sides and the top to see what you need to do to make it fit. Then, scribe and plane as needed for a good fit and place the door back in the frame.

4. With the door tight against the fitted hinge side, scribe the reveal on the strike side. You'll need to mark a space on the strike side that's double the reveal you need. If you want a reveal that's $^1/_{16}$ inch on both sides, place the door tight on the hinge side and scribe for a $^1/_8$-inch gap on the hinge side.

5. Finish fitting the door by fitting the top of the door to the header. Raise the door tight against the header and tight against the hinge side. Scribe and plane the top of the door as needed for a good fit.

Cutting Mortises for Hinges

Consider buying or renting a jig for making mortise cuts if you have many doors to do. If a jig isn't available, try these manual steps. If you're installing the hinges in a new doorway, there are two standard measurements you can use:

- The first standard is 5 inches from the jamb header to the top of the top hinge and 10 inches from the finish floor to the bottom of the bottom hinge. If you're using a center hinge, center it between the two hinges.
- The second standard is 7 inches from the jamb header to the top of the top hinge and 11 inches from the finish floor to the bottom of the bottom hinge. Again, if there's a center hinge, center it between the two hinges.

Follow these steps to cut the hinge mortises:

1. Lay the door on its side with the hinge side up. Mark the top of the door and the edge that will close against the stop. Some door slabs come with a bevel on the strike side so a finely-fit door won't bind on the leading edge as it closes. Lay out the door so the beveled edge will close against the strike side stop.

2. Measuring from the header down, note the hinge locations in the jamb.

3. Prepare to mark the hinge locations on the door by extending the tape the distance of the desired reveal past the top of the door. Most carpenters prefer a strong $^1/_{16}$ inch. For consistency, find a shim or a coin the thickness of the reveal you prefer. Place it at the top of the door and measure down to find the hinge locations.

4. Go to the jamb and measure the distance from the door stop to the hinge on the jamb. Transfer this measurement to the stop side of the door's edge at the hinge locations.

5. Place the hinges on the door edge one at a time and mark their location. For a clean fit, mark their location with a utility knife instead of a pencil. Place your chisel in the mark for a nice clean edge.

6. Finish by installing the door half of the hinge on the door and the frame half on the jamb. Two cordless drills are handy for this operation. Use one for the drill bit and the second as a power screwdriver. Use a little beeswax on the screws for easier placement.

7. Place the door in the opening. Slide the top hinge together and start the hinge pin. Next start the middle hinge pair and finally the bottom. You'll almost always have to tap the hinge sides slightly for final alignment when you don't use a hinge jig and templates for placement.

Trimming a Door

Trimming the bottom of a door isn't without risk. Because you'll be cutting against the grain, it's very easy to chip the bottom when using a hand plane, power plane, or circular saw. Doors are expensive, and you've already spent a lot of time getting to this point. One bad chip can waste the door and all that labor.

The most vulnerable spot for chipping on a door is the final edge — the end of the cut. Either a hand plane or power plane can throw a piece on the final edge. Minimize chipping by taking these precautions:

1. Keep your tools sharp. Sharp tools are the first step in preventing chips. Veneer doors are vulnerable to chipping on the entire edge. Panel doors are most likely to chip at the stiles when you're cutting the end grain.
2. Plane into the final edge an inch or two before planing into the direction of the leading edge.
3. Cut through the veneers on the scribe line with a utility knife before cutting with a circular saw.
4. If a door needs to be trimmed only slightly, use a belt sander. It makes a clean edge without chipping. Use a coarse belt to remove more material faster.
5. Build a simple but effective guide for your circular saw.
6. Using tape to protect the edge is sometimes suggested, but it's less effective than the previous methods.

Building a Door Trimming Guide for a Circular Saw

1. *Select a 1 × 10 at least 36 inches long.*
2. *Using a straightedge, mark a line the length of the board approximately 2 inches in from one edge.*
3. *Attach a $^3/_4$- × $^3/_4$-inch (or wider) guide strip to the straightedge line.*
4. *Using the circular saw you'll be using to trim doors, run the saw along the guide, sawing off the excess board.*
5. *You now have a guide that fits your circular saw and prevents chipping when clamped to the door.*

To use the circular saw guide:

1. *Clamp your guide to the door with the blade edge of the guide exactly on the line where you want to cut.*
2. *Cut by simply running the circular saw along the guide. When clamped tight, the guide edge will prevent chipping.*

Installing the Hardware

Locksets and deadbolts are the typical hardware installed on doors. They're available in many different backsets, but the most typical are $2^3/_8$ and $2^3/_4$ inches. *Backset* is the distance from the edge of the door to the center of the lock. In a new jamb, you can set the center of the lockset from 36 to 39 inches from the bottom of the door. For residential use, try to set the center of the lockset 36 inches from the bottom of the door. Set the center of the deadbolt at 40 inches from the bottom of the door.

Deadbolt and Lockset Installation

Deadbolts and locksets come with drilling templates and installation instructions from the manufacturer. Follow the manufacturer's instructions along with these installation tips.

1. Use the manufacturer's template to drill through the face of the door for the lock.
2. Again using the template, drill the hole for the latch through the edge of the hole.
3. Insert the latch into the hole and mark the outline. Chisel out the mortise for the face plate of the latch. Mark it with a utility knife for a nice clean edge.
4. Assemble the latch and lock as instructed by the manufacturer.
5. Locate the center of the strike on the jamb by closing the door and marking where the center of the latch contacts the jamb.
6. Use the strike as a square and mark the centerline across the jamb.
7. Place the strike over the latch on the door and note the distance from the latch to the edge of the door. This is the distance the latch should be placed from the door stop.
8. Scribe the strike location with the face of the strike against the jamb. Remove the scribed area and install the strike.

Installing Sliding and Patio Entry Doors

For many years, builders have used sliding doors to open up kitchens and family rooms to patios and decks. Patio doors accomplish the same thing with a swinging door. The expanse of glass not only provides light to the interior, but also gives the feeling that the patio is part of the living space. Sliding and patio doors are normally available from window manufacturers, so there's no industry standard as there is with other doors. You have to get specific sizes and framed opening dimensions from each manufacturer. Sliding doors are available in aluminum, wood, and wood with aluminum or vinyl cladding. Patio doors are available in wood and wood with cladding.

Install sliding or patio doors according to the manufacturer's instructions. The instructions should include placing a sealant such as silicone under the threshold as you install the door. You set wood units in place much as you would a window. Aluminum sliders may arrive on the job site in one piece. When broken down, the aluminum frames are usually assembled and installed and then followed by the installation of the fixed and the sliding glass leafs.

Use these guidelines along with the specific instructions provided by the manufacturer:

1. Use a level to check the floor where the unit is to be installed. Check for any humps in the floor that need to be eliminated before setting the door, and note where you may need shims.
2. Place the sealant on the floor.
3. Place the unit or frame in position and center in the doorway.
4. Check for level, shimming as required.
5. While it's still possible to make some adjustments, check the door for position and ease of operation. Patio doors should have an even reveal around the perimeter of the door. When in a full open position, sliding doors should have an even reveal between the door and the frame. After checking the reveal in a full open position, move the door until it is just touching the frame in a not-quite-closed position. The reveal here should also be even. If it isn't, the jamb isn't plumb, or there's a hump or dip in the sill.

Installing Sliding and Bi-fold Closet Doors

Closet doors are usually either sliding or bi-fold doors. Both types offer good access to closet contents, although sliding doors obscure half of the opening even when they're opened. Both types require a track across the header.

Sliding doors should have a guide on the floor at the center of the door opening to keep the two doors aligned. The guide prevents the doors from hitting during operation. Sliding doors hang from the track by their rollers. You can adjust both the height and plumb of the doors by using the wrench provided with the hardware package on the roller units. Sliding doors come as individual doors and a hardware package rather than as a unit. Using the hardware package, you can install any door style or type as a sliding unit.

Bi-fold doors are sold as units, complete with doors and hardware. They're controlled by three contact points. On the jamb side, the door is supported by a rigid floor pivot. A top spring-loaded pivot connects the top of the door to the header. The opposite top of the door has a spring-loaded roller which operates in the track. You make height corrections by adjusting the bottom pivot point, which is threaded and operated by a wrench provided with the hardware package. You can adjust for plumb with the placement of the bottom pivot in the bottom bracket, as well as by loosening the holding screw and moving the top pivot bracket.

Installing Pocket Doors

Pocket doors are ideal for some situations. They disappear into the wall, requiring no floor space when left in the open position. Several manufacturers offer pocket door frames. You can hang any door style you prefer in a pocket door frame. A pocket door frame consists of a header piece and two pairs of metal-wrapped half studs. Frames come for 3-0 doors and have markings for cutting down to smaller door sizes. Consult the frame manufacturer's specifications for rough framing dimensions.

Manhours

Manhours to Hang Doors, per each		
Type	**Manhours**	**Suggested Crew**
Hollow core, flush, to 3'0" × 7"0'	.941	1 carpenter
Solid core, flush, to 3'0" × 7'0"	1.15	1 carpenter
French doors, wood, 1 to 10 lites, 6'8" high	1.45	1 carpenter
Panel doors, 1 3/8" thick with raised panels 7/16" thick, 6'8" high	.827	1 carpenter
Prehung hollow core interior doors, 6'8" high, 1 3/8" thick		
To 2'0" wide	.581	1 carpenter
Over 2'0" wide	.827	1 carpenter
Prehung solid core exterior doors, 6'8" high, 1 3/4" thick		
2'8" or 3'0" wide single door units	.750	1 carpenter
5'4" or 6'0" wide double door units	1.00	1 carpenter
Sliding patio doors, 1 sliding, 1 stationary		
5' wide	2.00	1 carpenter
6' wide	2.75	1 carpenter
Pocket doors	2.29	2 carpenters
Door locksets		
Outside locks	.800	1 carpenter
Dead locks, double key	.615	1 carpenter
Bath or bedroom locks	.615	1 carpenter
Passage latches	.471	1 carpenter

Manhours to Install Closet Doors, per each		
Type	**Manhours**	**Suggested Crew**
Sliding bypassing, hollow core wood, 1 3/8″ thick, 6′8″ high, per each 2-door set		
4′ to 5′ wide	1.95	1 carpenter
5′, 7′ or 8′ wide	2.25	1 carpenter
Sliding bypassing units, steel frame with track/hardware, vinyl over hardboard, 6′8″ high, per each 2-door set		
4′0″ wide	2.07	1 carpenter
6′0″ or 8′0″ wide	2.58	1 carpenter
Sliding bypassing closet units, steel frame with track/hardware, mirror doors over hardboard, 6′8″ high, per each 2-door set		
4′0″ or 5′0″ wide	2.08	1 carpenter
6′0″, 7′0″ or 8′0″ wide	2.58	1 carpenter
Bi-fold closet, 1 1/8″ or 1 3/8″ thick, 6′8″ high		
2′0″, 2′6″ or 3′0″ wide	1.30	1 carpenter
4′0″ or 5′0″	1.60	1 carpenter
Mirror panels for bifold doors, polished edge	.406	1 carpenter

For more information on related topics, see:

Insulation, page 395
Painting, page 427
Trim, page 673
Wall Framing, page 709

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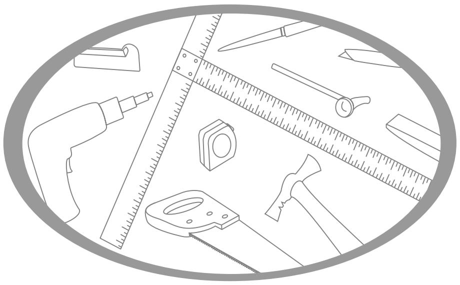

Drywall

Until the 1940s, interior walls were finished with an elaborate process using wet plaster and lath. This process has largely been replaced with drywall, so called because it's installed in solid panels as a "dry wall." Drywall is an inexpensive, less labor-intensive material that provides fire protection, noise insulation and, in certain varieties, can be used as a moisture-resistant barrier as well.

Drywall (also known as gypsum board, wallboard, sheetrock, plasterboard and gypboard) is made from a mineral called gypsum. Gypsum is mined, crushed into small particles, and heated to dry out the last bit of moisture. Then water is added and the mixture is molded and formed between two layers of kraft paper. The end product is a smooth, hard-surfaced material that can be produced and installed relatively inexpensively.

A wide assortment of drywall is available for a variety of purposes. Although it's most often used as a finish for interior walls, drywall may also be used as a moisture barrier and for fire resistance. Keep in mind, though, that even the water-resistant panels can't sit in water; it's only the exterior finish that's water resistant. If moisture gets into the gypsum core, the gypsum will deteriorate, eventually making the panel warp, sag or crumble.

The chart in Figure 1 lists the different types of drywall, the sizes available and their applications. Figure 2 describes the types of edges available on drywall panels and the expansion joints used between them. Figure 3 shows an expansion joint with the tape insert that you remove after finishing.

Type	Available sizes			Uses	Special requirements	Notes
	Thickness	Width	Length			
Standard	1/4, 5/16, 3/8, 1/2, 5/8″	4′	8 to 16′	General applications	None	
Type X; Fire resistant	1/2, 5/8″	4′	8 to 12′	Increase fire resistance with increasing thickness	Special joint finishing procedures	1/2″ sheets have a 45 minute rating
WR; Water resistant: Greenboard; Blueboard	1/2, 5/8″	4′	8 to 12′	Kitchens, baths and laundry rooms. (For high moisture areas like tubs or showers, use cement-base backer board under ceramic tile.)	Use water-resistant joint compound and no vapor barrier	1/2″ sheets have a 45 minute rating
Foil back; insulating drywall	*	*	*	For added insulation or as a vapor barrier	Don't use in hot, humid climates where moisture may be trapped	
Exterior ceiling panels	1/2, 5/8″	4′	8 to 12′	Indirect, exterior, horizontal overhead surfaces	Use battens or joint tape and water-resistant joint compound	Weather-resistant if not directly exposed to weather. 5/8″ panels are fire-rated
Exterior sheathing	1/2, 5/8″	2′	8′	Indirect, exterior, vertical surfaces	Must be attached to framing members, not just sheathing. Install horizontally on vertical surfaces	Must be covered with exterior finish. Adds water- and fire-resistance. 5/8″ panels are fire-rated
Backing board	1/2, 5/8″	4′	8 to 12′	High moisture areas	Cut edges must be sealed	5/8″ panels are fire-rated
Gypsum coreboard	1″	24″	7 or 14′	Solid gypsum partitions without framing members where high fire rating is required		V-shaped, tongue-and-groove longitudinal edges
Gypsum formboard	1″	24, 32 and 48″	8 to 12′	Forms for poured gypsum roof decks	Fasten forms to beams or joists; pour gypsum concrete; formboards themselves are nonstructural	Process creates a noncombustible roof. Faced with either paper or vinyl
Gypsum planks	2″	15″	10′	Structural roofing members	Not water-resistant; protect or immediately cover with roofing	Have steel reinforcement cast into them. Steel tongue-and-groove edging
Gypsum lath	3/8, 1/2″	16 and 24″	4 and 8′	Base for plaster	Solid or perforated face. Perforated face draws plaster into lath, creating a stronger bond	Increases fire-resistance. Easy, quick installation and smooth finish
Partition blocks	2 to 6″	12″	30″	Used instead of studs for framing members	Laminate drywall to both sides of finished partition block wall for smooth finish	Lightweight, highly fire-resistant, nonbearing. Won't shrink or warp, but won't withstand moisture
Radiant heating panels	5/8″	4′	4, 8 or 12′	As heat source in ceilings	Hang in suspended ceilings or nail or screw directly to joists	Connect the electrical leads through a junction box
Decorated drywall	1/2 , 5/8″	4′	8 to 10′	Needs no further finishing after installation	Install with either color-matched nails or adhesive, or use special moldings	Connect the electrical leads through a junction box
Veneer-base drywall; Blueboard	3/4, 1/2, 5/8″	4′	8 to 12′	Use as a base for veneer or plaster	Apply plaster in 1 or 2 coats, 1/16 to 3/32″ thick	1/2″ and 5/8″ panels are fire-rated

*1/2- and 5/8-inch panels are fire-rated. Unfinished, exposed edges and corners need special treatment, depending on type of drywall.

Figure 1
Types of drywall

Type	Uses	Notes
Metal trim	Trim unfinished, exposed edges at windows and doors	Nail through flange of trim; cover with joint compound or veneer plaster
Vinyl trim	Trim unfinished, exposed edges at windows and doors	Resistant to damage; can be painted
Corner bead; corner reinforcement	Allows a clean, sharp finish on corners; also protects them	V-shaped angle of slightly less than 90 degrees. Nail, staple or cinch to corner; cover with joint compound or veneer plaster
Expansion joints	Large expanses of walls or ceilings: Walls — floor to ceiling or door header to ceiling Ceilings — wall to wall	V-shaped expansion joints fit between panels; V has two flanges; cover flanges with joint compound or veneer plaster

Figure 2
Drywall edges

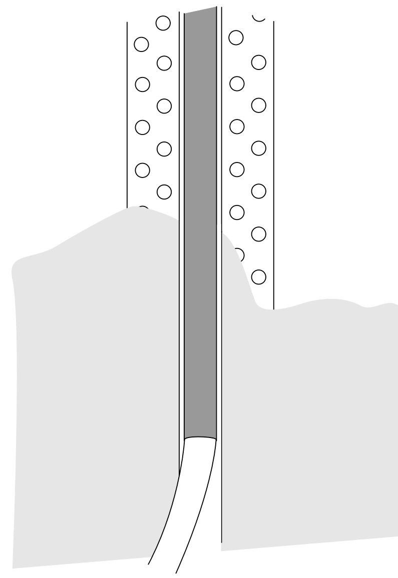

Figure 3
Expansion joint

Fire Rating

The fire resistance of a structure is an important consideration in most building design. If properly selected and installed, drywall can be a valuable part of a building's *fire rating* because gypsum is a noncombustible material. But the drywall is only a single component within a larger design. Even though drywall may not burn, if it's attached to wooden studs or joists, the structure itself can still burn. Drywall helps to protect the combustible part of the structure and the amount of protection it provides is measured in the form of a fire rating.

Architects design buildings with different fire ratings in mind. Most call for a 1-, 2- or 3-hour design. These are measurements of the entire system, not any single component within the system. The ratings indicate that a fire won't burn rapidly through the building materials, but rather, it should take 1, 2, or 3 hours to spread if a selected group of materials are used in the construction. The rating does not guarantee that any particular material itself won't burn. Specifications determined by Underwriters' Laboratories are used to rate a system's combustibility.

Each type of drywall is tested and given a flame-spread rating — a measurement of how quickly flames spread and how much smoke develops. This is expressed in a single number relative to how red oak (100) and inorganic reinforced cement board (0) burn under controlled conditions, 0 indicating the highest resistance. Drywall falls into the 10 to 15 range.

Since drywall itself is noncombustible, fire will try to find a path through any open joints. To block the path of the fire, you should tape and seal every single joint with joint compound. If you install drywall in multiple layers, stagger the joints of each layer. Also stagger the joints on the opposite side of each wall to eliminate a direct path from room to room.

A fire-rated wall must be covered on both sides of the studs with the following number of drywall sheets:

- 30-minute wall, 1 sheet of $^5/_8$-inch Type X on one side of the wall
- 1-hour wall, 1 sheet of $^5/_8$-inch Type X on each side of the wall
- 2-hour wall, 2 sheets of $^5/_8$-inch Type X on each side of the wall
- 3-hour wall, 3 sheets of $^5/_8$-inch Type X on each side of the wall

Sound Insulation

For many structures, such as apartments or office buildings, good sound insulation is a necessity. (See *Acoustics*.) Sound is transmitted through any direct pathway, like an air duct or a common wall. In a common wall, the sound travels through the drywall, the stud, and then through the drywall on the other side of the wall. When designing for sound insulation, think in terms of blocking that direct pathway.

In framing, you can do this with offset studs or parallel walls. (See *Wall Framing.*) Adding insulation inside the walls obstructs the passage of sound, and sealing wall perimeters and gaps around fixtures and outlets with a nonhardening caulk also helps to impede the path. Try to avoid putting outlets or fixtures back to back in the walls. That arrangement provides a direct route for sound transmission.

Soundboard (or sound-deadening board) provides good sound insulation. You can use wood-based fiberboard, plastic foam board or fiberglass board as soundboard. Install soundboard vertically. Then lay drywall over the soundboard, staggering the joints.

For additional sound insulation, architects may require you to use resilient clips or channels. These hold the drywall slightly apart from the soundboard, interrupting the direct pathway of sound. Attach the resilient channels horizontally to the soundboard, using screws rather than nails. Space the channels 24 inches on center, starting 2 inches up from the floor and ending 6 inches from the ceiling. Be aware, however, that any weight on the wall will compress the channels, canceling out their sound insulation value. Make sure the owners know they can't hang cabinets or fixtures on these walls.

Estimating Drywall

It's a simple job to estimate the amount of drywall needed for a job. Begin by calculating the square footage of all the walls (multiply the height by the width). To find the square footage of the ceiling, measure the floor. If you're using the same size panels for both the walls and the ceiling, add the ceiling and wall areas together to get a combined total. Unless the room has a large opening such as a picture window or wide arch, don't subtract for any openings. Once you have the total square footage, divide the number by the square feet in the panel size you're using to find the number of panels you'll need.

In the long run, it's often cheaper — and certainly easier — to use full pieces instead of cut pieces whenever possible. Labor costs are the largest part of a drywall job. Allow up to 10 percent for breakage and miscuts. Use the chart in Figure 4 for quick estimating.

No. of panels	Panel size (in square feet)			
	4′ x 8′ (32 SF)	4′ x 9′ (36 SF)	4′ x 10′ (40 SF)	4′ x 12′ (48 SF)
10	320	360	400	480
11	352	396	440	528
12	384	432	480	576
13	416	468	520	624
14	448	504	560	672
15	480	540	600	720

Figure 4
Estimating panel requirements

Fasteners, compound, and tape are fairly inexpensive, but since they add up quickly, you'll want to be reasonably accurate. Assume you'll use 49 nails or 35 screws per 4 × 8 sheet.

A 4 × 8 panel has 24 linear feet of edge. But don't figure a full 24 linear feet per panel. Floor joints aren't finished, and ceiling joints should only be counted once (either with the wall or with the ceiling). Also, joints are only taped once, so don't double-count here either.

Figure 5 shows some approximate numbers to use for estimating.

Material	Amount	Coverage (SF)
Nails	1 lb	200
Screws	1/2 lb	200
Tape	76 LF	200
Joint compound	1 gal	200

Figure 5
Estimating panel accessories

Moving and Storing Drywall

It goes without saying that drywall is heavy and cumbersome to move. Whenever possible, arrange for the supplier to deliver it not just to the building site, but to the specific room where it's needed. This will save you backaches and hours of moving time. In new construction, placement of the drywall with a boom truck is usually part of the delivery service. With a remodel job, where you may only need enough for a single room or an even smaller area, you'll probably have to get it to the site yourself. If the drywall is delivered out by the supplier and the work is on a second or third floor, try to find a window big enough for the delivery truck to hoist it through.

If you end up moving the drywall yourself, use a drywall dolly. Stack the material flat, rather than on edge, in the center of the room where you'll be working. Place the ceiling sheets on top because you'll cover the ceiling first. Drywall is extremely heavy, so stack it across the joists rather than with them. For large rooms, make several small stacks of drywall instead of a single tall, very heavy one.

Wait to have the drywall delivered until you're ready for it. The longer the panels sit at the job site, the more likely they are to get banged up or damaged from weather.

Measuring, Marking and Cutting Drywall

Tools

- *Pencil*
- *Chalk line (blue)*
- *Drywall square*
- *Measuring tape*
- *Utility knife*
- *Drywall or keyhole saw*
- *Sandpaper (80-grit) or rasp*

In every job you'll have to cut some pieces of drywall to fit odd spaces. This is where mistakes happen and the job slows down. Keep in mind that every edge and every joint will have to be finished, so planning for the fewest cuts and joints is basic to speeding up the job. Although the wallboard itself and the joint compounds are relatively inexpensive, material waste and extra labor still add unneeded costs.

Cutting a Simple Straight Edge

1. Measure the area to be covered. Using a pencil and tape measure, transfer the measurements to the face of the drywall (Figure 6). Snap a chalk line between the two marks to make a cut line.
2. Using a drywall square or other straightedge and a utility knife, carefully score the face paper and the drywall (Figure 7). For thinner pieces, you may be able to cut all the way through the drywall along the score lines or pencil markings, making a fairly clean edge.

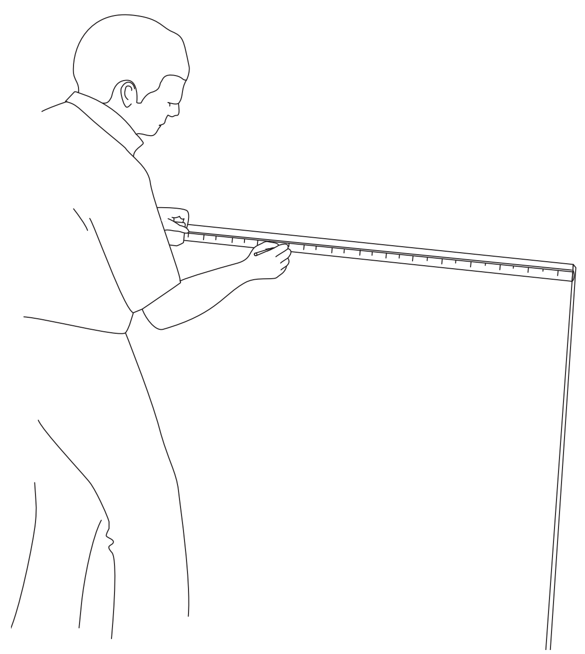

Figure 6
Transfer measurements to drywall panel

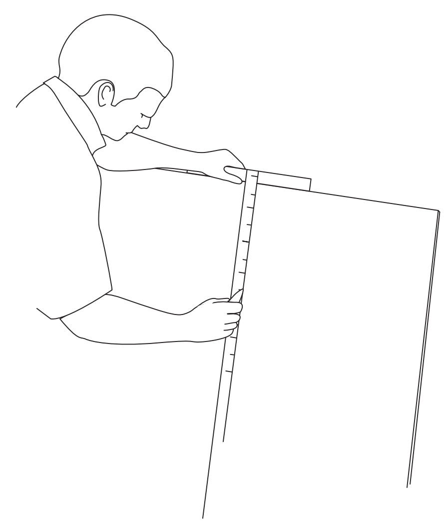

Figure 7
Cut along straightedge or T-square

3. Thicker pieces require extra steps. After scoring the face side, lift the drywall straight up on edge. Firmly hold the drywall on each side of the cut. Use your knee to gently force the board to bend at the cut line, pulling back at the same time (Figure 8).
4. The back paper and maybe some of the drywall will still be intact. Use your utility knife to cut through it (Figure 9). If the cut edge is rough, smooth it with a rasp or sandpaper.

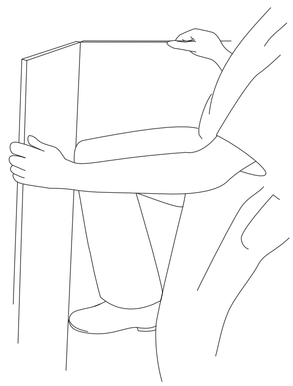

Figure 8
Bend along cut line

Making More Difficult Cuts

Thin strips don't break cleanly. For pieces that are 3 inches wide or less, you can use a drywall or keyhole saw. Or make multiple passes with a utility knife until you've cut through the sheet. A third way is to score the face, then carefully measure the back side, and score along the same line.

Making an Angled Cut

Find point A of the triangle. Measure the distance to points B and C. For an angle of a polygon, find A, B, C, and D (see Figure 10). Transfer the measurements to the face of the drywall and cut in the same manner as explained above.

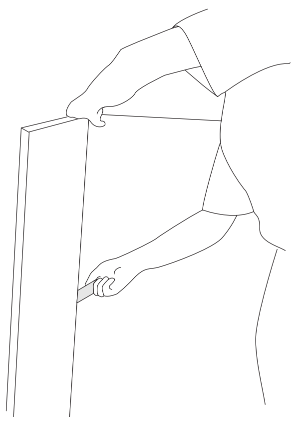

Figure 9
Cut through panel with utility knife

Cutting a V-Angle

A V-angle is nothing more than two polygons put together. Find the center point and then measure. There are a couple of ways you can do the cutting. You can score the face of the drywall, and then carefully measure the back side and score along the same line. Or use a drywall saw to cut the first line; score and break the second line as explained above.

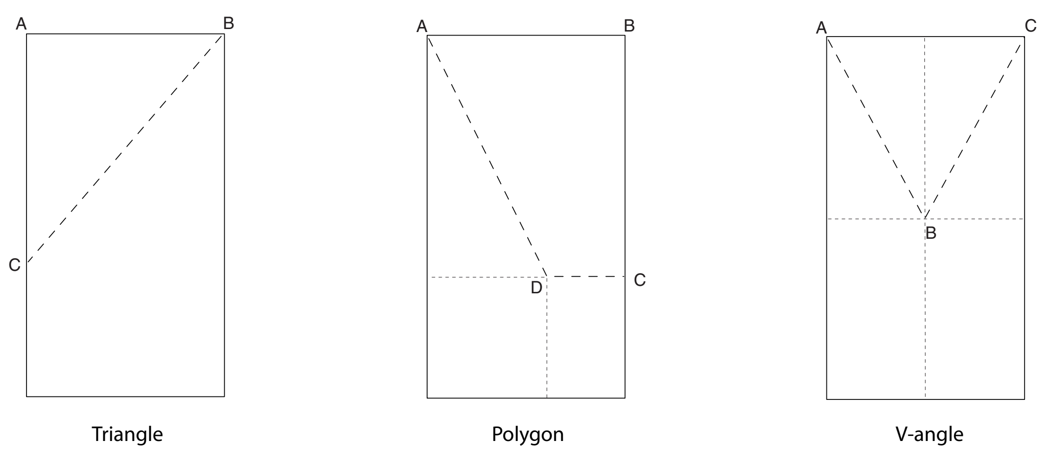

Figure 10
Measuring for an angle cut

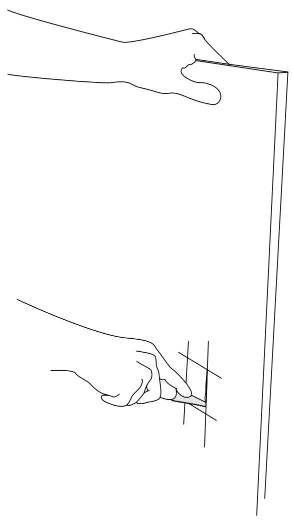

Figure 11
Make cutouts with a keyhole saw

Making a Small Cutout

You can measure and cut outlet cutouts before you hang the sheets. First, measure in from the vertical edge, then from the horizontal edge. Or use the outlet cover as a template and trace around it. Another alternative is to use a block of wood as the template. Carefully measure for placement. Set the block in place and tap with a hammer to make a clear impression. (More-experienced hangers measure prior to hanging and router out the cutout after they've fastened the drywall along the edges.)

Make the cutout slightly larger than the outlet box but small enough that the outlet plate will still cover it. With a keyhole saw, make holes at the corners and then cut the sides as shown in Figure 11.

Making a Large Cutout for a Door or Window

Hang and fasten the full sheet of drywall first. Once it's securely in place, use a drywall saw to cut upward along the vertical framing members. Score the horizontal line with a utility knife and gently break the drywall back. Cut the back side and rasp or sandpaper the edges as needed.

Drywall Fasteners

You fasten drywall with nails, screws, staples, adhesives, or a combination of fasteners. Nails are rarely used anymore because screws have 3 to 4 times more holding power than nails. Don't put any kind of fastener within $^{3}/_{8}$ inch of the edge. Figure 12 describes the different types of drywall fasteners and their uses.

Screws have three advantages over nails. First, once placed, they stay. Second, if you need to remove a section of drywall, it's easier and less damaging to remove screws than nails. And finally, nails have a tendency to work their way out, particularly if there's any shifting in the foundation. If the wood is wet, the nails may "pop" as the wood dries, requiring patch work.

When using screws, you don't need to use an adhesive. The screw head is shaped to grab the paper slightly as it's twisted in, which gives it more holding power. Use a screw gun to drive in screws to just below the surface, causing a slight *dimple*, about $^{1}/_{32}$ inch deep. Don't break the paper.

If you do use nails, you can use up to 75 percent fewer of them if you also use an adhesive. Using both nails and adhesive, you'll use about the same number of nails as you would screws. Adhesives actually hold better than the nails. Apply a $^{3}/_{8}$-inch bead of adhesive directly to clean wall studs or ceiling joists. Use the nails to fasten the drywall to the studs, spacing the nails 16 inches apart. They need to hold the panels firmly in place until the adhesive sets.

Type	Uses	Maximum spacing (in)		Minimum grip length (in)	Board thickness (in)	Minimum nail length (in)	Notes
		Ceiling	Wall				
Ring shank nails	Drywall to wood studs	7	8	$\frac{3}{4}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	$1\frac{1}{8}$ $1\frac{1}{4}$ $1\frac{3}{8}$	Ring shank nails hold about 20% better than smooth-shank nails
Cement-coated nails	Drywall to wood studs	7	8	$\frac{7}{8}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	$1\frac{1}{4}$ $1\frac{3}{8}$ $1\frac{1}{2}$	Cement coating provides good grip
Type W screw (wood)	Drywall to wood studs	12	16	$\frac{5}{8}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	1 $1\frac{1}{8}$ $1\frac{1}{4}$	
Type G screw (gypsum)	Drywall to drywall	12	16	$\frac{3}{4}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	$1\frac{1}{8}$ $1\frac{1}{4}$ $1\frac{3}{28}$	
Type S screw (steel or sheet metal)	Drywall to steel studs or sheet metal	12	16	$\frac{3}{8}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	$\frac{3}{4}$ $\frac{7}{8}$ 1	
Staples	Base layer of drywall to wood studs	7	7	$\frac{5}{8}$ Crown: $\frac{7}{16}$	$\frac{3}{8}$ $\frac{1}{2}$ $\frac{5}{8}$	1 $1\frac{1}{8}$ $1\frac{1}{4}$	

Figure 12
Drywall fasteners

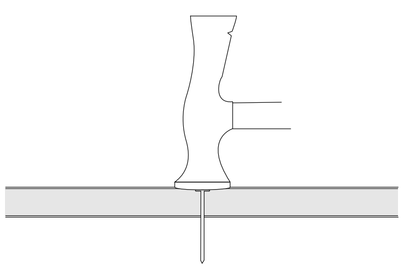

Figure 13
Indent, but do not break, face of drywall

There's an art to nailing drywall. The nail's head should be lower than the surface of the drywall paper, but never so low that the paper gets torn or broken. The end result should be a slight dimple as shown in Figure 13. If you do accidentally tear the paper, add another fastener about $1\frac{1}{2}$ inches above or below the first one. If possible, use a drywall hammer, which has a slightly rounded head to prevent the paper from tearing.

You can either single-nail or double-nail drywall. Generally you'll single-nail on the vertical and horizontal edges and double-nail on the studs in between. Begin in the center and work toward the edges, single-nailing a row on each stud 12 inches apart. When you've finished nailing the entire panel, go back and drive a second set of nails 2 inches from the first.

Hanging Drywall

A great taping job can only do so much to cover up a poor hanging job. A good hanging job can also only be as good as the framing job. If the studs are out of alignment, the drywall will be too. Shim or replace crooked studs before you install panels. (See *Wall Framing.*)

Although the quality of the taping job will make or break the finished wall, the quality of the hanging job is what makes or breaks the taping. A good hanger aims for snug joints, smooth edges, and as few joints as possible. If the hanger does a good job, then the taper won't need to spend time inefficiently filling voids with compound or smoothing up rough edges.

The best tapers try to tape in such a way that they have to do very little, if any, sanding, especially if the wall is to be textured. That's because sanding adds not just one, but two steps. First they sand, and then they have to thoroughly clean the area because any dust at all will change the texture, spreadability, and drying time of the joint compound. This means added hassles and labor.

Shifts, even slight ones, in the framing members will affect the drywall. So make sure the weight of the roofing materials is evenly spread on the roof, or loaded, before you install the drywall. The weight of the shingles will cause the framing to compress slightly and may result in damage to the drywall or taping. Heavy timber, such as a 4 × 12, shrinks as it ages. If you fasten drywall to one, you'll end up with a crack to repair later. Also, don't force pieces to fit. Cut them so that the gaps are as small as possible. Forcing panels may result in buckling or bowing.

Ceilings

When hanging drywall, begin with the ceiling panels. It's easier if you don't have to worry about banging up wall panels as you hang the ceiling sheets. And if the ceiling panels eventually start to sag, they'll be less likely to tear the joint if the wall panels are there to give them support. Installing drywall on a ceiling can be tricky, especially if you don't have a second person to hold and steady the panels. Fortunately, there are a couple of tools to help. You can make a T-bar by nailing 2 × 4s together. Or you can rent a panel hoist, which works well for a single installer.

Another option is to nail a horizontal block of wood close to the ceiling, set across at least two framing members. Place it down from the ceiling the width of the drywall plus about 1/8 inch. Rest the panel on this block as you fasten the drywall to the ceiling.

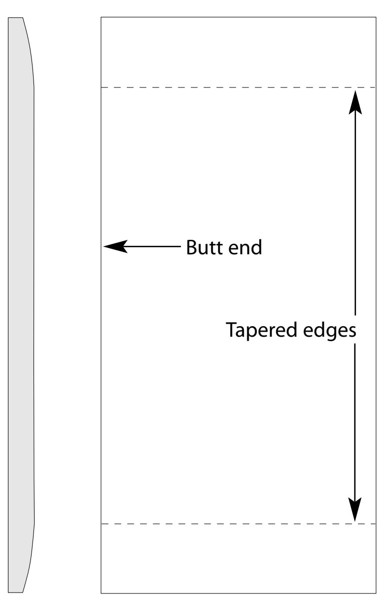

Figure 14
Hang tapered end to tapered end and butt end to butt end

Walls

Install drywall from the upper part of the wall and work down. Hang the sheets horizontally, tapered edge to tapered edge and butt end to butt end. (See Figures 14 and 15.) Even if the wall is over 8'1", we recommend installing the sheets horizontally. If the job requires a third strip, hang it in the middle rather than at the floor or ceiling. That makes the job a whole lot easier for the finisher.

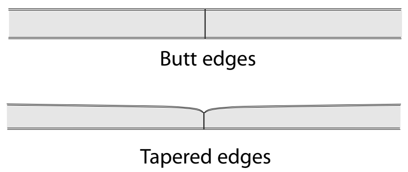

Figure 15
Drywall edges

It's harder to finish butt ends smoothly, so try to stagger the butt end joints and keep them from the center of the wall or ceiling. Also, for horizontal installation, use the longest panels available to reduce the number of vertical joints. If panel seams fall over doors or windows, center the seam if possible.

Installation Methods

Tools for installation include:

- *Marking, measuring, and cutting tools*
- *Fasteners — nails, adhesive and drywall hammer; or screws and screw gun*
- *Large nails, wood block and pry bar*

Here is a guide for your installation:

1. *Begin in a corner and work out, hanging full sheets. For ceiling panels, fasten the wood supports as explained above. For horizontal wall panels, drive several large nails about 4 feet down from the ceiling into the studs and use the nails to prop up the drywall panels. You can use a similar method to prop up vertical wall panels. Butt the end of the vertical panel against the ceiling. Baseboard trim will cover gaps at the bottom.*
2. *If you're using nails as fasteners, spread a bead of adhesive on the studs the space of a single panel. Lift and position the panel in place, resting it on the nails to hold it high enough.*
3. *Nail or screw the drywall to the studs or joist, starting in the center of the panel and working out. Hold the sheet tight against the stud or joist as you fasten.*
4. *Sometimes in the process of driving in nails or staples, others will loosen or pop out. Check each panel as you work. When you finish, recheck the entire room and adjacent rooms for loosened fasteners.*

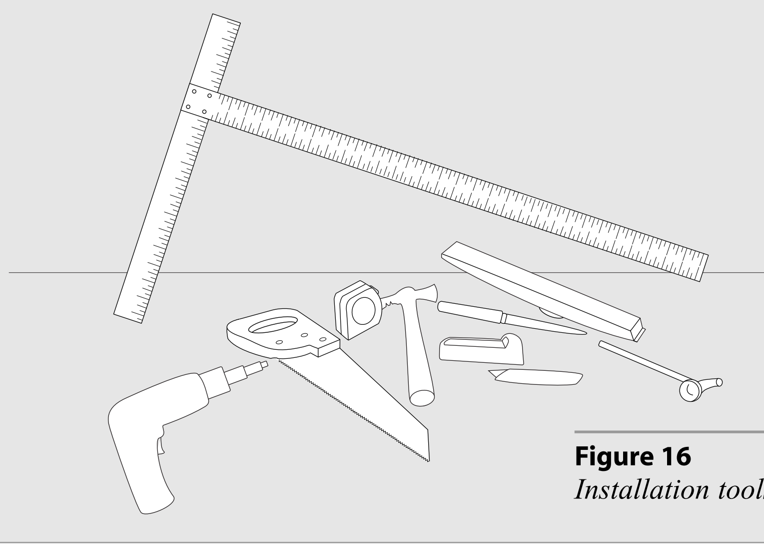

Figure 16
Installation tools

Finishing the Joints and Fasteners

Finishing joints is an exercise in patience. Here are some tips:

- *More is **not** better:* A thin, even layer of joint compound is essential and ultimately far less work than a thick layer.
- *Hurrying costs time:* Allow the compound to dry thoroughly before you apply the next layer. The better your spreading technique, the less sanding you'll have to do.
- *Never finish drywall in extreme temperatures or humidity:* Use the building's heating and cooling to control the temperature. Don't use space heaters, which can emit vapors and create wide temperature variations. Uneven heat causes uneven expansion of the product and can result in hairline cracks when finished. Drywall can be installed in temperatures no lower than 40 degrees F or higher than 95 degrees F, but for finishing, the temperature must be between 50 and 95 degrees F. The ideal temperature and humidity for finishing drywall is 70 degrees F and 50 percent humidity. That would provide a drying time of about 24 hours for a standard premixed joint compound. Always read the manufacturer's labels for specific recommendations.

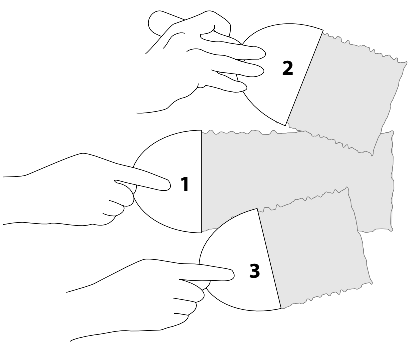

Figure 17
Work from the center out

The real art in joint finishing is "feathering" the joint compound, the process of spreading the compound as thinly and smoothly as possible You need to apply three coats of joint compound and they should be no thicker than the depression they're filling, maybe as little as $^1/_{32}$ inch.

To do this, you'll need a wallboard knife with a perfectly straight edge, and no nicks or grit to create ridges. Practice first, holding the knife at a 45-degree angle and using steady, even pressure and a minimal amount of joint compound. Work from the center of the tape out as shown in Figure 17. Always keep in mind that the end result must be smooth and undetectable.

Joint Compounds

Before using, stir the joint compound until it's the consistency of soft butter, thinning with water if necessary. To keep the compound from getting lumpy, add about an inch of water and securely cover the container. Joint compound dries by evaporation. So if it starts getting a little dry, just add some more water and mix thoroughly.

There are four types of joint compounds generally available, although some manufacturers offer more options.

Taping compound comes dry or ready-mixed. It has good bonding strength, but the glues in it make it harder to give a smooth finish coat. Dry compound is cheaper than ready-mixed, but it's tough to mix a smooth batch, especially for a novice.

Tools and Materials

You'll need the following tools and materials for finishing the joints on your drywall installation. There are various tools made to help both the novice and the experienced taper. Some of them are shown here.

- *Wallboard knives: 4-inch, 6-inch and 10-inch*
- *Utility knife*
- *Mud pan or hawk*
- *Corner knives (inside and outside)*
- *Saws*
- *Banjo*
- *Stilts*
- *Clinching tool*
- *Safety goggles*
- *Breathing mask*

Here are the basic joint taping materials:

- *Joint compound*
- *Joint tape*
- *Sandpaper (minimum of 100 grit) or sanding sponge*
- *Sanding block*
- *Water*

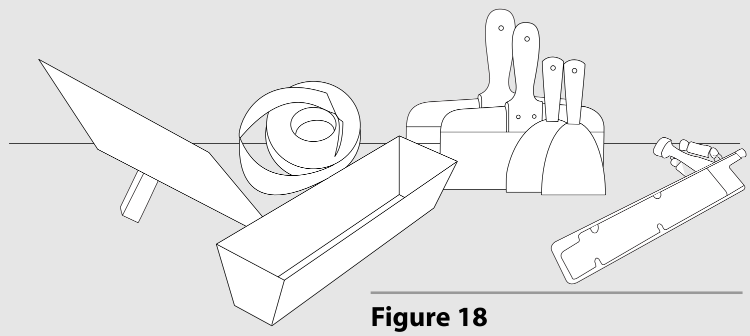

Figure 18
Taping tools

Topping compound is good for finish coats. It has a smooth consistency for easy workability, but it lacks the bonding strength of standard taping compound. Topping compound also lacks the hardness of taping compound, which is why it's easier to work with but also not as durable.

All-purpose compound falls somewhere in the middle of the two, but comes closer to taping than topping compounds in spreadability, hardness, and bonding strength.

*Quick-set compound i*s a fast-setting compound used for very small jobs or for building up areas quickly. It always comes in dry form; once water is added, it immediately starts to set up. Quick-set compounds are sold in various set times: 30-minute, 45-minute, 60-minute, and so on. Always use a topping compound to finish off the joints.

For the most part, unless you're doing a really small job, you're far better off buying both taping and topping compounds than using an all-purpose compound.

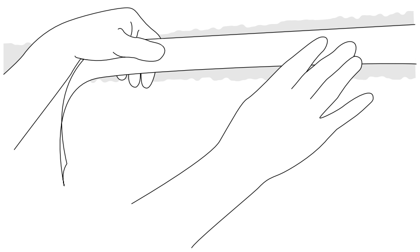

Figure 19
Lay tape into joint compound

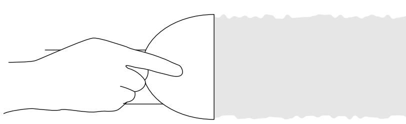

Figure 20
Press tape into compound with a wallboard knife

Joint Tapes

Two basic types of joint tapes are available. Again, manufacturers offer variations within each type. Tape is sold in 2-inch widths.

Paper tape comes perforated. The holes, which range from minuscule to $^{1}/_{16}$ inch, help the paper bond with the joint compound. It also has a center crease to make finishing corners easier.

Fiberglass tape is more expensive than paper tape. It's made of woven fiberglass and comes with or without an adhesive backing. The adhesive allows you to skip the embedding step; you just press it onto the drywall. Nonadhesive-backed tape must be stapled in place first, two staples at each end and every 24 inches in between. Fiberglass tape is durable in high-moisture areas. For the novice, though, it's tricky to use, especially on corners.

Tapered Joints

1. Start with the ceiling and work down. Using a 4-inch knife, spread a thin layer, or embedding coat, of joint compound in the seam between panels. This first coat acts as a glue to hold the tape to the panels as shown in Figure 19.
2. Using a wallboard knife, firmly press the tape into the joint compound. Draw the knife down the tape to force out extra compound. (See Figure 20.)
3. Lay a very thin skim coat over the tape. If the tape hasn't bonded somewhere, it'll show up in the form of a bubble. Use a utility knife to slit the bubble. Force a little joint compound underneath and smooth flat. Allow the application to dry completely, which may take 24 hours or more.
4. When the skim coat is totally dry, apply a second coat. Use a 6-inch knife to feather the sides out about 2 inches beyond the first coat. Again, let the compound dry completely.
5. If you have any dips, bumps, or other flaws, sand the area lightly and wipe it clean before applying the next coat. Be careful to avoid tearing the tape, and be sure you have cleaned away all the sanding grit. Any little bit of dust will cause more flaws in the final coat. Either dry- or wet-sand the flaws. Dry-sanding is simply using dry sandpaper. Use a sanding block to keep a more even pressure. Wet-sanding is done either with regular sandpaper that's been wetted or with a dampened sanding sponge. The latter will produce less dust, but the added moisture means you'll have to wait for the joint compound to dry out again. The drying time for this, though, is considerably less because the compound isn't nearly as wet as with a coat of compound. When sanding, wear safety goggles and a breathing mask.

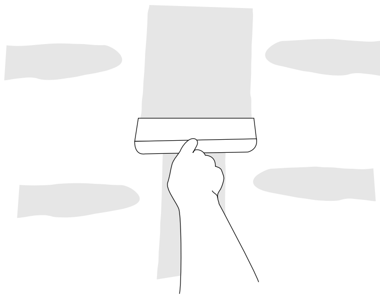

Figure 21
Use 10-inch knife for final coat

6. Apply a final coat using a 10-inch knife, as shown in Figure 21. Again, feather the edges out about 2 inches beyond the second coat.
7. Wet- or dry-sand the final coat as needed.
8. Clean off your tools in water, using a stiff brush. If joint compound dries on the tools, scrape off the excess with a drywall knife and clean with water.

Nontapered Joints

1. Nontapered joints, such as butt ends or two cut panels, are more difficult because there's no depression. They can also be weaker joints because you can't build as thick a bond. To get the strongest bond on these joints, the embedding coat is particularly important. Apply and feather out a thin embedding coat with a 4- or 6-inch knife.
2. Press the tape into the joint compound and proceed just as you would for an angle-tapered joint. Feather the joint out further than on a tapered joint to get a smooth, level finish. You may need to carry it out up to 18 inches.

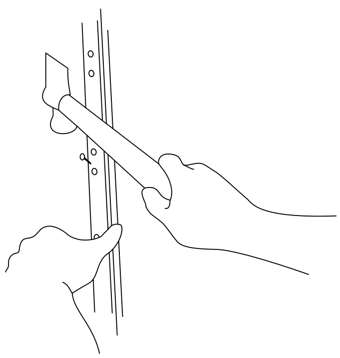

Figure 22
Install corner bead

Outside Corner Joints

1. Install the corner bead with either nails for metal corners or staples for vinyl corners (see Figure 22). Place the fasteners 9 inches apart. Or use a corner clincher and nails.
2. With a 4-inch knife, apply the first coat of joint compound, first on one side of the bead and then the other (Figure 23). Feather it out an inch or two beyond the flange of the bead. Allow to dry thoroughly.
3. Apply the second and third coats in the same way as for an angle-tapered joint. Using progressively wider knives, feather about 2 inches further with each coat (Figure 24). Allow each coat to dry thoroughly, sanding if needed between coats and after the last coat.

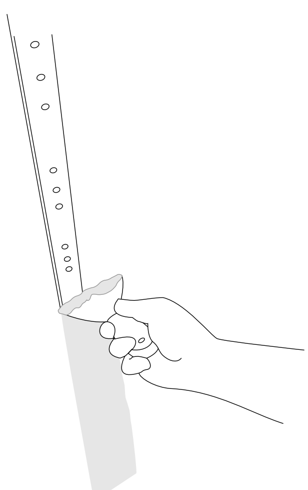

Figure 23
Apply compound over corner bead

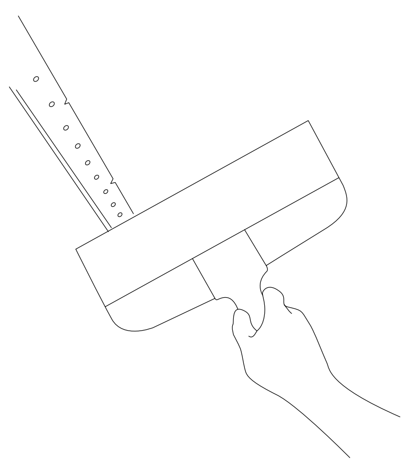

Figure 24
Feather corner with wide knives

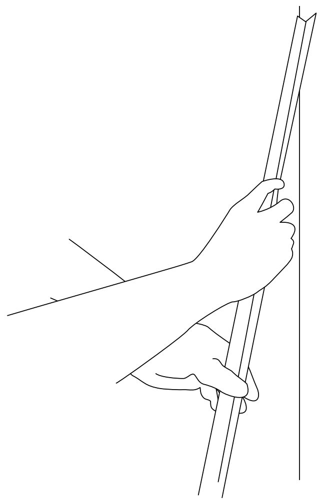

Figure 25
Fold paper tape down the middle

Inside Corner Joints

1. Use a 4-inch knife to apply an embedding coat to both sides of the corner.
2. Fold the paper tape down the center crease as shown in Figure 25. Place it into the corner and press into the embedding coat with a corner-finishing tool (see Figures 26 and 27). If you're using fiberglass tape, skip step 1. Instead, staple or press the tape into the corner. Proceed as you would for paper tape.
3. Apply a thin skim coat to the tape and feather it out, forcing out all excess compound. Allow it to dry completely.
4. Apply the second coat and third coats in the same way as for an angle-tapered joint. Using progressively wider knives, feather about 2 inches further with each coat (Figure 28). Allow each coat to dry thoroughly, sanding if needed between coats and after the last coat.

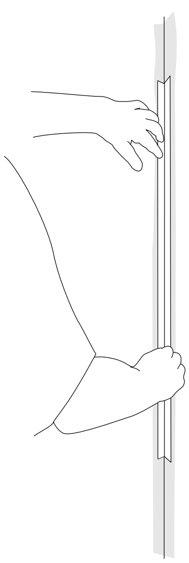

Figure 26
Press tape into embedding coat

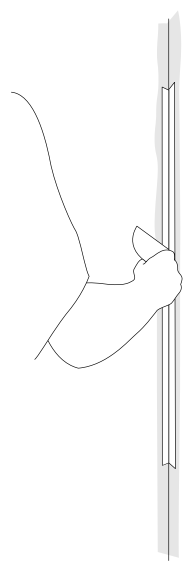

Figure 27
Use inside corner tool

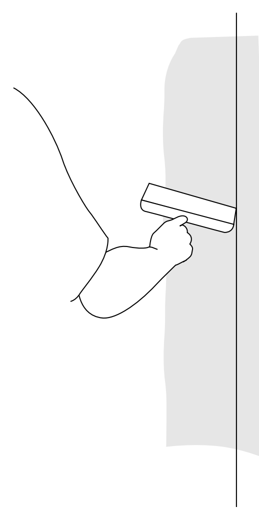

Figure 28
Feather corners

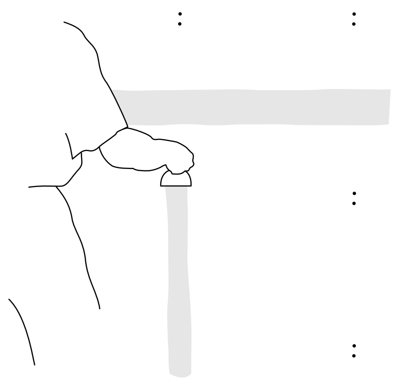

Figure 29
Covering a row of dimples with compound

Covering Fasteners

1. Spot, or fill, fastener depressions while waiting for joints to dry. Using the 4-inch knife, spread a small amount of joint compound on each dimple. For speed, start at the bottom of a row of dimples and pull up, as shown in Figure 29. Keep the knife tight against the drywall. Allow the compound to dry completely.
2. Apply second and third coats, sanding as needed.

Special Taping Jobs

There are a few special taping jobs that you should know about, such as finishing arches and taping fire joints.

Fire Taping

Fire tape joints when the fire rating of a wall is important but the finished appearance of the drywall isn't. Tape and seal every single joint (to block the path of a fire) in the same way as described for regular joints. However, fire taping requires only one coat of compound and tape. Although you don't want to end up with a rough, sloppy job, you don't have to be quite as meticulous because you would only fire tape joints that are in locations where they won't be noticed.

Arches

Occasionally you'll need to finish an arch. Some drywallers bow a sheet of drywall by misting it and shaping it. Another method is to cut a series of thin wedges, or kerfs, in the drywall backing to allow it to be shaped. Probably the easiest method, though, is to use Masonite or $^1/_4$-inch drywall panels cut to width and bent without any other treatment.

Drywall Surface Finishes

Drywall is really just the base for a wide variety of surface finishes. There are, however, different base requirements for different finishes. For a rated wall, the drywall may be only fire taped. Textured walls require a smoother finish, and walls being prepared for wallpaper or a slick finish should be as smooth as possible.

Regional differences exist in all areas of construction, but in drywall they are especially prevalent. In some areas of the country, textured walls are almost always used. But the type of texture preferred varies even within these areas. In places that predominately use slick walls, regional preferences dictate whether you achieve that affect with a total veneer plaster process, a skim coat of topping compound, or smoothly feathered taped joints.

Whatever final finish you select, drywall is the starting point, but the preparation to get to the finish will vary considerably. We'll cover smooth or slick wall finishes, veneer plaster finishes, and different types of texture coatings.

Tools and Materials

- *Drywall knife*
- *Topping compound*
- *Hawk or pan*
- *Sandpaper and block*
- *High quality primer*
- *Paint brush or roller*

Smooth or Slick Wall Finishes

Of all of the surfaces, a smooth wall is the most labor intensive — and the most expensive. Often referred to as a *slick wall*, there can't be even the smallest imperfection in your drywall installation because every tiny flaw is surprisingly visible once you paint. As a result, you'll normally give a slick wall an additional coating of topping compound to ensure a smooth, uniform finish.

Some drywall manufacturers use more porous paper than others, and there's often a visible texture difference between the joint compound and the paper once it's painted. In this case, you'll need to apply a skim coat to the entire wall to even out this contrast.

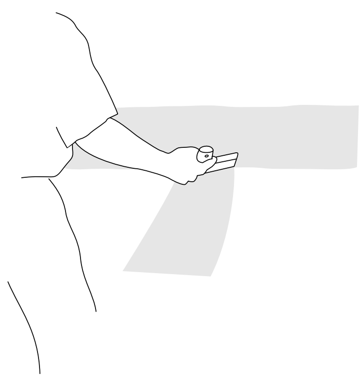

Figure 30
Apply topping compound using a drywall knife

Finishing Steps

1. Finish joints and fasteners as smoothly as possible.
2. Use the drywall knife to spread an extremely thin layer of topping compound over the drywall as shown in Figure 30. The topping coat should fill in the pores of the paper and any other minor flaws, but nothing more. Allow it to dry completely.
3. Very lightly sand the entire wall. Clean the compound dust off the walls by wiping it with a clean cloth or blowing it off with compressed air.
4. Apply a primer coat of paint. After the paint is completely dry, lightly sand again where the paper is raised. The wall is now ready for paint.

Tools and Materials

- *Fiberglass tape (and/or) paper tape*
- *Joint compound*
- *4-inch drywall knife*
- *Veneer plaster*
- *Trowel*
- *Hawk*
- *Spray equipment (if using spray application)*

Veneer Plaster

Although the look of veneer plaster is similar to the look of a slick wall, the finished surface of veneer plaster is considerably harder and more durable. The application process for each finish is quite different as well.

Use veneer-base drywall panels if you're going to have a veneer plaster finish (refer back to Figure 1). They provide a better bond with the plaster than standard panels. Also, fiberglass tape is better than paper tape for the joints. If you do use paper tape, be sure to use a joint compound that works with veneer plaster.

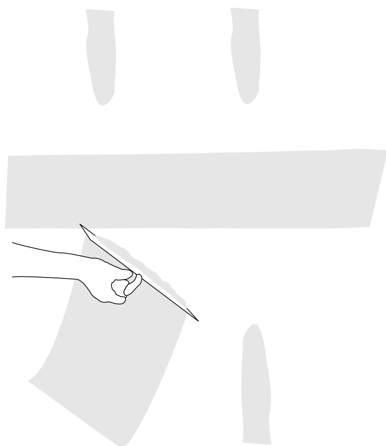

Figure 31
Apply a thin coat of veneer plaster by hand

Veneer plaster comes only in dry powder form. Mix only a little at a time because it sets up within a few minutes. Clean your tools before the plaster hardens; otherwise, the plaster will be tough to remove. You can apply veneer plaster by hand or with spray equipment. If you spray it on, practice first to get a smooth, even coat.

Finishing Steps for Manual Application

1. If you're using fiberglass tape, attach the tape to the panels. If you're using paper tape, embed the tape in joint compound in the same manner you would if you're using standard drywall, except only do the first coat. Let it dry completely.
2. Mix a small amount of veneer plaster. Using a trowel, apply a $^{1}/_{16}$-inch coat over the fiberglass or paper tape joints.
3. When the joint layer is firm, apply a thin coat of veneer plaster over the entire wall (both joints and panels) as shown in Figure 31. Apply it to about a $^{3}/_{32}$-inch depth. Either trowel the wall smooth, or use a trowel, a brush, or a sponge to create different textures.

Finishing Steps for Spray Application

1. Tape as above.
2. Spray the veneer plaster in two passes, applying the second pass at right angles to the first.
3. Trowel the surface smooth or apply a texture as described in the manual application above.

Texture Finishes

Again, regional preferences will probably dictate the kind of texture you'll choose. But almost all of them fall into one of the following categories: troweled, brushed, rolled, sprayed, or a combination of these.

Apply textures using the formulated texture compounds available from drywall suppliers. These compounds, unlike taping and topping mixes, are almost always available in dry mix only. You can also use all purpose mixes. You'll need to do some experimentation to get the proper mix for your choice of texture. With all but the troweled textures, you'll need a mix that's surprisingly wet, with an almost thick-paint consistency.

Trowel Finishes

Finishers who are adept with a trowel or drywall knife can produce a variety of beautiful surface finishes. You can create different effects by adding texturing agents to joint or topping compounds or by using premixed texturing compounds.

Tools and Materials

- *Drywall knife or trowel*
- *Taping, topping, or premixed texturing compound*
- *Putty knife*
- *Hawk or mud pan*

Commercial texturing agents come in different grades of coarseness, or you can add your own additives, such as sand or even cornmeal, to create your own unique finish. The texturing agents will cause the plaster to tear, or flow somewhat unevenly, under the trowel and add a roughness to the wall surface. Varying your trowel pressure and strokes will further affect the final finish. For even more variety on a troweled surface you can sponge, brush, blot or trowel again.

Use a 10-inch drywall knife or a 10- to 24-inch trowel. The smaller the trowel, the easier it is to handle, but it will take twice as many strokes as a larger one to complete the job. Experiment with different strokes until you feel comfortable that you can get an even pattern throughout.

Applying the Textured Finish

1. Finish the drywall joints as you would for a smooth wall.
2. Use a putty knife to put compound on the trowel, about $^{1}/_{2}$ inch wide and $^{1}/_{2}$ inch thick the length of the blade.
3. Spread the compound to a depth of about $^{1}/_{16}$ inch. When you have spread all the compound on the trowel, go back and trowel over the area again to produce the desired pattern or texture.

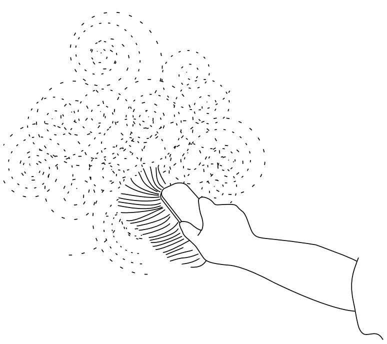

Figure 32
Creating a brush texture

Brush Texture — There are two main types of brushes used for a brush texture; each creating a different effect. Use a wallpaper type brush to create a swirl pattern. You can make a more refined, uniform pattern by twisting your wrist in overlapping patterns. For a random pattern, use a 3-knot brush. Move across the wall in a rapid slapping motion, again with a slight twist of the wrist.

Creating a brush texture finish is a two-step process:

1. Apply the texture material to the wall with a paint roller.
2. While the texture material is still very wet, use the brush to create the desired patterned texture as in Figure 32.

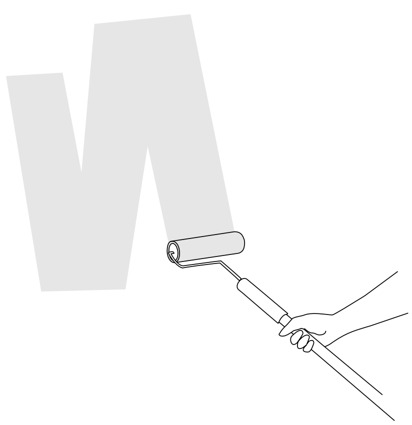

Figure 33
Use paint roller to apply texture

Rolled Texture — Apply rolled textures with a paint roller as shown in Figure 33. Again, the consistency of the mix should be wet, almost paint-like. The nap length of the roller you use will have an effect on the resulting texture.

Texture Paint — You can also add texture to a surface by using texture paint, a heavy latex paint with a texturing agent added. Because of its rough finish, texture paint can hide small flaws. You can apply it with either a roller or a sponge.

Sprayed Textures — Apply spray textures using a spray rig that utilizes compressed air and a hopper. Use a stationary rig (these are usually trailer mounted) for large jobs that require high output. Two hoses, one with air and one with liquid, are run to a spray nozzle controlled by the operator.

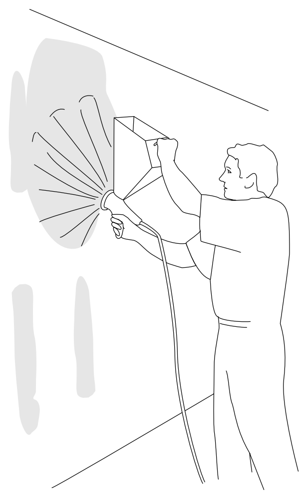

Figure 34
Spray on texture

For smaller jobs where it isn't cost effective to bring in a large rig, use a hand-held hopper, again with compressed air. These units have an air hose that runs to the hopper containing the liquid. At the base of the hopper is the nozzle or "gun" as shown in Figure 34.

The basic spray texture is a splatter or "orange peel" effect. With either type of spray application, large rig or hand-held type, the texture is controlled by the viscosity of the liquid, the orifice on the gun, and the air pressure. Varying any one of these three will create a slightly different texture. You can also create a "knockdown" or "lace" pattern by lightly pulling a trowel or drywall knife over a freshly sprayed wall.

Acoustical Coating

The term acoustical coating can be misleading. (See also *Acoustics*.) While the coating itself has some acoustical qualities, unless it's used over a sound-absorbing base like fiberboard, it won't absorb much sound. Drywall, the most common backing, reflects rather than absorbs sound.

The texture in acoustical coating comes from adding vermiculite or perlite to the mix. Both materials are lightweight and durable. Their varied sizes produce a range of textures.

Acoustical coatings are usually applied to ceilings. Use the same spray units and application techniques as you would for other spray textures. Wear protective goggles and a cap when you spray ceilings and be sure to mask and cover the floor and walls.

Removing Acoustical Ceiling Texture

To remove unpainted acoustical texture, cover the floor, then use a garden-type sprayer to spray the ceiling with water. The coating will loosen and drop with light scraping. Be careful not to over-saturate the coating or you may damage the drywall underneath. Allow the ceiling to dry thoroughly before applying a new finish.

Avoiding Drywall Problems

Problems with drywall can occur before the compound is dry or years later, depending on the cause. Potential problems can be reduced by following basic construction common sense:

- *Handle the panels carefully* — They're easily banged up and dented, and much less easily repaired.
- *Use only fresh, clean joint compound* — If it looks or smells bad, it is. Joint compound mixed from dry powder should always be used within 24 hours.

- *Install the materials correctly* — Crooked screws, torn paper, or poor embedding and skim coats, although easily avoided at the time, mean hours of repair work later.
- *Use only dried lumber* — As wood dries, it shrinks and will cause nail pops or joint cracks.
- *Have adequate ventilation and heating* — If there's too much variation in either, materials may expand and contract, which will cause the fasteners to loosen.
- *Follow soils reports and build an adequate foundation* — Shifting or expansive soil will cause the building to move or settle, which in turn will cause problems with drywall.

Remember, following these guidelines doesn't mean you won't have any drywall problems down the road. It only means you'll have fewer of them. Before you ever hang your first sheet of drywall, it would be a good idea to read through the following list of common repairs.

Common Drywall Repairs

You should pay special attention to the causes of these drywall problems, and keep in mind that all of the problems listed below are far more easily prevented than repaired.

Fasteners

Nail Pops

Characteristics: Raised nail head; texture may be knocked off, exposing the nail.

Causes: Lumber wasn't dry enough; studs weren't aligned; drywall panel wasn't nailed from the center out; drywall wasn't driven tight to stud originally.

Repair: Replace nail with longer nail or screw or drive another nail within $1^1/2$ inches of first; spot fill depression as you would for a new fastener.

Fastener Depression

Characteristics: Fastener head is depressed.

Causes: Fastener driven in too far initially; not enough compound used; not enough fasteners used.

Repair: Add more fasteners if needed; spot as you would for a new fastener.

Joint Problems

Ridging

Characteristics: Raised line along the joint between two panels.

Causes: Poor installation (panels were forced); too much joint compound used; there was high humidity or poor ventilation during installation.

Repair: Poor installation: cut thin gap between panels, tape and apply compound as for a new joint. Too much compound: sand ridge smooth, apply new topping coat. High humidity/poor ventilation: back blocking or multiple drywall layers should have been installed as a preventative.

Tape Photographing

Characteristics: Tape or fasteners are visible, either as a slightly different color or with a higher or lower gloss than surrounding wall.

Causes: Didn't force out excess compound from under tape; high humidity slowed drying; tape wasn't wetted first and absorbed too much moisture from compound.

Repair: Sand tape edges. Seal with primer, then apply one or two thin coats of joint or topping compound.

Joint Depression

Characteristics: Valley or depression along panel joint.

Causes: Not enough compound applied over joint initially; compound was too thin; joint was over-sanded.

Repair: Apply topping compound, then sand if necessary.

High Joints

Characteristics: Wide section of joint is higher than surrounding wall.

Causes: Too much compound was used; improper feathering.

Repair: Sand joint as much as possible without sanding tape; apply topping coat or coats, feathering each coat wider than previous one.

Joint Discoloration

Characteristics: Lighter, darker, or discolored joint.

Causes: Moisture trapped in joint; painted during high humidity; poor quality of paint used.

Repair: Make sure compound is thoroughly dry before adding new coat; use dehumidifier when painting and apply only good quality paint.

Tape Blisters

Characteristics: Bubble in the joint.

Causes: Tape was not properly embedded; the joint is too wide; tape was not wet enough before embedding.

Repair: Use utility knife to slit blister; cut and remove raised section; sand out dried compound; push new compound under tape and embed patch of tape over hole; apply skim coat and finish as for a new joint.

Edge Cracks

Characteristics: Joint cracked along edges.

Causes: Compound dried too fast, causing uneven shrinkage; joint compound applied too thick.

Repair: For thin cracks, apply latex emulsion or thin topping coat, then sand; for thick cracks, scrape out loose compound, paint area with primer, apply topping coat; sand.

Center Cracks

Characteristics: Crack in center of joint.

Causes: Joint compound applied too thick; settling; tape was sanded through.

Repair: Thin cracks: apply latex emulsion. Wide cracks: apply topping compound; sand. Torn or damaged tape: remove tape and joint compound, spread new embedding coat, tape and skim coat; finish with one or two more coats as needed.

Compound Problems

Debonding

Characteristics: Compound won't bond or loosens from the tape or drywall.

Causes: Dirt, sanding dust, or oil was on the panel surface when compound was applied; compound was old or was mixed with improper amount of water; compound was mixed with dirty water or applied with dirty tools.

Repair: Remove old tape and compound as much as possible, including the feathered portion; apply new compound and tape as you would for a new joint.

Pitting

Characteristics: Pits or small voids in the compound finish.

Cause: Overmixed compound; too much water added to mix; too little pressure used when applying compound.

Repair: Sand to a smooth finish; apply topping coat, feathering it wider than original coat.

Sagging

Characteristics: Drips, runs, or sags in compound.

Causes: Cold water used to mix compound; too much water added.

Repair: Sand to a smooth finish; apply new topping coat.

Shrinking

Characteristics: Compound shrinks or draws into the tape.

Cause: There was too much water in compound; one coat was not dry before next one was applied; compound applied too heavily.

Repair: When coat is completely dry, apply another coat of compound and sand as needed.

Drywall Panels

Dent

Characteristics: Drywall dented but not perforated.

Cause: Varies. Tools, ladders or materials bumping into panels can cause dents.

Repair: Spot as you would for fasteners.

Nail Holes

Characteristics: Small perforations in panel surface.

Cause: Nails used to hang items on walls, then removed.

Repair: Use spackling and putty knife to fill holes; sand and repeat as needed.

Small Hole

Characteristics: Hole in panel, less than the width of joint tape.

Cause: Punctured with sharp object.

Repair: Apply thin embedding coat in area around hole; press tape over hole; skim coat, feathering edges; let dry completely and repeat with additional coats as needed.

Medium Hole

Characteristics: Hole in panel is larger than tape width.

Cause: Puncture.

Repair: Use a keyhole saw to cut a rectangle around the hole; apply wallboard adhesive on each end of a 1 × 2 that's 4 inches longer than the hole; place in hole and hold against inside of drywall while screwing it to drywall; cut drywall patch slightly smaller than hole; glue to 1 × 2; tape as for a new joint.

Large Hole

Characteristics: Hole is large, but smaller than panel.

Cause: Blow to wall panel.

Repair: Use keyhole saw to cut out rectangle between studs; screw 1 × 3 boards that are slightly longer than the hole to each stud; cut patch slightly smaller than hole; screw piece to 1 × 3s; tape as you would for a new joint.

Drywall Blisters

Characteristics: Facing paper delaminates from drywall.

Causes: Manufacturing defect; careless handling.

Repair: For small blisters, force aliphatic glue (see *Adhesives*) into blister and press it flat; for large blisters, cut out loose paper, apply joint compound and tape as for a new joint.

Cracks

Characteristics: A crack in face of the drywall.

Cause: Settling.

Repair: Clean out loose material; apply joint compound and tape as for a new joint.

Fracture

Characteristics: Panel is broken all the way through.

Causes: Settling; improper handling.

Repair: Cut out the damaged area and repair as you would for a large hole.

Manhours

Manhours to Install Drywall, per SF		
Walls and Ceilings (including tape and finishing)	**Manhours**	**Suggested Crew**
3/8" or 1/2" thick, standard	.025	1 drywall installer or 1 carpenter
5/8" thick, standard	.026	1 drywall installer or 1 carpenter
Laminated 3/8" thick sheets, standard	.034	1 drywall installer or 1 carpenter

For more information on related topics, see:

Acoustics, page 21

Adhesives, page 25

Ceramic Tile, page 125

Framing Materials and Planning, page 363

Insulation, page 395

Trim, page 673

Wall Framing, page 709

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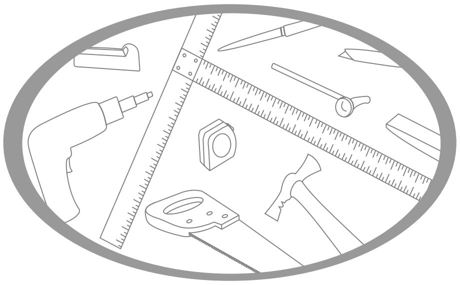


Electrical Installation

We all know that when we turn on a light switch, a light comes on. We also know that to light that lamp, electrical power must be provided. This electricity comes from a generator fueled by energy from nuclear reaction, coal, water, wind, or petroleum-based products. Electrical energy, or current, travels from the generator to the lamp. When energized by the current, the lamp lights.

Electrical current is actually the movement of electrons. The generator causes electrons to move from one atom to the next through a conducting material. Conducting materials are chosen for their ability to allow electrons to move freely. Copper and aluminum are both good conductors. Of the two, copper is the more widely used for home electrical components.

Electricity is often compared to the movement of water through a hose. Using this analogy, the hose would be the conductor, the water the electrons, and the faucet the generator. The amount of water going through a hose is determined by the pressure at the valve and the diameter of the hose. Both the volume of water and the pressure can be measured, and this information is used to control or limit the flow of water for specific purposes. The same concept applies to electricity.

Measuring Electricity

To use and control electricity, you need to first become familiar with its units of measurement. The units of measurement that are most useful to the trade are volts, amperes, watts and ohms.

Volt

The pressure the generator places on the electrons is measured in volts. Through the use of transformers, this pressure is maintained as the electrons move from the generator toward the point of use. A final transformer, usually for a group of houses, reduces the pressure to 120 and 240 volts for common usage.

Ampere

The amount of water moving through a hose is measured in gallons. The electrons moving through a conductor, or the current flow, is measured in amperes or "amps." The amount of amps that pass into a device is controlled by the breakers at the control panel. For residential use, these are usually 15, 20, 30 or 50 amp breakers.

The purpose of a breaker is to prevent more amps from passing through the wires it controls than the wires can safely handle. For example, a 20 amp breaker limits the amps passing through the wire to 20. Just as too much water flowing through too small a hose will cause the hose to burst, too many amps in too small a wire will cause problems. The wire will begin to heat up, which may result in an electrical fire.

Watt

A watt is often referred to as the power measurement. Appliances from light bulbs to hair dryers use watts to indicate the amount of power required for their operation. Using predicted or known wattage requirements, electrical circuits can be properly sized. Electric meters register kilowatt usage, which is the amount of power used.

Watt's Law

The relationship of watts to volts and amps is known as Watt's Law. It says: the power available (in watts) equals the amperage multiplied by the voltage. If you know two of the three measurements, you can use them to determine the third. To determine wattage, volts or amps, you can use these equations:

$$\textit{Watts} = \textit{Amps} \times \textit{Volts}$$

$$\textit{Volts} = \textit{Watts} \div \textit{Amps}$$

$$\textit{Amps} = \textit{Watts} \div \textit{Volts}$$

Ohms

An ohm is a unit of measurement used primarily for testing or troubleshooting. Water flowing through a hose encounters resistance from the sides of the hose. This resistance becomes more obvious if a smaller diameter hose is attached to the faucet or if the hose is bent or kinked. The resistance of the conductor is measured in ohms. A properly wired circuit creates very little resistance, while a poor connection shows more resistance. A short in a circuit shows a great amount of resistance. You can measure ohms with an ohm meter or a multimeter.

Ohm's Law

The relationship of current (amperes), voltage, and resistance (ohms) is known as Ohm's Law. This relationship can be seen most clearly in the form of the equation: Current (I) equals voltage (E) divided by resistance (R), or:

$I = E \div R$

Again, using Ohm's Law, you can solve for one value if you know the other two, for example:

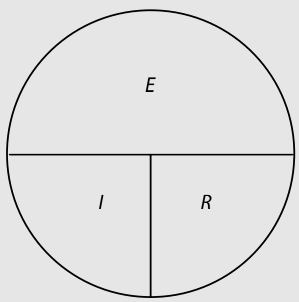
Voltage = Resistance × Current ($E = R \times I$)

Resistance = Voltage ÷ Current ($R = E \div I$)

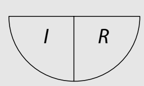
Current = Voltage ÷ Resistance ($I = E \div R$)

Ohm's Law: $E = I \times R$

In any given situation, if you know two of the quantities, you can solve for the third. A simple way to remember and use Ohm's Law is shown in the chart below:

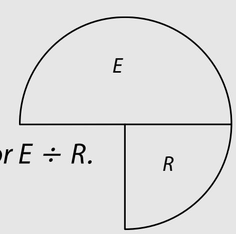


To find a quantity, cover it on the chart. Then you can multiply or divide the remaining two quantities to find the one you need.

For example, knowing I (current) and R (resistance), you can find E (voltage) by covering E with your finger. The chart then shows that E = 

or I × R.

Or, to find I, when you know E and R, cover the I. The chart shows that I = E/R or E ÷ R.



Power Plant Generator to Service Entrance

In most cases, the building contractor or homeowner is responsible for his own electrical power leading from the service panel. The power provider is responsible for getting the power from the alternator to the panel. Electricity is provided in the United States and Canada as either single or triple phase alternating current. The high voltage service lines from the power source to user locations are run either overhead or underground, with transformers maintaining even power. Figure 1 shows the typical residential installation.

Alternating Current and Direct Current

Electrons, or electricity, are delivered through a current. Most countries around the world use a direct current (DC) for delivery. The U.S. and Canada use alternating current (AC) because it can be sent with better control over longer distances than direct current. However, we are familiar with direct current through battery based electrical systems on vehicles or other battery powered devices.

To create electricity, a conductor, powered by water, wind, or fuel, spins inside a magnetic field. Direct current is created when the electricity produced is continuous in one direction. Alternating current reverses or "cycles" between directions. The frequency of the cycles is measured in a unit called a hertz (Hz). If you look on an electric motor, such as a drill motor, you'll find a Hz specification. A drill motor has a design Hz specification of 60, which represents 60 cycles per second.

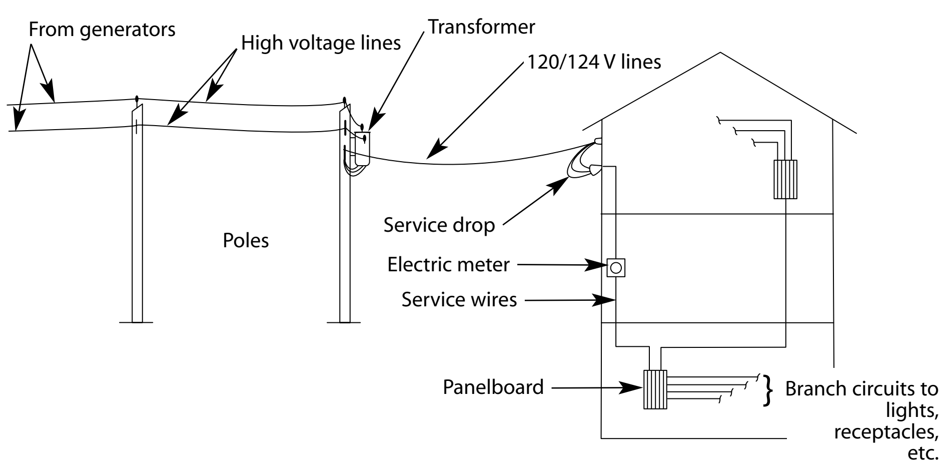


Figure 1
Typical sections of a residential wiring system

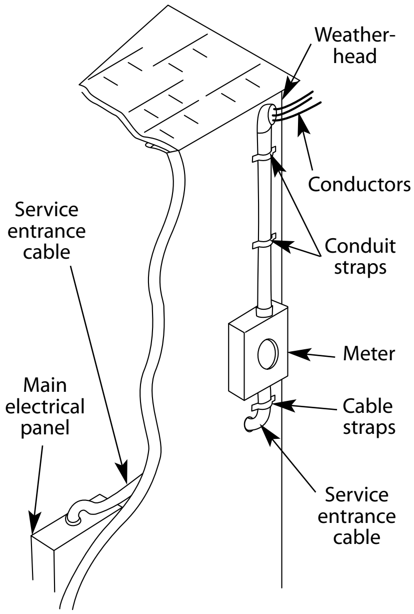


Figure 2
Residential service entrance

Single and Triple Phase Electricity

Most electrical usage is in single phase, that is, at 60 cycles per second. Power plants, however, generate electricity in triple phase because it creates three times the electricity for each revolution of the armature. This is done by placing three separate windings on the armature instead of a single winding. When the armature spins at 60 revolutions per second with a single winding, 60 cycles are sent; 60 revolutions with three windings creates 180 cycles.

Electricity is produced in triple phase because it's more efficient. We primarily use triple phase electricity for running heavy industrial equipment, such as large electric motors. However, for most residential and commercial use we divide triple phase electricity into 60 cycle, single phase.

Transformers

Transformers control the voltage of the electricity as it's distributed. A transformer either increases or decreases the line voltage, depending on how it's set up. Electrical distribution lines carry high voltage electricity to service areas where transformers then decrease the line voltage to 120/240 volts for consumer use.

Service Entrance

Electrical service is run from the transformer to the building service entrance. A typical residential service entrance consists of a 200 amp service panel, a meter base, and a mast for overhead service or a drop for underground service. See Figure 2. All of these materials, except the meter base, are available from either an electrical supplier or from many lumber yards. The meter base is usually provided by the utility supplier, which in most cases is the city electric division.

Most new developments use underground service, but there are still instances where you may need to use overhead service.

Overhead Service

With overhead service, the service entrance is made up of a service head or mast, a meter base, and a service panel. These three items, and the wiring being fed by the service entrance, must be installed by an electrician and inspected before the utility provider will install the meter and the service drop. The service drop refers to the overhead wires connecting the service entrance to the nearest transformer.

The utility provider usually runs the service to the mast, which is connected to the meter base. The mast is comprised of the conduit, a weatherhead, connectors, and mounting brackets. The mast supports the conductor wires which extend approximately 18 inches out from the weatherhead for connection to the service drop.

Underground Service

The service entrance for underground service is made up of the meter base, service panel, and conduit for the feed cable. You need to install the conduit from the meter base to a depth of at least 18 inches below ground level to protect the cable. Dig a trench 4 inches wide and 26 inches deep (unless otherwise specified by the governing code) between the building and the transformer.

In most areas that use buried cable, it's supplied and placed to the transformer by the builder's electrician. He runs direct burial cable through the conduit from the transformer to the meter in the trench. This buried cable is called the service lateral. A conduit sweep is usually placed from the transformer to a depth of at least 18 inches. You must have the feeder cable and direct burial installation inspected by the agency issuing the permit before the utility can connect the service.

Installing the Service Entrance

The architect or electrical engineer sizes the service panel based on the requirements of the structure that it's designed to serve and the size of the main breaker. For example, a 200 amp panel carries a 200 amp main breaker. When a service entrance is made up, the wiring leads from the main breaker in the service panel to the point at which the utility provider makes the connection. The circuit breaker installed in the service panel is part of the interior wiring.

The designer determines the location of the service panel, and this needs to be approved by the agency issuing the permit. It can be anywhere in the structure that is approved by code, but it's usually installed close to the meter base to cut down on the use of expensive feeder wire.

Conductor wire is used to connect the service panel to the meter base. For a 200 amp service panel, the wire size should be at least 8 AWG (American Wire Gauge) copper or 6 AWG aluminum. Aluminum wire is acceptable as a conductor for the service feeds, but don't use it for circuit wiring. Always protect exposed conductor wire with conduit between the meter base and the service panel.

The service panel is powered by the three wires fed from the power line servicing the area. For residential wiring, these typically include two 120 volt lines and one neutral line. The panel must be grounded using a ground wire connected to a cold water pipe or a grounding rod. A grounding rod is a copper rod, $^1/_2$ inch in diameter and 8 feet long, that is driven into the ground. See Figure 3.

The meter base location is also assigned by the designer and approved by the utility and agency issuing the permit. Its location should be a compromise between aesthetic appeal (in other words, not next to the front door), ease of access for meter readers, and proximity to connections for feed lines.

Electrical Branch Circuits

From the service panel, electricity is distributed to the various electrical devices, such as lights, outlets, or clothes dryers, through branch circuits. Each of these circuits is protected from overload by a circuit breaker. Each circuit is designed so that the circuit breaker and the conducting wire are sized for the anticipated load of the electrical device.

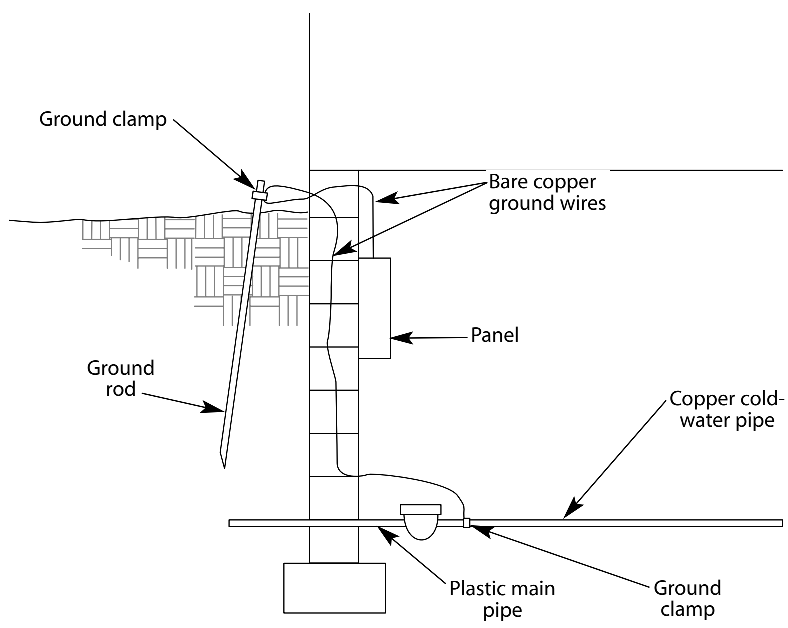


Figure 3
Typical grounding for residential wiring

Wire

Copper wire is the conductor of choice for branch circuits. It's available in a wide variety of sizes and protective coatings. The coatings are necessary so that wires can be run side by side without shorting out. The coatings are labeled to indicate their protective values, such as for heat or abrasion resistance. Type TW is the most common coating. Type THW has higher heat resistance for installations that need it.

Sizing

American Wire Gauge (AWG) sizes run from 18 to 1, with 18 gauge being the smallest and 1 being the largest wire in diameter. After 1 gauge, the next larger AWG designations are from 0 (often written 1/0, and called "one aught") to 0000 (4/0), with 1/0 being the smaller wire diameter. The most common wire used for residential wiring is 12 gauge.

Cable

Most residential electrical devices require three wires, a positive, a neutral, and a ground. Additional wires are required for specialty wiring such as three-way or four-way light switches. You can install these wires as individual wires pulled through conduit or as groups manufactured together. When two or more wires are placed together in a sheathing, it's called a cable. Cable is manufactured with metal clad sheathing or nonmetallic sheathing. Check with your local codes to see which types are acceptable in the location where you're working.

Cable is labeled with the size and number of wires inside, plus the ground, which is not counted. The most common residential cable is 12-2. This refers to two 12-gauge insulated wires plus a bare ground wire. The ground wire isn't counted because it's required, and therefore always assumed to be there. So, 14-3 cable has a total of 4 wires, 3 insulated 14-gage wires and a bare ground wire.

Metal clad cable, or armored cable (AC), is a flexible metal-sheathed cable containing loose individual wires. It's often called BX. The primary wires are insulated with a plastic coating and wrapped in a paper sheath. The ground is bare.

As mentioned earlier, there are a variety of coatings applied to wire to protect them from heat and abrasion. In the same manner, there are different types and configurations of plastic sheathing on cable for protecting the wires inside. Protection is available for direct burial and sunlight, as well as resistance to oils and chemicals. Plastic sheathed cables are used for most residential wiring, with nonmetallic, or NM, sheathing being the most common. Nonmetallic sheathed cable is commonly called Romex on the job. This cable houses the primary insulated wires as well as a bare ground wire. Like the metal clad cable, the wires are wrapped in paper inside the sheathing.

Boxes

Make all your wire connections in UL approved electrical boxes. Outlet boxes are available in metal and plastic, but you can only use Romex cable with the plastic boxes. You can use metal boxes for armored cable (AC), electrical metal tubing (EMT), and NM cable. Metal boxes should be grounded; they have a grounding screw for this purpose. Because plastic is an insulator, a plastic box doesn't require grounding. Use outlet boxes for all outlets and switches.

Boxes are available in a variety of sizes and configurations. The *National Electrical Code* (*NEC*) stipulates how many conductors you can place in each box size. Boxes designed for more than one outlet or switch are called gang boxes. By removing a screw and a side, you can gang metal boxes together. Before getting too creative, however, be certain that a cover plate is available for your creation. You can purchase plastic boxes in the various configurations. Take care to plan ahead and place a large enough box where multiple wires will come together.

Use junction boxes when you need to splice wires together. Make the splice inside the junction box and use wire nuts. Again, if the junction box is metal, it must be grounded. Place junction boxes where they are accessible, and never make a splice outside of an electrical box.

Circuits

A branch circuit is a conductor path where electricity flows from the power source through a number of electrical devices and back to the source. The source in a residential circuit is the service panel. The electrical devices may be a series of outlets or a series of lights. A feeder circuit is a conductor path where electricity flows from the power source to a single use such as a kitchen range or an electric hot water heater.

The electrical designer calculates the load for each circuit. Light circuits are kept separate from outlet circuits. This prevents dimming from power draws on outlet circuits. Because 12-2 wire is used for almost all residential outlet circuits, the designer will determine the circuit load by how many devices this conductor can carry.

Branch circuits are protected from overload by breakers. The breakers are rated in amperes. Typically, a 20-amp breaker is used for an outlet branch circuit. The breaker will trip when the power usage exceeds the designed load. This prevents the circuit wire from heating and possibly shorting. It also protects the electrical devices from damage.

While standard circuit breakers protect the circuit conductors and electrical devices, a ground fault interrupter (GFI) offers personal protection. Should an overload occur, standard circuit breakers are able to react fast enough to protect the circuit and prevent a possible short and fire. However, they aren't fast enough to prevent a person from being shocked. A ground fault interrupter, available as an individual outlet or a panel breaker, is designed to trip quickly enough for personal protection. They're a must in bathrooms as well as work areas like garages where tools are used. In addition, you should always use them in temporary service panels providing electricity to construction job sites.

Ground Wire

For the ground to offer protection, you need to run and connect the ground securely throughout the circuit. Inside the electrical box, make sure that both incoming and outgoing ground wires are connected. In addition, you need to ground electrical devices, such as receptacles, and metal boxes.

The easiest ground to make is a single receptacle with a single cable in a plastic box. Simply connect the ground wire from the cable to the ground screw on the receptacle. Because only one wire should be attached to each screw, join multiple ground wires with a wire nut.

Rough Wiring

Wiring takes place in two main phases. The first phase, the rough wiring, is done after the structure is framed, but before you install the insulation or wall coverings. It involves running the branch circuits to provide power for receptacles, switches and appliances. The second phase comes after you finish the walls. It includes installing the outlets, switches and light fixtures.

Before you can enclose the first phase of the wiring in the walls, you must have a rough inspection. The inspector ensures that the wiring is protected and installed in accordance with the *NEC*.

Steps to Residential Rough Wiring

1. Lay out the switch and outlet locations. Use a story pole made from a 1 × 2 to establish the height above the floor line for switch and outlet boxes.

2. Set boxes so their faces extend out from the stud the distance of the finished wall. This is usually $^{1}/_{2}$ inch for residential applications. Check the plans or consult the project supervisor to determine the depth of the wall finish.

3. Install backing or use telescoping box brackets for light boxes. Make sure ceiling fans and other heavy light fixtures have boxes with a backing capable of handling the load.
4. Fasten all the boxes in place, including those for light fixtures.
5. If you have questions or there are changes in the plans, walk the floor plan with the project supervisor to confirm door swings, cabinet layouts, and other possible conflicts with the electrical layout.
6. Drill holes in the framing members for cables. For engineered wood products, such as wood I-beam floor joists or micro-laminated beams, be certain you know where you can and can't drill. A drill chart should be posted on the job showing acceptable drilling locations for these engineered products.
7. Pull cables through the holes and into the boxes, finishing each circuit with a "home run" to the service panel.
8. Secure the cable according to *NEC* guidelines and any additional local requirements. Consult the *NEC* for specifics.
9. Mark the circuit on the cable at the service panel to eliminate confusion when the panel is made up.
10. Inside the boxes, strip back the cable sheathing and make up the grounds. Leave the protective coating on the primary wires.
11. Lastly, neatly roll up the wires inside the box where they won't interfere with the installation of wall finishes.
12. You're ready for the rough wiring inspection before the walls are finished.

Installing the Outlet Receptacles and Switches

Once the walls are completed, you can install the outlet receptacles and switches. At this point, the boxes are set and the wire cables pulled into the boxes and secured to the supporting members. As a convenience to the trim carpenters, you should finish the electrical after the walls and ceilings are painted but before the start of the interior trim.

Outlets

One of the most important keys to installing outlets is keeping the polarity straight by keeping the power and neutral wires to the proper sides of the outlet. Always run the black wire (power) from the breaker to the brass screw side of the outlet throughout the entire circuit.

Always run the white wire (neutral) from the neutral busbar in the service entrance panel to the silver screw side of the outlet.

There are two basic ways to wire an outlet: first, with a source cable only, or second, with a source and a second cable to continue the power supply to an additional fixture. See Figure 4. The wiring is the same for plastic cable, such as Romex, as for the single wires pulled through EMT or found in the armored cable.

Making Up Receptacles

Observe the following guidelines for making up receptacles:

1. Pull all the wires out of the box. Clean away any drywall compound or plaster that may interfere with your work.
2. Trim the wires to equal lengths, approximately 8 inches so you can "fold" the wires into place. Cutting the wires too short makes it more difficult to place them back in the box.
3. Most receptacles have a strip gauge on the back that indicates how much insulation to strip from the wire. It's usually $^3/_4$ inch.

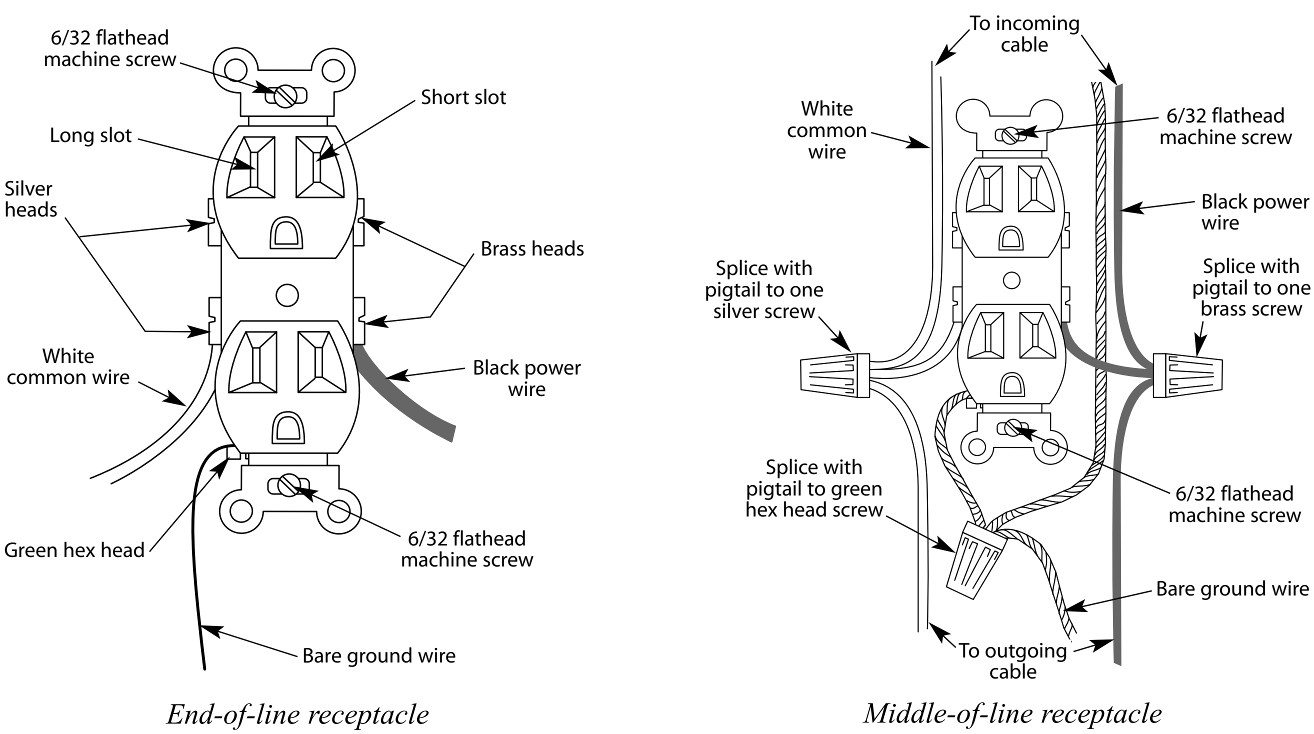


Figure 4
Two ways to wire an outlet

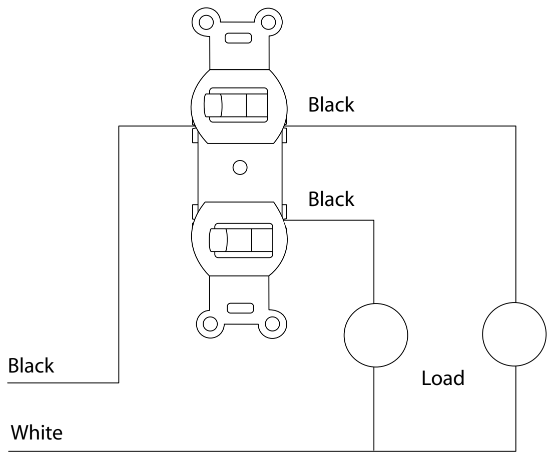
4. Most receptacles have holes in the back to make the terminal connections, in addition to the standard terminal screws. If you've stripped the right length of insulation from the wire, you can insert it into the hole for a good connection.
5. Connect the ground wire (bare, or green if insulated) to the green ground screw. It's located on the bottom left side of many outlet receptacles.
6. You can either use the terminal screw or the quick connect hole to make the connection for the primary wires. For quick connect holes, ensure that the wire is fully inserted for a solid connection. You shouldn't be able to pull the wire back out without using a screwdriver in the release slot.
7. Connect the black wire (positive) to either the brass screw or the hole next to the brass screw. Connect the white wire (neutral) to the silver screw or to the hole next to the silver screw.
8. Fold the wires behind the outlet while pushing them into the box.
9. Attach the receptacle to the box using the top and bottom screws. Use the slot in the receptacle to adjust for proper alignment.
10. Finally, use the single center screw to attach the cover plate to the outlet.

Light Switches

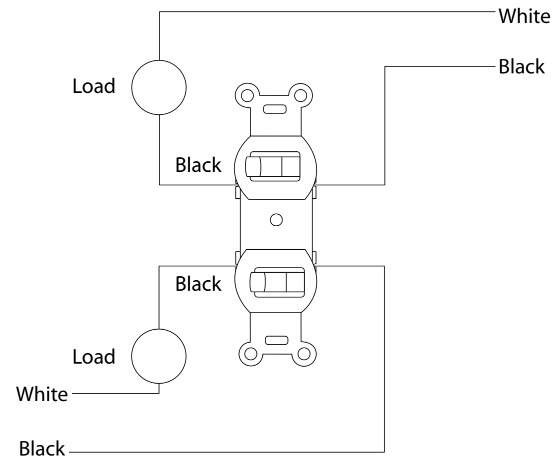
Wiring light switches can be considerably more complicated than outlet receptacles. The fact that another device is added in-line creates additional combinations to the two encountered when you wire outlets. Also, three-way (a light that's controlled from two switch locations) and four-way (a light that's controlled from three switch locations) switches provide even more combinations.

Light switches have no ground screw. Only the black and white wires are connected on a wall switch. The ground wire from the cable grounds the box if it's metal, and connects to the ground of any cable leaving the box. You need to ground the box for the light fixture if it's metal. Some light fixtures have a ground screw and should be grounded as well.

The wiring is the same for plastic cable, such as Romex, armored cable and for the single wires pulled through EMT. Figure 5 shows how to wire both a common feed and a separated feed switch. You can control more than one light fixture with the switch or switches. Use these illustrations together with the following basic steps as a guide when installing light circuits.



Common feed (both switches on same circuit)



Separated feed (switches on separate circuit)
The breaker tab is removed

Figure 5
Common and separated feed switches

Installation Steps

Use the following guidelines for installing switches:

1. Pull all wires out of the box. Clean off any drywall compound or plaster that will hinder your work.
2. Trim the wires to equal lengths, approximately 8 inches. Cutting the wires too short makes it more difficult for you to place them back in the box. A longer length allows you to fold the wires into place.
3. Use the strip gauge on the back of the switch to see how much insulation you need to strip. Normally, it's $^3/_4$ inch.
4. Most switches have holes in the back to make the terminal connections. These are in addition to the standard terminal screws. If you've stripped the proper length of insulation from the wire, you can insert it into the hole for a good connection.
5. Connect the ground wire (bare, or green if insulated) to the box if it's metal and to the ground of any additional cables leaving the box. Plastic boxes don't require grounding.
6. You may either use the terminal screws or the quick connect holes to make the connections for the primary wires. For the quick connect holes, make sure that the wire is fully inserted for a solid connection. You shouldn't be able to pull the wire back out without using a screwdriver in the release slot.
7. Connect the black wire (positive) to either the brass screw or the hole next to the brass screw. Connect the white wire (neutral) to the silver screw or to the hole next to the silver screw.

8. Fold the wires behind the outlet while pushing them into the box.
9. Use the top and bottom screws to attach the receptacle to the box. Adjust for proper alignment using the slot in the receptacle.
10. Screw the cover plate to the switch.

Wiring the Service Panel

In new construction, there shouldn't be any power to the service panel before all the interior wiring is completed and inspected. Most utility providers won't install the meter until this stage. Power or no power, get in the habit of always checking that the main breaker is in the *off* position before starting work. Having no power past the meter base is absolutely necessary before you wire the service entrance cable to the main breaker. After you wire the main breaker, it controls power to the circuit breakers.

The Main Breaker

The three parts of the service panel are the main breaker, the neutral busbar, and the circuit breakers. A service panel is sized based on the amperage capacity of the main breaker. Logically, a 200 amp panel has a 200 amp main breaker. The main breaker is powered by the service entrance cable leading from the meter base. Make sure the service entrance cable is in conduit if it would otherwise be exposed. Connect the two hot conductors (red and black) to the two terminals on the main breaker. Connect the neutral wire to the neutral busbar.

Bringing Circuit Cables into the Service Panel

When the circuit wires are pulled, they all end up with a home run to the panel. When these home runs are made, they're usually initially left as dangling cables hanging next to the panel with their circuits labeled. Always put these cables or wires in EMT, or use armored cables back to the panel.

Service panels are manufactured with knock-outs for both the circuit wires and the service entrance cable. Use the knock-out suitable for the cable you're bringing in. All cables, whether armored, EMT, or Romex, must have a solid connection to the panel using a clamp or connector. Once inside the panel, prepare the wires for connection to the breaker and neutral busbar.

Use the following guidelines for bringing the cables to the service panel:

1. Select a cable clamp or EMT connector to fit the wire or cable that you're bringing into the panel.

2. In most cases, you'll be bringing the wires in through the top or the bottom. However, where they enter the panel isn't important as long as you take the wires neatly to the breaker and busbar.
3. Remove a knock-out that will fit the clamp or connector. Use a screwdriver to pop it open. You may need pliers to help finish twisting it out.
4. Set the clamp or connector in place, with the screw threads of the connector inserted into the panel.
5. From the inside of the panel, place the retaining nut onto the threads of the connector. Use a screwdriver to tighten the nut in place. Be certain that it bites into the panel for a secure connection.
6. Pull the cable through the clamp and into the panel.
7. Tighten the two clamp screws on the outside of the panel to the cable.
8. Use a knife or a wire stripping tool to remove the outer plastic cover to expose the wires. Do *not* remove the protective plastic insulation from the individual wires.

Installing the Circuit Breakers

Circuit breakers are available in a variety of amperages in both single- pole (120 volt) and double-pole (240 volt) configurations. Fifteen amp single-pole breakers are most commonly used for lighting circuits. Twenty amp single-pole (120 volt) breakers are the typical choice for outlet receptacle circuits. Double-pole breakers provide 240-volt power to residential appliances such as kitchen ranges and clothes dryers.

To install the circuit breaker, follow these easy steps:

1. Attach the ground wire and the neutral wire (white) to the neutral busbar.
2. Attach the black wire to the breaker. Double-pole breakers have two connections. Utilize the black and red wires, each carrying 120 volts, for these two connections.
3. After attaching the conductors securely, simply snap the breaker in place. Panel manufacturers have slightly different systems, but they all involve snapping the breaker onto a power bar controlled by the main breaker.
4. Tuck the wires into the panel as neatly as possible. A neat installation makes the wires easier to follow for the installer. It also looks more professional to both the owner and the inspector.

5. When all the breakers are in place, fit the panel cover to the breakers using the breakouts on the panel that correspond to the breaker spaces that you've used.
6. When you complete the panel and the grounding, install the cover securely in place.

Grounding the Service Panel

Take the ground and neutral (white) wires from the circuit to the neutral busbar. To ground the neutral busbar, run a ground wire to the ground (the earth). Do this by running a ground wire from the busbar to a cold water pipe as it enters the building or by running it to a ground rod. A ground rod is a $^1/_2$-inch by 8-foot copper rod driven fully into the ground.

Make sure the ground wire runs without interruption from the ground busbar to the ground rod or water pipe where it's clamped in place. If there's a water pipe attached to it before it exits to the ground, place jumper wires over any potential openings in the line (such as a union).

Powering up the Panel

After all circuits, the service entrance, and the panel are inspected and approved, the panel is ready to receive power. The utility provider will have the passed inspections on record and know when they're cleared to install the meter. Leave the main breaker turned off until after the meter is installed. When the meter's in place, you may feed power to the main breaker.

Power up one panel circuit at a time. To begin, make sure the main circuit breaker and all branch circuits are in the *off* position. Switch the main circuit on, followed by the first circuit. Check the first circuit for any problems. Move on through the panel, clearing each circuit one at a time. There are simple three-pronged plug-in devices available that you can use for checking outlet receptacles. When you plug it into the outlet, the device will indicate improper grounding, reverse polarity, open wires or any other wiring faults.

Low-Voltage Wiring

Create low-voltage electricity by stepping down the standard 120 volt electric to 12 volt with a transformer. The two primary uses for low-voltage electricity in residential construction are for thermostat and doorbell wiring.

Because low-voltage wiring is less of a threat, it doesn't need to be installed by an electrician. You should be aware, however, that this may open up a debate between the heating and air conditioning installers and the electrician who's responsible for the installation of the thermostat wire. Make certain it's included in one of the contracts. Your HVAC contractor should be able to install the low-voltage wires as well as troubleshoot the electrical on the heating and air conditioning components.

Lighting Types

The two basic components of a lighting device are the fixture, which electricians call *luminaire*, and the light bulb (*lamp*, to the electrician). Lighting types are most often categorized by the type of lamp used in the luminaire. The two largest categories are incandescent lamps and electric discharge lamps.

Incandescent Lamps

Incandescent lamps are what we know as the common light bulb. These lamps all have a filament, which produces light. When electricity flows through the filament, it becomes white hot. Standard incandescent lamps have a tungsten filament placed in a vacuum inside a glass bulb. Variations include halogen lamps, which have halogen instead of a vacuum surrounding the tungsten filament.

Electric Discharge Lamps

Electric discharge lamps include the familiar fluorescent, as well as neon, sodium-vapor, mercury-vapor, and metal-halide lamps. Electric discharge lamps are filled with a vapor such as sodium or mercury. An electric current passes through the vapor and causes it to glow. These lamps are more efficient, providing more lumens per watt than the incandescent types. There's now a wide range of energy-saving fluorescent lamps that are designed to replace incandescent bulbs.

Measuring Light

All lamps or lighting use one of three types of measurements: watts, lumens or foot-candles. As a rule, you can base most of your purchases on the wattage of the lamp. Since watts are a measurement of electric power, however, the wattage only indicates the amount of power used to light the lamp, not the amount of light given off. In most cases, higher wattage means higher light output. However, more efficient lamps are now available from manufacturers that claim they can provide the same amount of light using less watts than other brands using higher wattage.

Lumens and foot-candles are better measurements to use to determine the amount of light produced by a lamp. Some lamps are marked with the average lumens as well as wattage. You can use lumens produced compared to wattage as a guide to the efficiency of a lamp. Both lumens and foot-candles are based on the light of one candle. Obviously, the higher the number, the more light is produced.

Manhours

Manhours to Install Residential Electrical

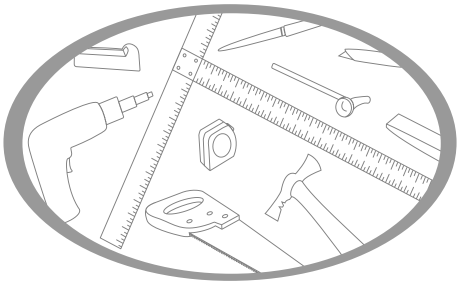
Item	Unit	Manhours	Suggested Crew
Weathercap			
100 amp service	Each	1.43	1 electrician
200 amp service	Each	2.29	1 electrician
Service entrance cable (typical allowance is 20 LF)			
100 amp service	LF	.176	1 electrician
200 amp service	LF	.254	1 electrician
Meter socket			
100 amp service	Each	5.71	1 electrician
200 amp service	Each	8.89	1 electrician
Entrance disconnect switch			
100 amp service	Each	8.89	1 electrician
200 amp service	Each	13.3	1 electrician
Ground rod, with clamp			
100 amp service	Each	3.81	1 electrician
200 amp service	Each	3.81	1 electrician
Ground cable (typical allowance is 10 LF)			
100 amp service	LF	.114	1 electrician
200 amp service	LF	.143	1 electrician
3/4" EMT (typical allowance is 10 LF)			
200 amp service	LF	.152	1 electrician
Panelboard			
100 amp service	Each	16.0	1 electrician
200 amp service	Each	26.7	1 electrician

Manhours to Install Residential Electrical (continued)			
Item	**Unit**	**Manhours**	**Suggested Crew**
Wiring per outlet or switch, wall or ceiling			
Romex, non metallic sheathed cable, 600 volt, copper with ground wire	Each	.714	1 electrician
BX, flexible armored cable, 600 volt, copper	Each	.952	1 electrician
EMT with wire, electric thinwall, 1/2"	Each	1.90	1 electrician
Rigid with wire, 1/2"	Each	2.86	1 electrician
Wiring, connection, and installation in closed wall structure, add	Each	1.43	1 electrician

For more information on related topics, see:

Heating and Air Conditioning, page 379

Wall Framing, page 709



Financing

Unless the job is really small, it's a rare client who'll pay you cash for your work. Often clients arrange for financing first and then contact you when they're ready for you to start. Sometimes, though, a client is confused about how to get money and needs someone to point out his available options. Each client's financing needs will be different, depending on whether the job is new construction or remodeling, and of course, on the size of the loan they need.

New construction requires two types of loans: a short-term construction loan and a permanent mortgage. As the contractor, you'll be paid out of the construction loan. When the project is complete, the loan is converted into a long-term mortgage. Lenders require that all permanent mortgages be approved before giving a construction loan.

For small remodeling jobs, your clients can take out a consumer loan. For large remodeling projects, it's better for them to get an equity loan or a second mortgage. An equity loan uses the existing value in the property as collateral. A second mortgage may draw on existing value. If they don't have enough equity in the property before construction, but enough value will be added through the remodeling, the client may be able to apply for a construction loan and add a second mortgage when the job is finished.

Money Sources

Banks provide consumer, construction, and short-term permanent loans for commercial projects. A short-term permanent loan, although amortized over 10 to 20 years, will have a balloon payment in a much shorter period, maybe 3 to 5 years.

Savings & loans (*S & L)* give home mortgage loans, but rarely construction or consumer loans for something like a small remodeling project.

Credit unions offer consumer loans to their members, usually at a lower rate than a bank. The catch is that the client has to be a member to qualify.

Mortgage companies don't make construction loans. Their role is to broker mortgages. They collect fees for their services and then sell the mortgages.

Finance companies make consumer loans. They charge a higher interest rate than other sources, largely because they give loans to higher risk clients.

Loan Costs

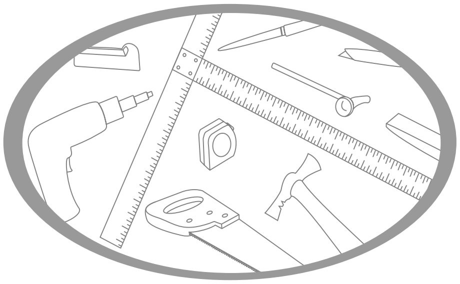
Regardless of where the money comes from, there's more to consider in a loan than just the interest rate. Mortgage companies and S&Ls charge an application fee, which covers an appraisal and credit report. When the mortgage is approved, they charge an origination fee, usually 1 percent of the loan, and points, which cover their charges for writing and processing the loan. Title insurance, recording, and survey fees also add to the cost of the loan.

Of all of these costs, the one that varies most is points. One point equals 1 percent of the loan. Lenders will sometimes offer no-point loans; more often though, they'll charge 1 or 2 points. They can certainly charge more points, however, depending on the economy and the local real estate market.

Consumer loans have fewer up-front fees, but they'll also have a higher interest rate.

Interest Rates

First mortgages always have the lowest interest rate. Second mortgages or equity loans run about a half percent higher. Construction and consumer loans are usually pegged 2 to 3 percent above prime rate or some other base rate.



Fireplaces and Chimneys

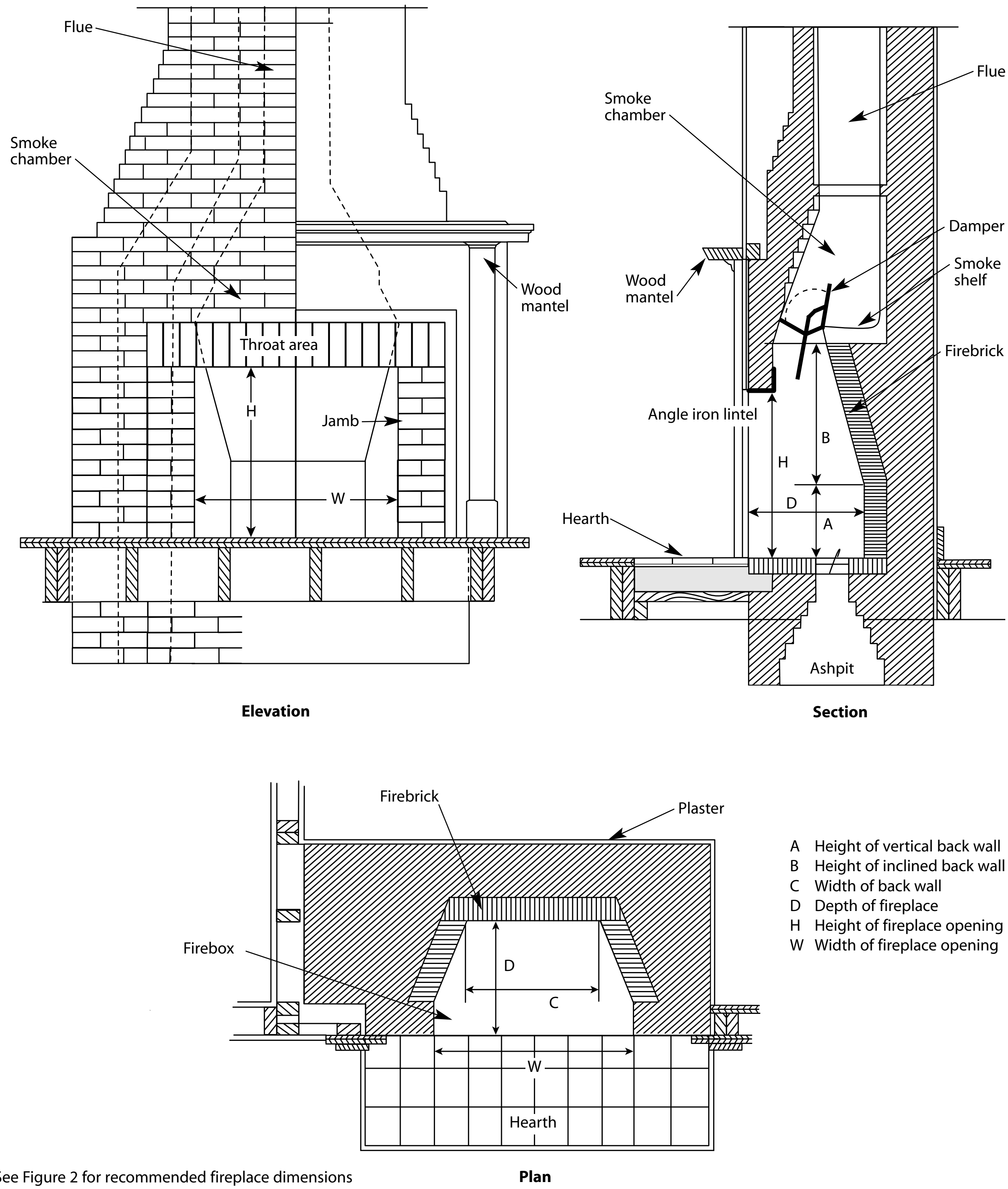
Advances in construction materials have changed the way fireplaces and chimneys are built today. You can buy the materials, usually made of clay or metal, as part of a complete kit, or you can select from a variety of individual pieces that are designed to work together. The building plan may specify the fireplace design and the materials required for construction, or the final choices may be left to you. In order to make the correct choices for your customer, it's important to understand the process of how a fireplace and chimney work. This information is also helpful in troubleshooting problems if you're working on an existing fireplace in an older home.

Fireplace and Chimney Components

The purpose of a fireplace, aside from its aesthetic appeal, is to furnish heat to the living area. In order to maximize the heat, you must provide a good draft which both feeds the heat source and eliminates smoke and sparks created by the fire. There are four basic components of a fireplace which work together to accomplish this goal:

- the *firebox*, which is the area that contains the heat source or flame
- the *throat* and *smoke chamber* above the firebox
- the *damper*, which controls the air flow through the throat opening
- the *chimney flue* through which the smoke is exhausted

The style and type of fireplace you use will depend on the individual job, but the basic components will always be the same.
Figure 1 shows construction details for a typical masonry fireplace. Let's look at them in more detail.



See Figure 2 for recommended fireplace dimensions

Figure 1
Construction details of a typical fireplace

The Firebox

The firebox opening, or *combustion chamber*, should never be less than 20 inches — and it will rarely be that small. The exception to this is the Rumford fireplace, a design from the early 1800s that has regained popularity lately because it provides a high concentration of heat for its size. It's available as a kit, or you can buy the components for a custom installation. Its unique feature is a firebox that's allowed by code to be one-third the width of the fireplace opening, but no shallower than 12 inches.

For heat reflection, the firebox is lined with noncombustible refractory brick, or *firebrick*. The minimum thickness of the lining is 2 inches, the standard thickness of firebrick. The fireplace wall must be at least 8 inches thick, including the refractory brick, with the bricks joined using a refractory mortar. In some geographical areas, local codes allow fireplaces to be built without a lining. Unlined fireplace walls must be at least 12-inch-thick masonry construction.

The fireplace opening is topped with a lintel that supports the masonry. It's generally made of steel, extending a minimum of 4 inches on either side of the opening.

The hearth, or fireplace floor, and the hearth extension must be made of concrete or solid masonry, and be a minimum of 4 inches thick. The hearth extension should be 8 inches wider than the fireplace opening, and extend out from the opening at least 16 inches.

The Throat, Smoke Shelf and Smoke Chamber

The sides of the firebox are vertical up to the throat, which begins 6 to 8 inches above the bottom of the lintel. The area of the throat tapers up through the smoke shelf but must remain at least as wide as the flue, and its length must equal the width of the fireplace opening.

Above the firebox is the *smoke shelf*, which is also made of 8-inch-thick solid masonry, although you're not required to use refractory brick here. The smoke shelf prevents downdraft.

The throat opens up into the *smoke chamber* above the smoke shelf. The top of the smoke chamber forms the base for the chimney flue. About 5 inches above the throat, the side walls should begin to slope inward to meet the flue. The walls of the fireplace and chimney are built of standard brick or block.

If you use a $^{5}/_{8}$-inch-thick clay liner for the throat and smoke chamber, you can reduce the minimum wall thickness for the area above the firebox from 8 inches to 4 inches. The clay liners are sized to fit within standard masonry unit chimney dimensions. They come in sections that are placed on top of each other (and the joints sealed with refractory mortar) within the shell of the chimney and fireplace as it's being constructed. Code requires that the lining used for the fireplace walls extend a minimum of 4 inches down into the throat.

The liner may continue up through the chimney and actually serve as the chimney flue within the masonry, or it may transition into another material used for the flue, such as sheet metal, brick or concrete block.

The Damper

The damper is a cast iron device with a hinged lid that opens and closes to control the draft through the throat into the combustion area. The air draft dictates the size and intensity of the fire, and allows the smoke to exhaust into the chimney. The damper can also be closed to prevent the infiltration of cold air when the fireplace isn't in use. To ensure proper operation, make sure the full damper opening is the same as the area of the flue.

The Chimney

The chimney must be constructed on a masonry base and can't serve as any loadbearing or structural component of the house. The placement of the chimney should ideally be inside the dwelling, not on an outside wall. One reason for this is to capture heat that's radiated from the chimney. Another is to prevent the chimney from being exposed to the damage caused by extremes in temperature. It's more likely for dangerous levels of creosote to build up in chimneys subject to extreme temperature changes.

A chimney works on the principle that warm air rises. A chimney won't work if, for any reason, the warmer air can't rise up through the flue. The height of the flue and its diameter (the chimney opening and passageway) are critical to this process. The relationship between the area of the fireplace opening and the area and height of the flue must be perfect for the fireplace to work properly. The table in Figure 2 shows the correct dimensions to use for a fireplace built with a flue lining.

The chimney is one case where bigger is *not* better. Unfortunately, you'll often run into oversized chimneys in older homes that don't work right. If the flue is too large, the hot air starts to cool as it rises so it can't push past the cold air at the top of the chimney to escape out of the opening. You also need this column of hot air rising to create a draw of cold air down into the firebox for fire combustion.

The height of the chimney above the structure is also critical to its function. The code requires all chimneys to be a minimum of 15 feet high, from the base to the top. The top of the chimney must be at least 3 feet above the point where it penetrates the roof, and at least 2 feet above the highest roofline or projection within 10 feet of the chimney. This helps ensure good airflow and safe operation of the chimney. If wind is deflected off of the roof, it can cause turbulence in the area of the chimney opening, and either block the air flow or create a dangerous downdraft. Take the entire structure into consideration when determining the highest roofline.

Fireplace Kits

Manufactured fireplace kits contain all the parts you need to build a fireplace in a new home or to install one in an existing residence. The firebox, smoke chamber, smoke shelf and damper control are generally made of heavy metal. Depending on the type of kit, they may be combined in a single unit or the firebox and smoke chamber may need to be joined during installation.

The kits can be installed inside a hollow framed wall. In most installations you'll need to provide about a 15-inch airspace around the unit to prevent any contact with combustible materials, although this may be reduced if the chase is lined with cement board. It's always a good idea to check local code requirements before you begin your installation. They may differ from the manufacturer's specifications. Zero clearance fireplaces are designed with a heat-insulating multiwall system that allows them to come into contact with wood or other combustible materials. The outer wall of the unit remains cool, so it can be attached directly to the wall studs with metal straps and screws.

There are two primary advantages to installing a fireplace kit rather than building a custom masonry fireplace:

1. The kit's firebox design is correctly proportioned to assure a smokeless fireplace.
2. When properly installed, they heat more efficiently than masonry fireplaces.

Opening size						Required flue lining	
Width W*	Height H*	Depth D*	Minimum width of back wall C*	Height of vertical back wall A*	Height of inclined back wall B*	Standard rect. outside dimensions	Standard round inside diameter
24	24	16-18	14	14	16	$8^1/_2$ x $8^1/_2$	10
28	24	16-18	14	14	16	$8^1/_2$ x $8^1/_2$	10
30	28-30	16-18	16	14	18	$8^1/_2$ x 13	10
36	28-30	16-18	22	14	18	$8^1/_2$ x 13	12
42	28-32	16-18	28	14	18	13 x 13	12
48	32	18-20	32	14	24	13 x 13	15
54	36	18-20	36	14	28	13 x 18	15
60	36	18-20	44	14	28	13 x 18	15
54	40	20-22	36	17	29	13 x 18	15
60	40	20-22	42	17	30	18 x 18	18
66	40	20-22	44	17	30	18 x 18	18
72	40	22-28	51	17	30	18 x 18	18

*See Figure 1 for locations of letters indicated in table.

Figure 2
Recommended fireplace dimensions and required flue lining sizes (inches)

Some kits include heat vents which you install in the face of the finished chimney wall. Other units have optional blower fans that you can install for extra air supply. Some of these are even designed to hook into the home's central forced-air heating system to further increase the unit's heating capacity.

Most kits have a chimney that consists of sections of multiwalled insulated metal pipe. The sections snap together and seal tightly to form a leakproof joint. The top piece ends in a rain cap with a spark arrestor or screen. Use metal straps to attach the chimney pipe to the studs and special flanges to brace them inside the wall and add support, as shown in Figure 3. At the roof opening, install a metal boot for flashing to the shingles.

Although the chimney sections usually come with the kit, your supplier can furnish you with additional parts to fit with your design if necessary. Be sure to provide your supplier with a copy of the plans so he'll know exactly what you need. The dimensions, and the ratio of the combustion area to the flue opening, must be exact.

Figure 4 shows the exterior walls of the fireplace covered with cement board. Make sure to cover the outer edges of the firebox and seal all the joints and seams to prevent heat and smoke from leaking into the interior wall space. You can finish the walls and hearth extension with brick or stone veneer to give it a custom-built appearance.

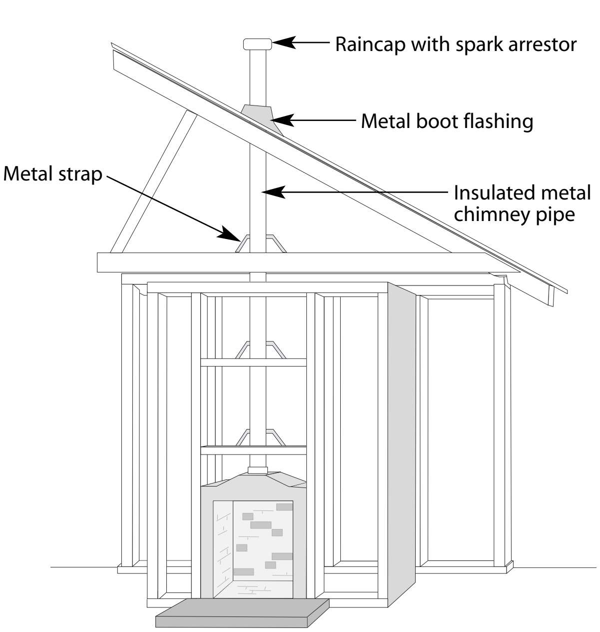


Figure 3
Prefabricated fireplace kit

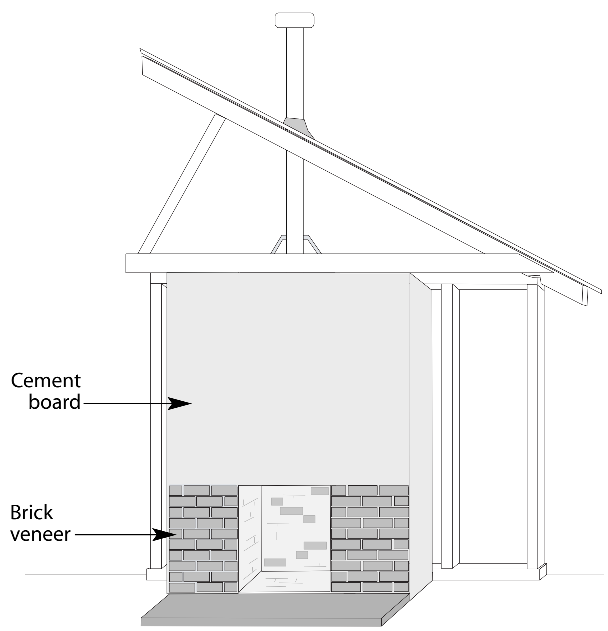


Figure 4
Finished prefabricated fireplace

Manhours

Manhours to Install Fireplaces		
Type	**Manhours**	**Suggested Crew**
Masonry		
Firebox, smoke chamber, throat & hearth	9.75	1 bricklayer, 1 helper
Chimney, per LF	5.625	1 bricklayer, 1 helper
Prefabricated fireplace kit		
Radiant heating, open front only	5.00	1 bricklayer, 1 helper
Radiant heating, 3 sides open	6.00	1 bricklayer, 1 helper
Forced air heat circulating	5.50	1 bricklayer, 1 helper
Add for blower unit connection	0.500	1 electrician
Add to connect vent system to fireplace	0.167	1 bricklayer, 1 helper
Fireplace flue, straight vertical, per LF	0.167	1 bricklayer, 1 helper
Add for flue spacers for ceiling	0.167	1 bricklayer, 1 helper
Add for flue offset	0.250	1 bricklayer, 1 helper
Add for flashing and storm collar	3.25	1 bricklayer, 1 helper
Add for spark arrestor top	0.500	1 bricklayer, 1 helper

For information on related topics, see:

Brick Masonry, page 51

Floor Framing, page 299

Framing Materials and Planning, page 363

Heating and Air Conditioning, page 379

Roofing, page 561

Ventilation, page 701

Wall Framing, page 709

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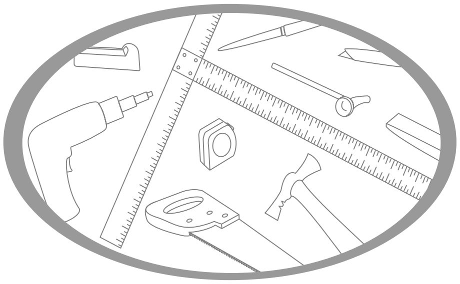


Floor Framing

Floor framing begins with the foundation in place and, in most cases, the backfilling complete. Having the backfilling complete makes working around the project easier for the framers. However, some foundation designs will specify that the foundation mustn't be backfilled before the floor framing is in place. The purpose of this is so that the framing will provide support for the foundation during backfill and compaction.

You must select, size and install the floor framing components to provide a stable, squeak-free floor system and, most important, to be capable of supporting the required loads. The floor system includes the following:

- Columns
- Girders
- Sill plate attachment
- Floor joist installation
- Laying a plywood subfloor or single floor system.

The information in this section should provide you with an understanding of loading and design, material selection, and the installation information you need to frame a floor system.

Columns

Columns are used to support girders under the floor joists of building floors, porches, and decks. These columns may be constructed of masonry, concrete, steel, or wood. The following general information on column design will help you understand this process as well as provide you with information on installation. However, the actual design and column load calculations should be done by the architect or project engineer.

Column Loading

Regardless of the material used to construct the columns, the design must take into account the load they'll be carrying. To understand these loads a little better, you might want to look ahead to the section on *Girders* beginning on page 310. Because the columns support the girders, knowing the loads the girders carry is necessary to design the columns.

Looking at *Girders* — Building Loads, under the headings *Distributing the Load with* $^1/_2$*-Width Lengths and Loads per Linear Foot of Girder*, you can follow through the loading procedure to see how the girder and, in turn, the column is loaded. You'll see that all of the loads that bear on the girder must be calculated to combine both the dead and live loads. These calculations are done using $^1/_2$- or $^5/_8$-widths, depending on floor joist. Then you convert the load to a *load per linear foot of girder*. Once you have this load, you can determine the bearing weight on the column.

Before we go through an example of how to determine this load, first look at the relationship of columns to girders. Figures 1 through 3 show single and multiple columns supporting girders in much the same way that single and multiple girders are seen supporting joists in the section on *Girders*. Compare Figure 1 to Figure 2. Figure 1 has a girder spliced over the single column while Figure 2 has a continuous girder. The load is figured as $^1/_2$ width or $^5/_8$ width in the same manner that the floor load is figured for the girder. If the girder is spliced over the intermediate support (or column in this case), you figure the load as $^1/_2$ width. If the girder continues over the post, the load is figured as $^5/_8$ width. If it continues over the post and is spliced to one side, it's figured as $^5/_8$ width on the unspliced side, and $^1/_2$ width on the spliced side.

In the section under girders, there are two illustrated examples on how to calculate the load per *linear foot of girder* (pages 315 and 316). Both examples use a foundation with an overall width of 24 feet. In Figure 10 you have a single-story truss-roofed building with the floor load calculated to be 50 pounds per square foot. Multiplied times the $^1/_2$-width of 12, the *load per linear foot of girder* equals 600 pounds.

Building on that example, you can determine the load on the posts, or columns, for a foundation length of 40 feet, like the one in Figure 3. Dividing the length into four spaces of 10 feet each, in addition to the two outside walls, you'll need three columns for support.

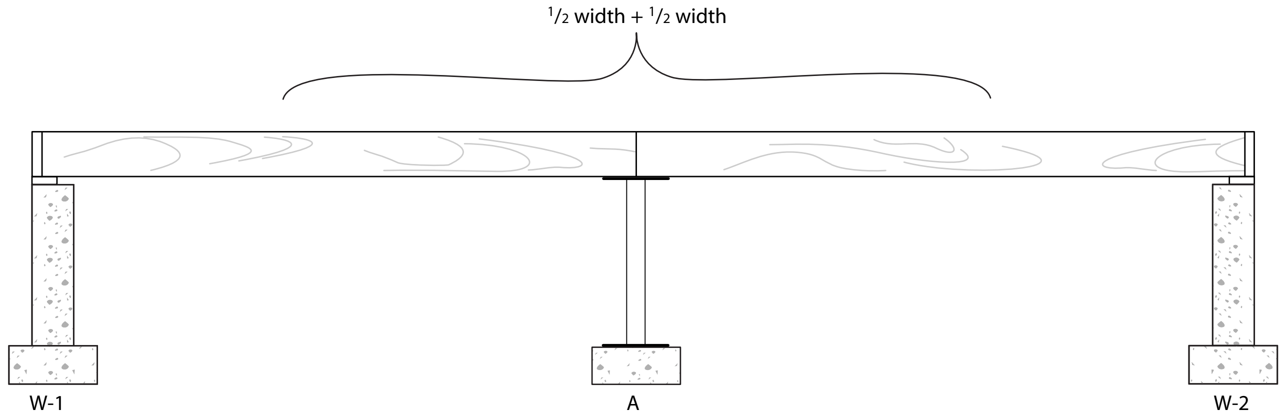


Figure 1
Column loading with spliced girder

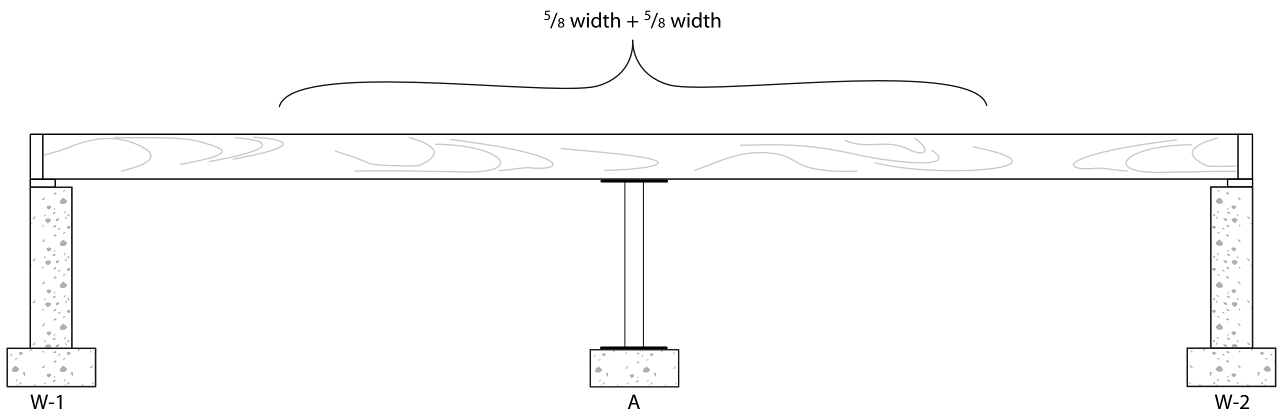


Figure 2
Column loading with continuous girder

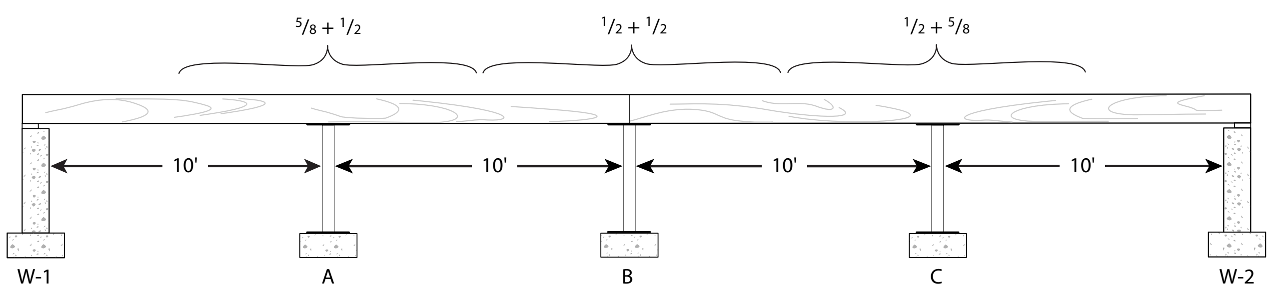


Figure 3
Figuring loads with multiple columns

Example 1

Using the same load of 50 pounds per square foot, you can calculate the load per column for the one-story house in Figure 4 as follows:

Column A

	W1 A = $\tfrac{5}{8} \times 10$ =	6.25 feet
	A B = $\tfrac{1}{2} \times 10$ =	5.00 feet
Total linear feet of girder loading column A		11.25 feet
Total load per linear foot of girder		500 pounds
Total linear feet loading column A		× 11.25 feet
Load on column A		5,625 pounds

Column B

	A B = $\tfrac{1}{2} \times 10$ =	5.0 feet
	B C = $\tfrac{1}{2} \times 10$ =	5.0 feet
Total linear feet of girder loading column B		10.0 feet
Total load per linear foot of girder		500 pounds
Total linear feet loading column B		× 10.0 feet
Load on column B	=	5,000 pounds

Column C is a mirror of A, with the same load of 5,625 pounds.

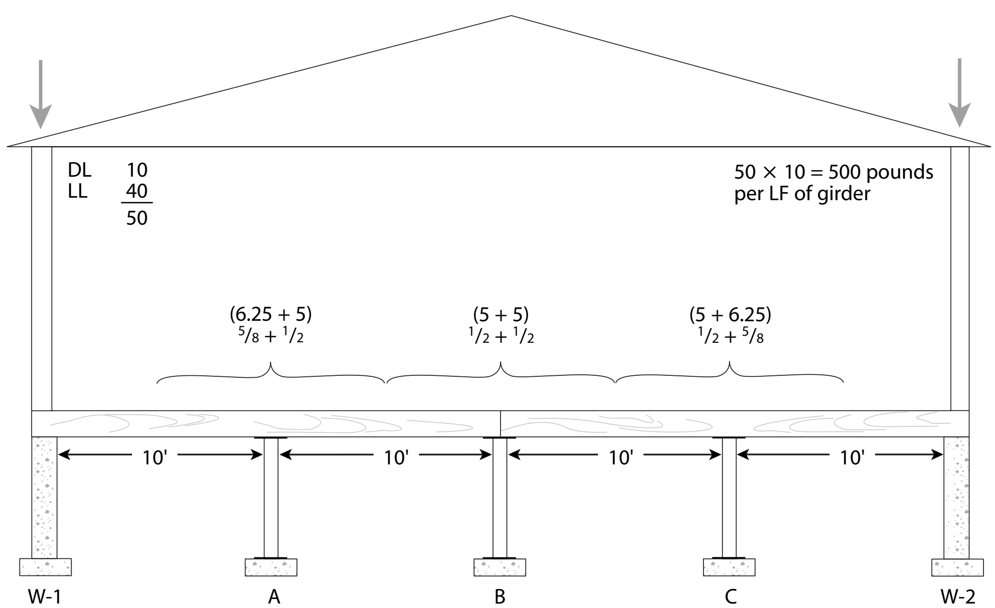


Figure 4
Calculating column loads for a one-story house

Example 2

Figure 5 is a two-story house with a 40-foot foundation. Using the same loads from the example in Figure 11, we can figure that the load per linear foot of girder for this example is 130 pounds. The load for each column can be calculated as follows:

Column A

W-1	A = $^5/_8$ × 10 =	6.25 feet
A	B = $^1/_2$ × 10 =	5.00 feet
Total linear feet of girder loading column A		11.25 feet

Total load per linear foot of girder	130 pounds
Total linear feet loading column A	× 11.25 feet
Load on column A	1,462.5 pounds

Column B

A	B = $^1/_2$ × 10 =	5.0 feet
B	C = $^1/_2$ × 10 =	5.0 feet
Total linear feet of girder loading column B		10.0 feet

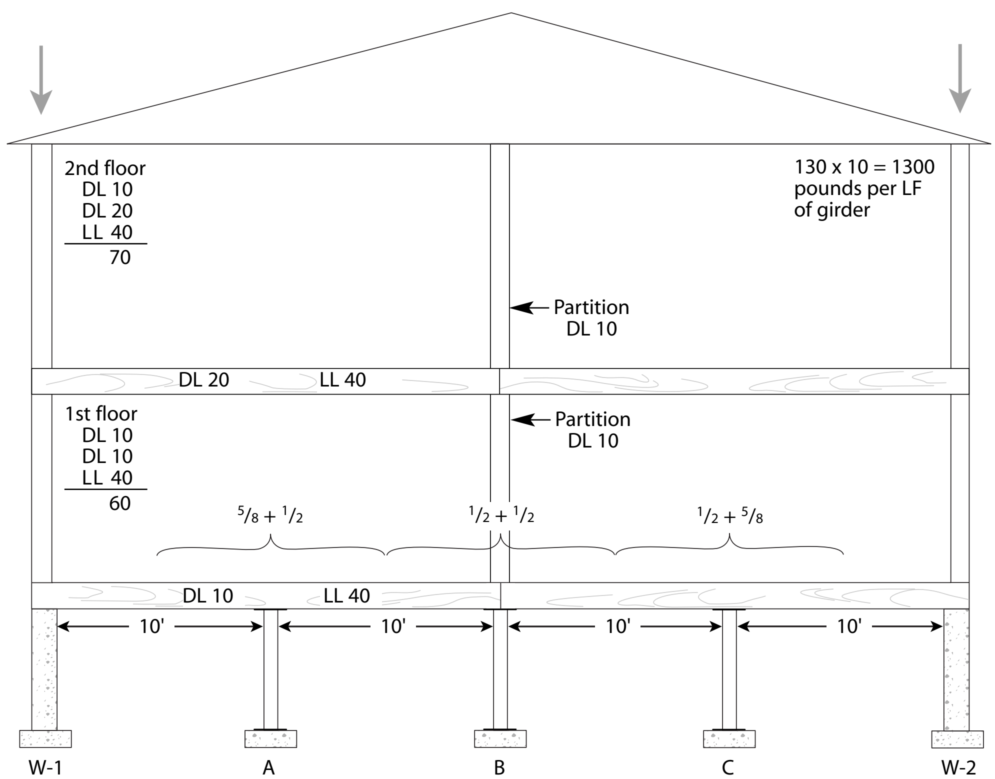


Figure 5
Calculating column loads for a two-story house

Total load per linear foot of girder	130 pounds
Total linear feet loading column B	× 10.0 feet
Load on column B	1,300 pounds

Column C is a mirror of A with the same load of 1,462.5 pounds.

Column Selection

Columns can be constructed of wood, steel or masonry. The type of material you're required to use for the columns may be based on its load-carrying capacity, or other factors may enter into making the initial selection. Special design considerations or future plans may also dictate the material you use. For example, you might want to use a steel column in an unfinished basement so that if it were to be finished in the future, it could be concealed in a 2 × 4 framed wall.

Sizing the Material

Once the column material is selected, consult an engineer to ensure that the bearing capacity is adequate for the loads that will be carried. You must factor the height of the column with the load it will carry to determine the size of column you need. Consult manuals for the specific material you're using to determine the capacity of the wood or steel. The following information will provide you with a few general guidelines.

***Wood Columns* —** Wood columns are designed in the same way as joist and girders. When your load calculations are complete, first check to see which wood species will best match your requirements. When you've selected the most probable species, consult a species reference (such as the one provided in the *International Residential Code*) to determine the bearing capacity of that species.

***Steel Columns* —** Steel columns are constructed from steel pipe. In some areas, adjustable premanufactured columns are acceptable for residential use. These columns are load-rated so you can purchase them for the capacity of the load they need to carry. Some jurisdictions require that columns be permanently welded and nonadjustable. Other areas require that steel columns be fabricated by a certified welder or shop. Check local codes for the requirements in your location.

***Masonry Columns* —** Though they're not as common as wood or steel, you may sometimes want to use masonry columns of brick or block. The most logical use of masonry columns is with a block foundation. You can lay the columns at the same time as the foundation walls. With the columns already in place, the framers can begin one step ahead.

The best use for masonry columns in residential construction is in crawl spaces where their size won't be an important factor. You should construct brick piers a minimum of 12 inches square, or larger as the loads increase. Block piers should be a minimum of 16 inches square because of the 8- × 16-inch block size. These minimum sizes make masonry columns awkward obstacles to build around and conceal. You may run across this problem if you're finishing a basement in which steel or wood columns would have been a more suitable choice.

When you use masonry columns, lay the hardware to attach the girder to the column into the pier as you construct it. If you use a metal saddle, size it for the girder that you'll be using. Check a hardware attachment catalog for the appropriate attachment piece. Most hardware suppliers have a catalogue from Simpson Strong Tie or another manufacturer whose products they represent.

Footings for Columns

Minimum footings for any of the columns we've discussed should be 16 x 16 x 8 inches deep. Construct the footings using concrete reinforced with #4, grade 60 reinforcing steel that is bent in a loop or square. (See Concrete Reinforcement.) Overlap the reinforcement a minimum of 30 bar diameters or in the case of #4 steel, 15 inches. You can also use four short bars, laid in the form of a square with the ends crossed, to reinforce some footings (see Figure 6).

Place footings for columns in accordance with the plans. The footing placement is determined by the span that the girder is capable of carrying. Any misplaced footing will need to be replaced so that the designated span distance remains unchanged.

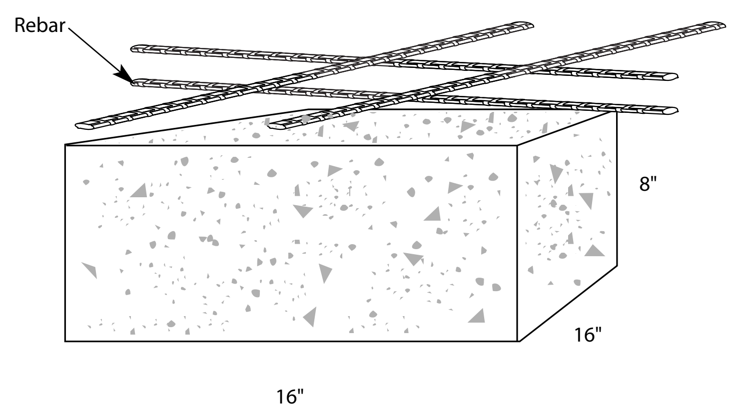


Figure 6
Reinforcing for column footings

Establishing Column Height

In commercial construction or on tightly-run residential construction, you can establish the column heights (or the lengths of the columns you'll be using) from the drawings. In order to do this, you must build the column footings, as well as all other foundation work, on the exact elevations established on the plans. With accurate workmanship, you can order steel columns and have them built and on the job site ready for installation from the measurements taken off the plans.

If the footing elevations aren't established from the plans, or you don't follow the plans accurately enough, you'll have to establish the column heights on the job site based on the elevations of the footings and sill plates. This is frequently the case in residential construction where you'll often use wood columns and premanufactured adjustable steel columns that you cut or adjust on site.

You must establish a height for wood and steel columns. For masonry columns, you just need a top elevation. To obtain these measurements you'll need the elevation of the girder. This is usually the top of the sill plate for wood girders and the bottom of the sill plate for steel. You'll also need the elevation of the footing, as well as the depth of the girder.

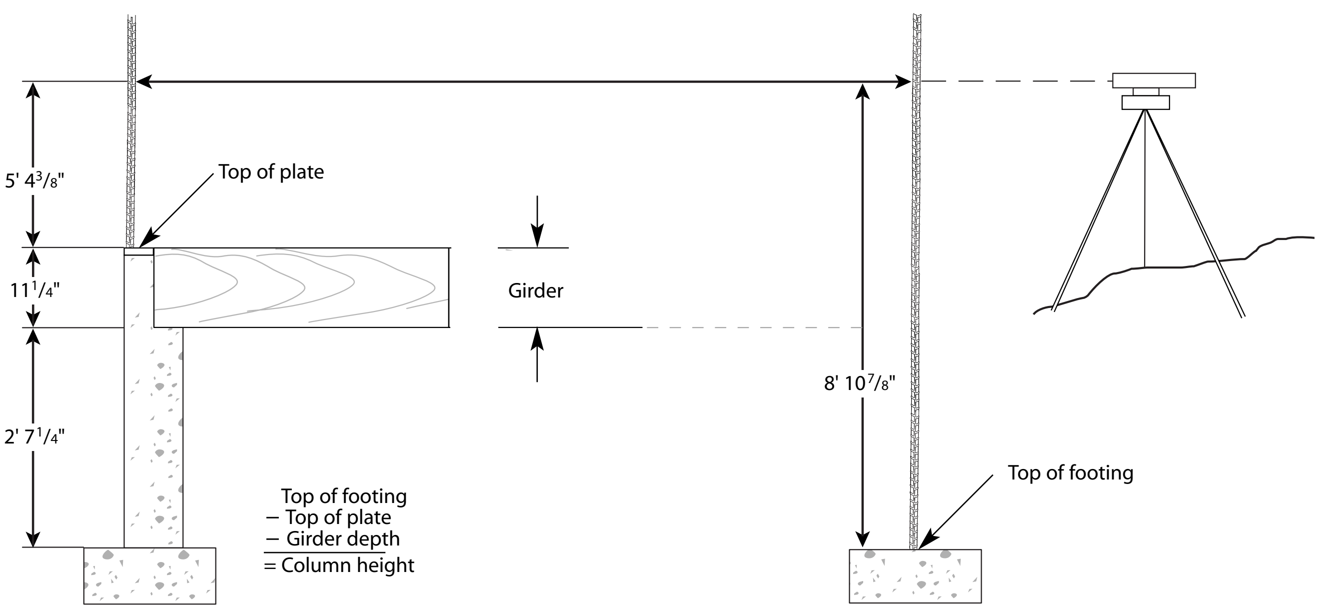


Figure 7
Finding column height using elevation readings

The steps we'll follow in determining these measurements are based on a wood girder with the top of the sill plate being the desired elevation for the top of the girder. You'll normally place a 2-by plate on top of steel girders for easier joist attachment, in which case you'll need to allow for the plate in addition to the girder thickness.

Determining Height Using Elevation Readings

1. Use a transit or builder's level, set up so you can take readings off the top of the plate and the top of the footing.
2. Take a reading for the top of the plate.
3. Take a reading for the top of the footing.
4. The difference between these readings will give you the overall measurement from the top of footing to the top of plate.
5. Subtract the depth of the girder as well as the thickness of any framing anchors to be used for attachments from the overall measurement (Step 4) to obtain the height of the column.

You can find the height for the columns in the crawl space in Figure 7 by following these steps:

1. Top of plate reading: 5'4 3/8"
2. Top of footing reading: 8'10 7/8"
3. Subtract top of plate from top of footing for overall height:

Top of footing reading	8'10 7/8"
Top of plate reading	– 5'4 3/8"
Overall height	3'6 1/2"

4. Subtract the girder depth from the overall height to determine the column height:

Overall height	3'6 1/2"
Built up 2 x 12 girder depth	– 11 1/4"
Column height	2'7 1/4"

Determining Height Using a String

For some small jobs, you can find the top elevation of the columns by stretching a string from the tops of the plates on the foundation walls as shown in Figure 8. You then measure from the footing to the string and subtract the girder depth and framing anchor thicknesses to get the column height. When you use a string to take measurements, you must be careful to ensure that the measurements aren't affected by sag or wind.

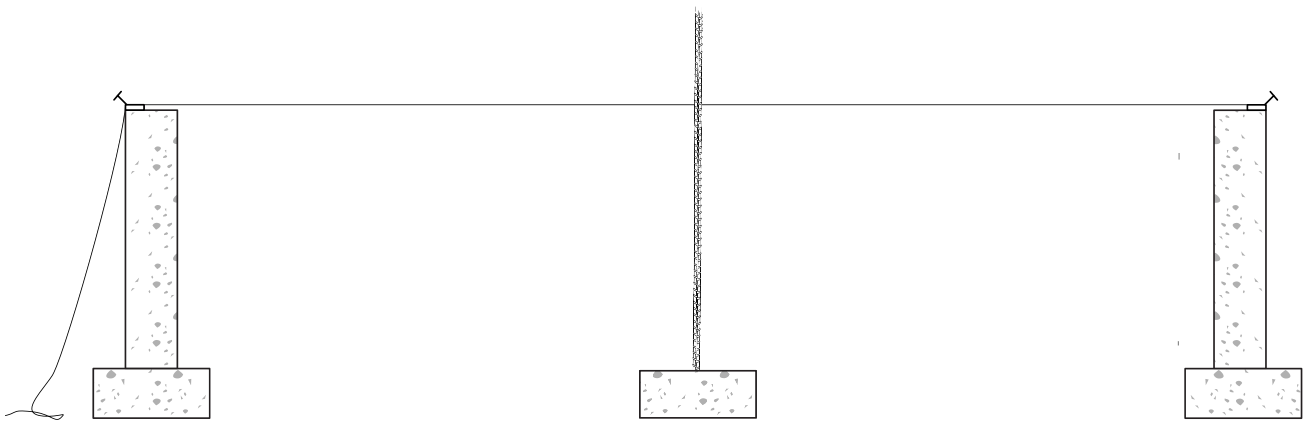


Figure 8
Finding column height using a string

Steel Column Installation

Adjustable residential steel columns are the easiest columns to install. The footing pad elevations aren't as important as you can adapt the columns for any irregularities with a simple screw adjustment. The base of the columns have predrilled holes to use in attaching the column to the footing. The top plate has predrilled holes as well as a flange that you can bend around the girder to secure it into position.

You can also have steel columns custom fabricated to a specific length. Figure 9 shows how the column bases for these steel columns are built. They consist of a steel plate with four anchor bolts welded to them. This style of base is useful for heavy loads, and when placing a pad at an elevation at which a steel beam will be attached directly to the plate. The plate is embedded in the concrete pad, which will then support the columns and girder.

Setting Plates and Framing Anchors

Accuracy is vital in the plates' elevation and spacing. Girders are designed to carry the load for a specific length. Proper spacing of the columns is mandatory to maintain the designed girder span. And, since prefabricated steel columns are made up off of the plans, if the elevation is off, the columns will have to be rebuilt.

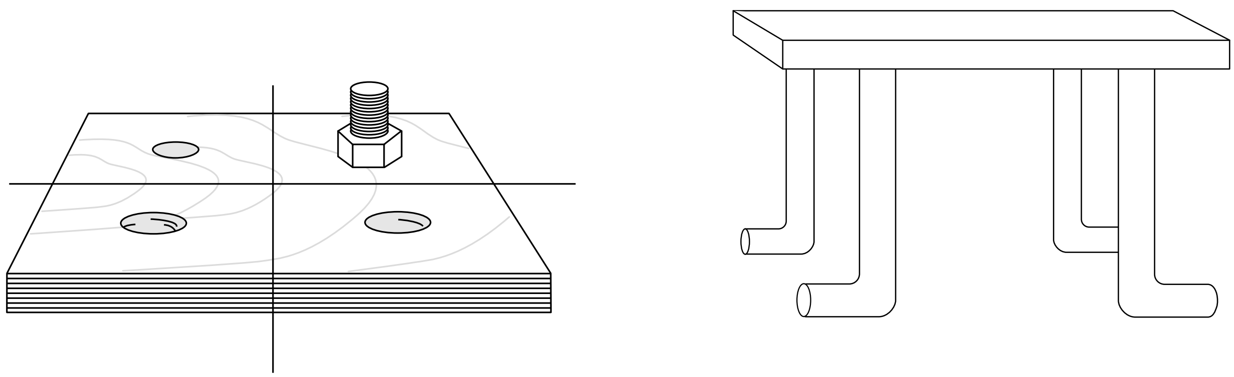


Figure 9
Base plates for steel columns

Use these guidelines for setting plates or framing anchors in the footing for steel columns:

1. Make the centerline layouts and elevation markings when setting the formwork for the pad or footing.
2. Fill the formwork with concrete and reinforcement.
3. Place the steel plate in the prelocated position.
4. Use a builder's level or transit to confirm the elevation.
5. Use a small level, such as the 6-inch torpedo level common in plumbing, to level in the plate while cross-checking the elevation with the transit.

Another method you can use to install lighter columns is to drill holes in the base of the columns for anchor bolts or expansive bolts. When you use expansive bolts, the elevation of the pad remains important, but you no longer need to precisely locate the anchor bolts. You can locate and drill the holes for the expansion bolts in the pad at the time the columns are set. Set the pads or footings as discussed above. (See also *Concrete, Footings*.)

Installing Steel Columns

1. Stretch a string or use a builder's level or transit to check and verify the column location on the footing.
2. Measuring off of the control points (walls, etc.), mark the column location on the steel plate or footing.

3. Place the columns in position, bracing them as required, and attach them as follows:

   a) attach each column to the metal plates by welding the bottom plate of the column to the steel plate embedded in the concrete footing; or

   b) attach the column directly to the footing using expansion bolts. Mark the holes where the expansion bolts will be placed and drill the concrete as required. Set the column in position, insert the expansion bolts, and tighten.

4. Brace the column as required until it's stabilized by the girders and floor system.

Wood Columns

Wood columns are much more forgiving than steel. Your framing crew can determine their length and make the necessary cuts during the installation process:

1. Find the column height as outlined earlier under *Establishing Column Height*. Cut the column to the required length.
2. Place the column in the framing anchor. Attach it according to the requirements of the type of framing anchor you're using.
3. Brace the column as required until it's stabilized by the girder and flooring system.

Girders

The actual floor framing begins with placing the girders required for the structure. A girder is an intermediate support member designed to carry the floor joists as well as the loads that will be placed on the joists. Girders are constructed of built-up dimensional lumber, micro-laminated beams, or steel. The project engineer or the architect determines the girder size, since the loads that must be taken into consideration include the dead and live loads of the floors, as well as any roof loads that may be transferred to the girder. Girders are supported by intermediate posts or columns set on pads in the crawl space or basement. The fewer supports there are, the larger the girder needs to be to carry the span.

Sizing Girders

We'll go through an example of how girders are sized. Keep in mind that, generally, engineering should be left to engineers. This example is only designed to help you better understand the process of sizing girders.

Three rules govern the dimension of wood girders:

- *Length* — The longer the wood member, the less weight it can carry.
- *Width* — Doubling the width doubles the strength.
- *Depth* — Doubling the depth increases the load capacity four times.

Girder design applies these rules to the objectives of the design to produce a structurally sound girder. The design objectives may vary from job to job. One job may require a large open span while another design will call for maximum ceiling clearance. The following information tells you what the architect or engineer's calculations are based on.

Building Loads

All structures have weight or loads that they must carry. Within the structure, various components are engineered to support specific loads, and some must support more than others. So, while rafters are designed to support only the weight of the roofing and potential snow, the foundation walls and girders must support the rafters, roofing and snow, as well as intermediate walls, ceilings, floors and the people and furniture who occupy the structure. All of these items are combined into two types of loads: dead loads and live loads.

Dead Loads — Dead loads are any loads created by the building components of the structure itself. These loads include:

- Floor joists
- Flooring material for all levels, including storage areas such as attics
- Bearing partitions and permanent loads supported by those partitions
- Attic partitions
- Attic joists for the top floor
- Ceiling and wall coverings, such as lath and plaster, including the basement ceiling if it's plastered or finished

Live Loads — Live loads refer to the weights that aren't a part of the building, but which must still be carried by the structure. These loads include:

- Snow
- Furniture and appliances
- People
- Other temporary or movable weights

The live loads and dead loads of the structure are combined to give the total load that must be carried by the girder. Figures 10 and 11 show two examples of girder loads. Notice how the girder for the truss-roofed single-story building in Figure 10 is carrying the weight of the floor joists and their related weights only. Compare this to the two-story building in Figure 11 with a second floor area and two bearing walls. Once the total load is figured, the next step is to determine how much of that load will bear on each girder.

Distributing the Load with 1/2-Width Lengths — In figuring the load a girder will carry, you must make calculations to distribute the load between the girder, or perhaps multiple girders, and the outside bearing foundation walls. When the floor joists are spliced over the girder, the first calculations you do are to determine the 1/2-width. Regardless of whether there are single or multiple girders, the method of weight distribution remains the same. The span on either side of the girder to the next supporting member (girder or foundation wall) is divided in half. The halves of both sides are added together to come up with the total load the girder must be designed to carry.

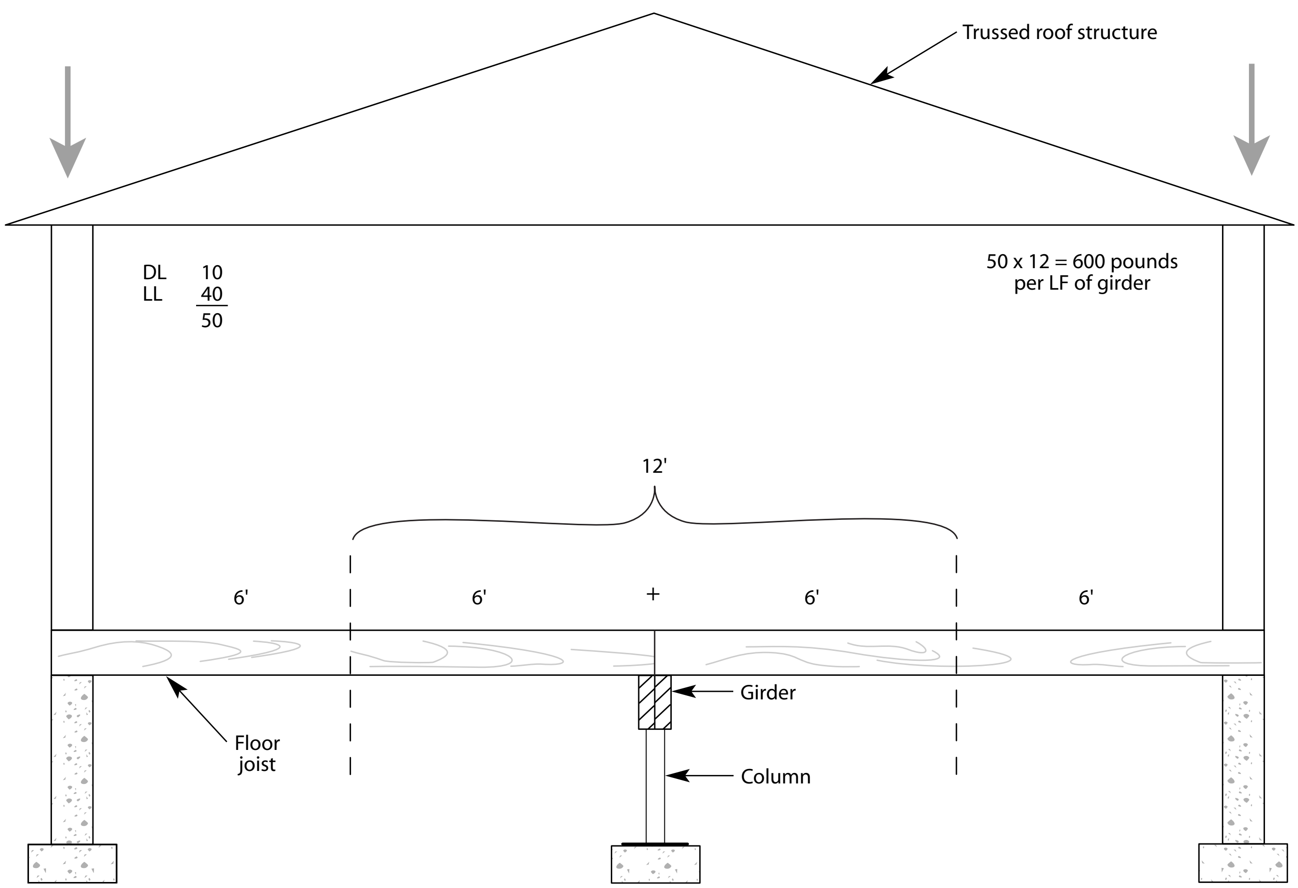


Figure 10
Single-story girder load

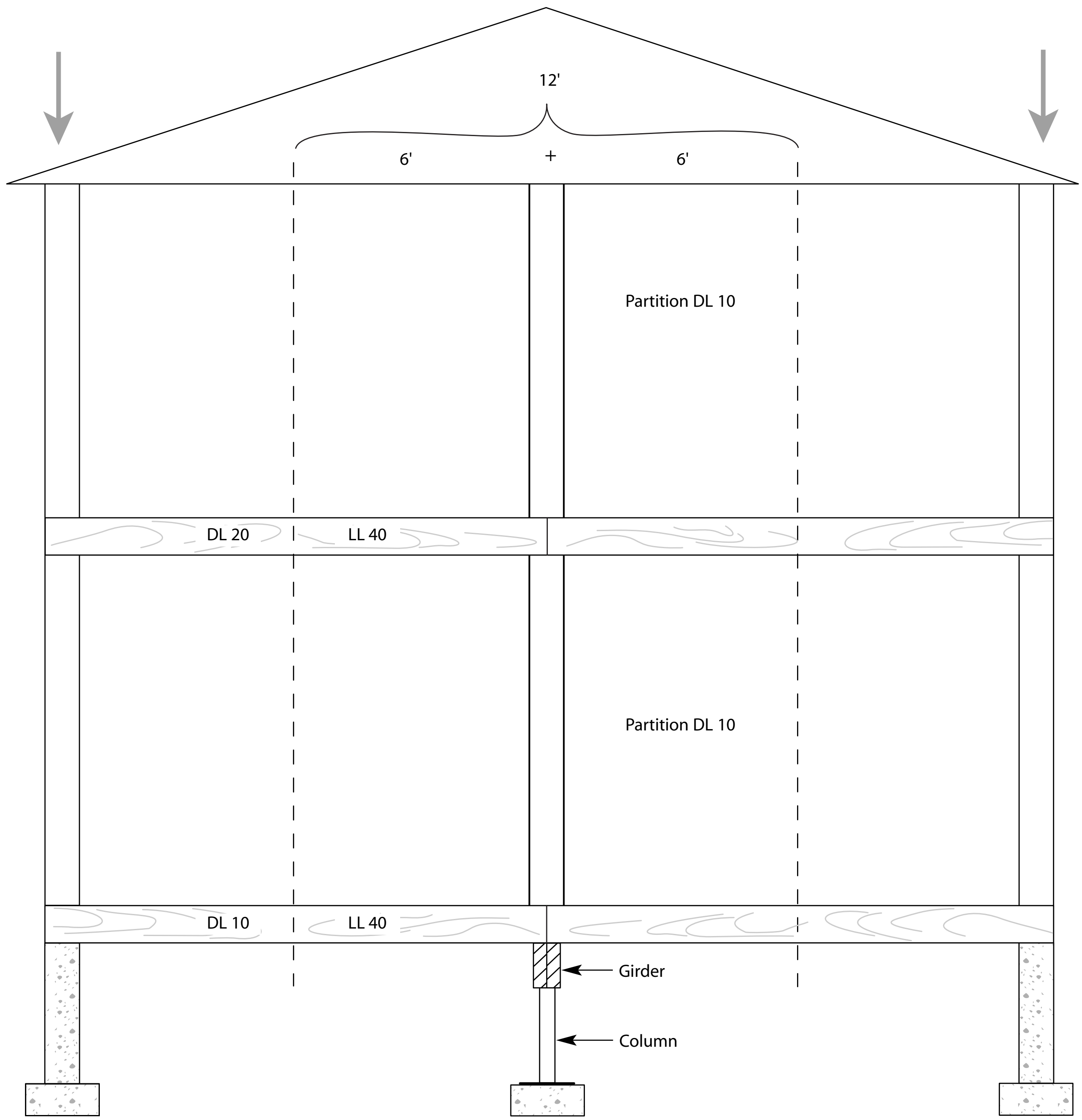


Figure 11
Two-story girder load

Figure 12a shows a girder centered in a 24-foot span. Notice that half of the distance on both sides of the girder to the supporting side walls is 6 feet, giving a total $^{1}/_{2}$-width supported by the girder of 12 feet.

Figure 12b shows an offset girder with the same 24-foot span. While the side spans are different, 5 feet and 7 feet still total to make a 12-foot $^{1}/_{2}$-width to be supported by the girder.

Figure 12c shows a multiple girder situation with varying spans. You can see that the girders on the outside walls are treated the same when determining the $^{1}/_{2}$-width.

NOTE: Only joists spliced over the girder are figured as $^{1}/_{2}$-width. Because of the difference in the way that continuous joists flex as compared to spliced joists, the load the girder carries is greater with a continuous joist. Because of the greater load placed by continuous joists, the load is figured in the same manner as spliced joists with the exception that $^{5}/_{8}$ of the load on both sides of the girder is totaled instead of $^{1}/_{2}$.

In the examples to follow, we'll use loads based on the weights given below. While these weights may be representative of actual working weights, you must use locally-accepted weights for your own calculations. Note especially the live load of the light roof. In snow areas, the snow load alone could be 30 to 50 psf or higher. A slate or tile roof will also add considerable weight to the dead load of the roof.

Dead load of first floor	10
Live load on first floor	40
Dead load of partitions	10
Dead load of second floor	20
Live load of second floor	40
Dead load of attic floor	10
Live load of light roof	20

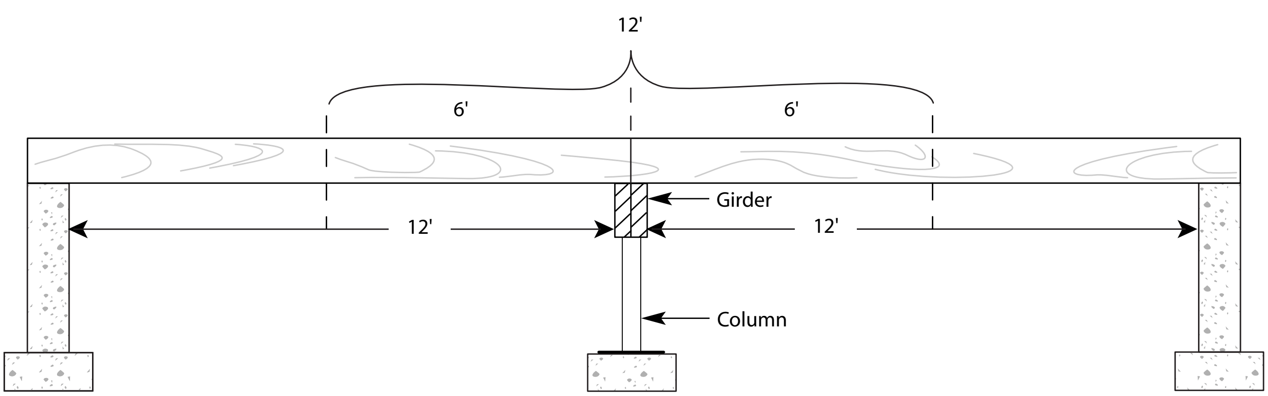


Figure 12a
Centered girder

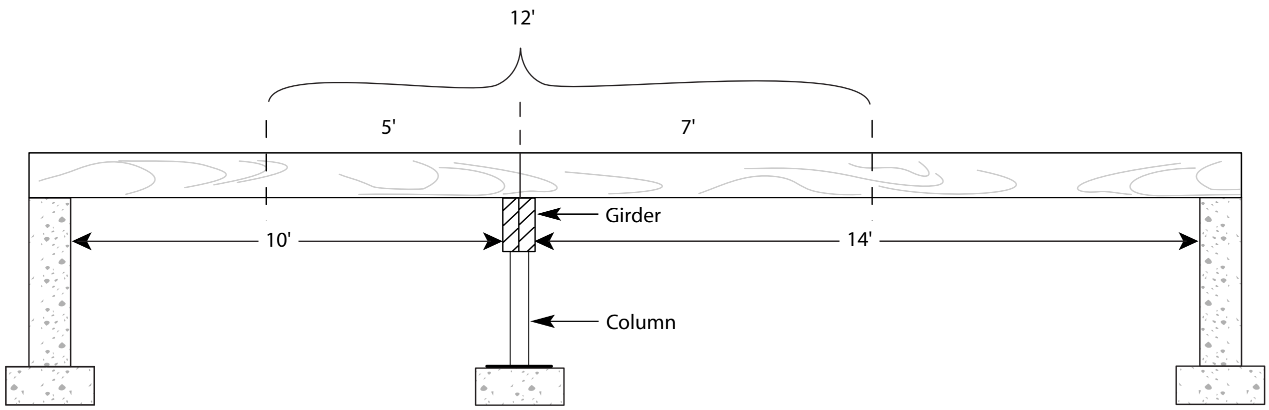


Figure 12b
Offset girder

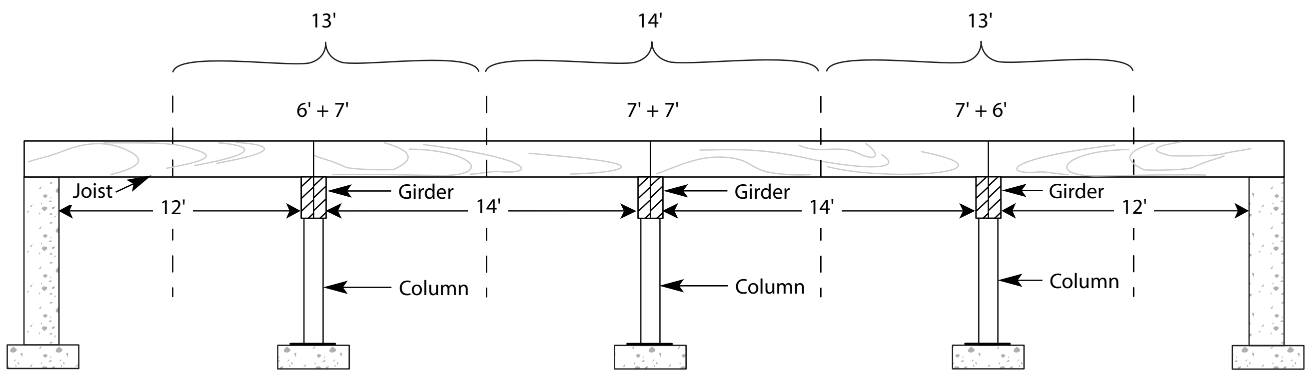


Figure 12c
Multiple girders, multiple spans

Loads per Linear Foot of Girder — The structure must be analyzed to see how much of the loads will bear on the girder. These loads must be totaled and a weight obtained per linear foot of girder. To obtain the load each linear foot of girder must carry, multiply the square foot load (resulting from the total of the dead and live loads) times the $^1/_2$-width length.

Example 3

Refer again to Figure 10 for this example. It's a simple trussed structure with the only load on the girder being the dead and live load of the floor. The total span of the floor joist is 24 feet, using two joists spliced over the girder. You obtain the $^1/_2$-width by adding the $^1/_2$-length from both sides of the girder, which is 6 feet in both cases. This results in a total $^1/_2$-width of 12 feet. The floor load is a dead load of 10 and a live load of 40. The calculations to determine the load per linear foot of girder for this example are as follows:

First floor dead load	10
First floor live load	+40
Total load per square foot	50

Total load per square foot	50
$^1/_2$-width span	×12
Load per linear foot of girder	600 pounds

To determine what size and span of girder you can use for a project, begin with the species and grade of the proposed girder. Use reference tables that are approved for the area in which you'll be working to obtain the listings for wood species and their grades.

When you know the allowable grade for the species the girder will be made from, you can go to the appropriate table in your code to determine what size and span of girder you can use.

Example 4

A slightly more involved example would be the two-story building in Figure 11. Using the same 24-foot span as in the last example, the first floor loads are the same, 10 psf dead and 40 psf live. Next you add in the first floor partition with a 10 psf dead load and no live load. The second floor has a dead load of 20 psf, and a live load of 40 psf. The second floor partition has the same 10 psf load as the first. Since the roof trusses bear on the exterior walls, there's no roof load transferred to the girder. The primary difference between these two examples is the simple arithmetic of totaling the loading. After you total the loading, you figure the $^1/_2$ width and multiply it times the loading to give you the load per linear foot of girder. Here are the calculations:

First floor dead load	10
First floor live load	40
First floor partition	10
Second floor dead load	20
Second floor live load	40
Second floor partition	+10
Total loading per square foot	130

The joist $^1/_2$-width span is 12, which you figure the same as in the last example.

Total loading per square foot	130
$^1/_2$-width span	× 12
Load per linear foot of girder	1,560 pounds

To complete the sizing of the girder, you need to decide whether more columns (shorter spans) and a smaller girder — or a larger girder and fewer columns (longer spans) — will be more practical for your application. When you know what your desired column spacing is, size the girder by multiplying the load times the linear feet between columns.

An 8-foot span at 1,560 pounds per linear feet requires a girder that will carry 12,480 pounds ($8 \times 1{,}560 = 12{,}480$). A 10-foot span requires a girder that will carry 15,600 pounds ($10 \times 1{,}560 = 15{,}600$), and a 12-foot span requires a girder that will carry 18,720 pounds ($12 \times 1{,}560 = 18{,}720$).

As with the last example, you need to find the species and grading of the proposed girder in a resource book approved for your area to find the size girder to support the required weight.

These examples are just for information only. You may find more complicated arrangements, such as a multiple girder situation where one or more girders are carrying point loads with others carrying floor loads. Always consult an engineer or architect for girder sizing.

Steel and Laminated Wood Beams

Steel, laminated (glu-lams), and veneer-laminated wood beams (micro-lams) are often the first choice for girders. These products can carry more weight than similarly sized solid wood girders. Consult your supplier or manufacturer for charts showing the load-carrying capabilities of these products.

Girder Placement

To balance joist sizes, place girders as close to center as possible. When they're offset, use the same joist size on both sides to keep from having to step, or build up, the supporting girder or foundation walls to accommodate a difference in joist size. An offset girder results in an "over engineered" shorter side which costs more than two equal spans. The usual reasons for placing a girder off center are space arrangements in the basement or the position of a bearing wall above.

You must plan your girder placement and set beam pockets accurately to support any bearing walls. You can't offset girders or supporting walls more than the depth of the joist below a bearing wall.

Beam Pockets

When you place a girder in a beam pocket, the *International Residential Code* states that no less than 3 inches of bearing should be provided when the ends of a girder are supported by masonry or concrete. This is the *minimum* bearing requirement. For greater spans and loads, you need to provide more bearing. When you set a girder in a wood beam pocket, you must calculate the load the girder will be carrying in relation to the compression of the supporting wood member.

A wood girder that's to be set in a concrete or masonry beam pocket must be constructed of treated wood or there must be $^1/_2$ inch clearance on the sides and end of the beam. With this in mind, you'll want to block out a pocket 4 inches deep when you form or lay the concrete or masonry wall. Figure 13 shows a beam pocket.

Elevation of Wood Girders

Place the girder so the floor joists pass over the top or so the joists hang from the girder. In a crawl space where headroom isn't important, the girder elevation isn't probably important. However, hanging the joists on a raised girder is certainly an advantage if the girder goes through a basement recreation area.

In a crawl space, the basic factors you use to determine girder elevation or crawl space depth are the minimum separation requirements between the ground and untreated wood framing members. A girder can be no closer than 12 inches to the ground, and floor joists can be no closer than 18 inches to the ground.

Installing a Plate on a Steel Girder — Place a wood girder that's designed to have the joists pass over the top so that the top is level with the top of the sill plate. Place a steel girder in the same location

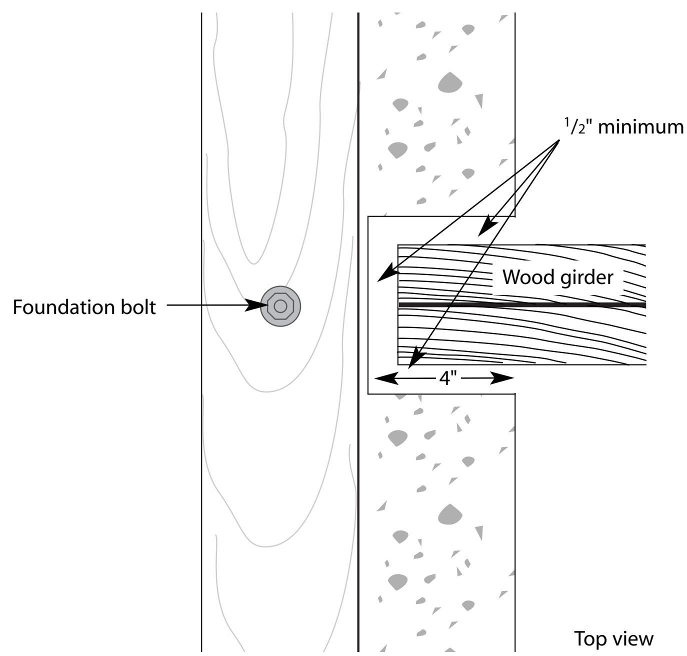


Figure 13
Beam pocket for wood girder

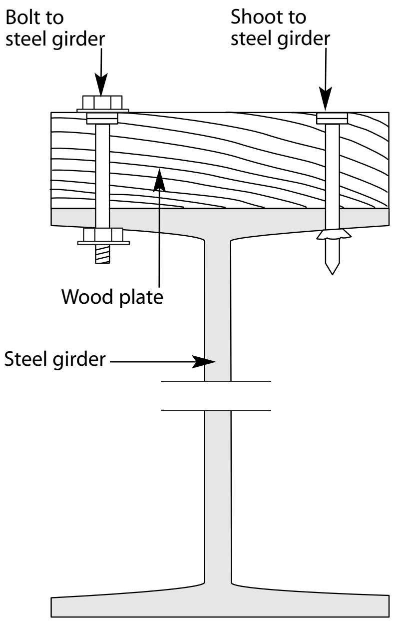


Figure 14
Bolt or shoot wood plate to girder

so that it's level with the bottom of the sill plate. You need to allow for a wood plate to be fastened to the steel beam so you can attach the floor joists to it. You can attach the wood plate to the steel beam in several different ways. You can "shoot" it on with a power-actuated fastener, such as a Ramset, or you can drill and bolt it on. Both methods are shown in Figure 14.

Girder Installation

In residential and light commercial construction, you do the girder installation in conjunction with the installation of the supporting columns. (Refer back to *Column Installation* if you need to review the information on columns.) You shouldn't do the actual installation of the girder until the columns are securely braced, taking into account the height of the column as well as the weight of the girder you'll be placing.

Steel Girders

Before placing the girder, check the elevation of any beam pockets that you'll be using in the foundation wall. If a pocket is low, build it up using a dry pack grout made of a 50/50 mix of fine masonry sand and portland cement. Mix the grout with water to the consistency of a stiff paste. In some cases, pockets are designed and built with enough depth to allow for a steel plate sized in accordance with the girder, usually $^3/_8$ to $^1/_2$ inch. Grout the plate to a level position at the desired elevation (Figure 15).

Place the steel beam from beam pocket to beam pocket if the span is small enough to make this possible. Set non-adjustable steel columns in place and brace them. When you have them positioned as required, check for proper elevation. In some cases, you may need to use steel shims to make slight elevation changes. If you're using an adjustable column, simply adjust the screw to the desired elevation. Some building departments require that you spot weld the screw to prevent any future movement.

If the span is too great for a single steel beam, make unwelded splices between two beams over a column. Attach the two pieces to each other with a steel plate and bolts. The thickness of the plate should correspond with the steel it's connecting. Its dimensions should be the same, or only slightly smaller in height, as the distance from flange to flange on the beam. The width should be at least the same as the height. Four bolts, two into the end of each beam, should be adequate to secure the plate. Consult the architect or engineer for specific plate and bolt sizing.

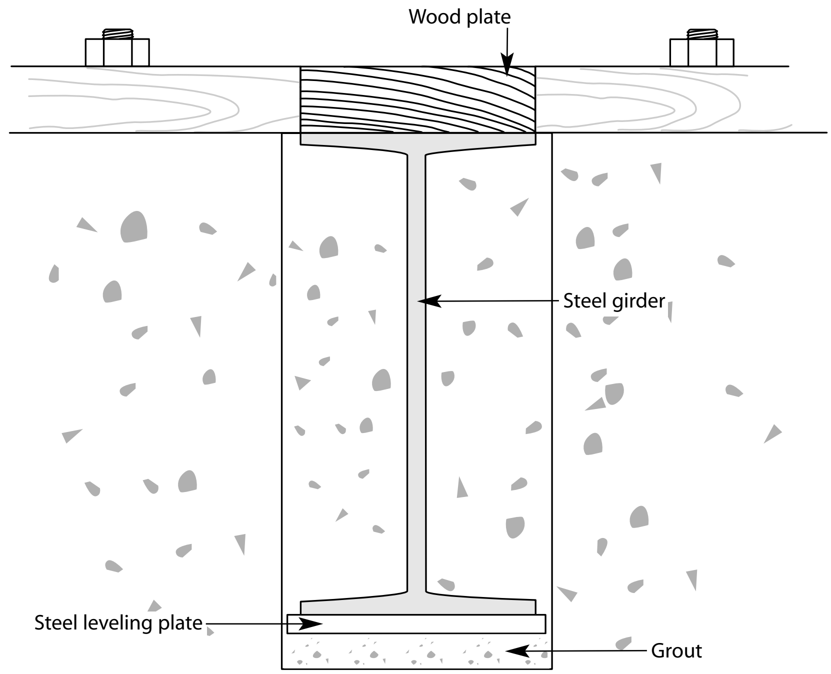


Figure 15
Grout steel plate in place

Wood Girders

Wood girders may be constructed of built-up beams of dimensional lumber, veneer-laminated beams, dimensional lumber laminated beams and timbers, or solid wood beams. The installation methods for built-up beams and veneer-laminated beams are much the same. Install dimensional lumber laminated beams and timbers or solid wood beams as you would steel.

Built-up Girders — Built-up beams consist of multiple planks nailed side by side. They may be dimensional lumber or veneer-laminated beams. Because of maximum length limitations, you'll probably need to splice girders made of dimensional lumber. Micro-laminated beams are available in lengths up to 60 feet, so in most cases they won't need to be spliced. However, should you need to splice them, do it the same way as you'd splice girders built of dimensional lumber.

When you need to splice a girder, make the joints over a supporting column, but stagger them so that the joints for all the members don't fall over the same column. Figure 16 shows a girder with 8-foot spans built of 16-foot material. In this case, the center member was started with a full 16-foot piece while the outer two were started with 8-foot pieces. Full pieces were then run on both the inside and the outside, finishing up at the opposite end with an 8-foot piece in the center.

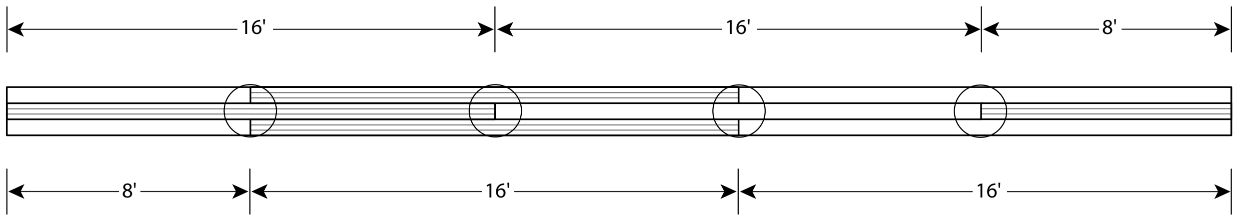


Figure 16
Built-up girder

1. When you use dimensional lumber, select solid members, free of defects, and as clear as possible.
2. Place the planks with the crowns up.
3. Fasten the planks together with 20d nails. Nail two nails at the ends of all planks. Nail the remainder of the girder at 32 inches on center at top and bottom with the top and bottom nails staggered. Don't drive the nails through if more than two members are being joined because the protruding nails will make attaching the additional members more difficult. After all the members are in place, finish driving all nails.
4. Nail the girder from the opposite side, staggering the nails from the other side. When this is done, you'll have nails at 16 inches on center top and bottom.
5. Attach the built-up girder to the column using the appropriate framing anchor. You can get suitable framing anchors for column-to-girder connections from a variety of framing anchor manufacturers.

Glue-Laminated Beams and Solid Wood Beams

The installation for glue-laminated beams and solid wood beams is somewhat similar to steel beams. As with steel, glue-laminated beams are available in greater lengths and in some cases are capable of spanning from beam pocket to beam pocket. In lengths where you're using multiple members, join both glue-laminated and solid wood beams over supporting columns. Where the dimension of the column is compatible with the girder, use a plate in the shape of a T to join these three members together. Depending on the size of the members, you should use bolts a minimum of $2^1/_2$ inches through each member. Use two plates at each connection, with the framing members sandwiched between them.

When the columns aren't the same size as the girder, you can get framing hardware to make most required connections. The architect or engineer who designs the project will, in most cases, call out a specific manufacturer and model number for the hardware you need.

Bracing

You'll need to have bracing in place during the construction and placement of the girders to keep the columns and girders safe and stable. After completing all the girder connections, check the bracing to see that it's secure and that the girder is properly aligned. Go over the bracing with the installation of the floor joists in mind. If it appears that any bracing will be in the way when you install the joists, change it to a position that offers less interference. After you place and attach the floor joists, the girder will be stabilized, and you can remove the temporary bracing.

Sill Plates

Sill plates are the first wood members that you place. Because they come into contact with concrete, sills need to be made of a decay-resistant wood species, like foundation grade redwood or cedar, or from treated wood. These provide decay resistance to moisture and some degree of protection from termites as well.

Attach the sill plates to the foundation with anchor bolts. You'll need to place the anchor bolts a maximum of 6 feet on center, with an anchor bolt no more than 12 inches from the ends of each sill plate as shown in Figure 17. With this in mind, coordinate the placing of the anchor bolts with the foundation crew so that standard length sill plates will work without too much cutting and waste. On long lengths, you must allow for splices with a set of anchor bolts set no more than 2 feet apart. With the splice in the center, the anchor bolts will be within 12 inches of the ends of both plates.

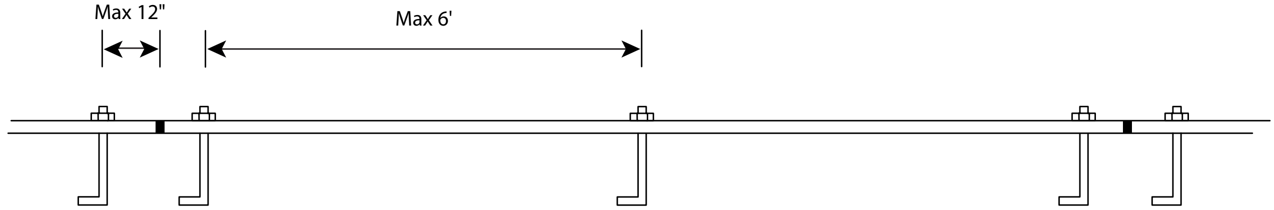


Figure 17
Attach sill plates with anchor bolts

Placing Sill Plate on Preset Anchor Bolts

With the anchor bolts in place in the concrete or block foundation wall, here's how to place the sill plate:

1. Recheck the foundation for square, making any necessary adjustments. Because there may be points where the sill plate may extend over the foundation, you might have to mark the corner points on what will be the inside of the plate.
2. Determine whether the sheathing will run flush with the outside of the foundation wall (framing in 1/2 inch) or on the outside of the wall (framing flush with concrete).
3. Chalk a line on what will be the inside of the plate, taking into account Step 2.
4. Lay the plate in position with the outside of the plate on the chalk line, which will be on the inside of the anchor bolts.
5. Using whichever square you're comfortable with (a speed square or tri-square usually works best in this situation), square off of the plate, and mark both sides of the anchor bolt on the plate as shown in Figure 18a.
6. Measure from the outside of the plate (the chalk line) to the center of the anchor bolt as in Figure 18b. Mark that distance, measuring from the inside of the plate between the two square lines that indicate the outside of the bolt (see Figure 18c).
7. Drill a hole the diameter of the anchor bolt on your centerline as in Figure 18d.

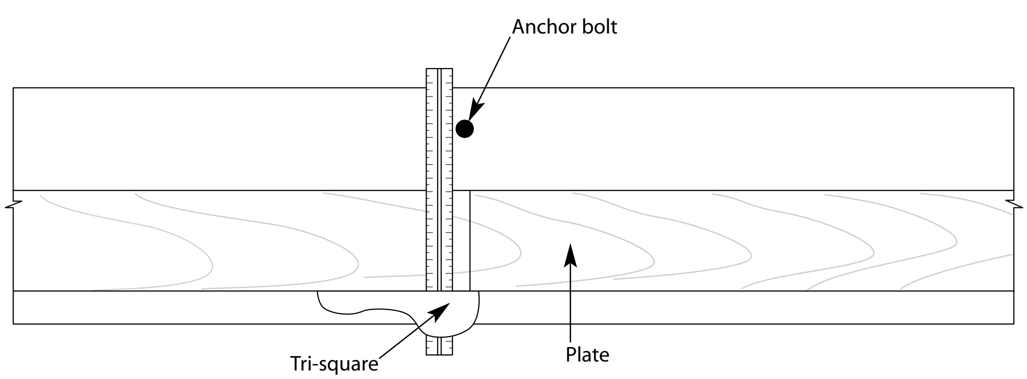


Figure 18a
Mark both sides of anchor bolt on plate

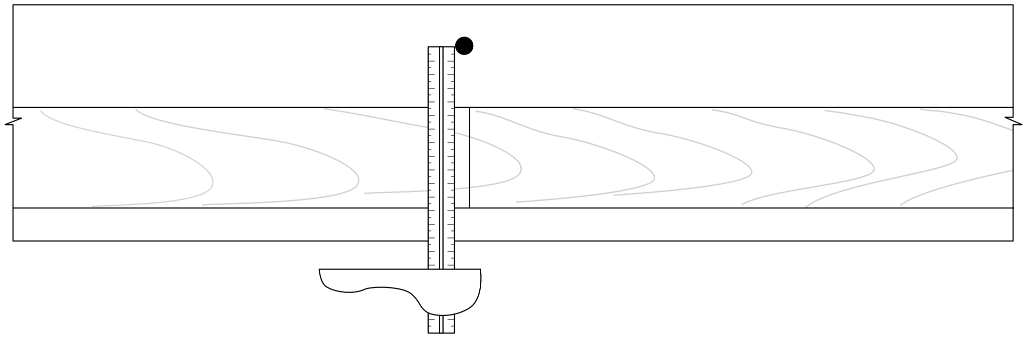


Figure 18b
Measure from the outside of plate to center of bolt

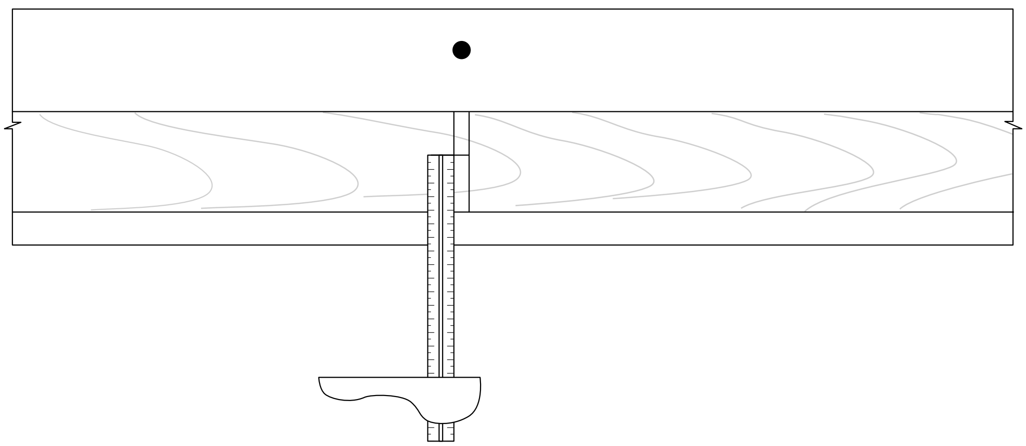


Figure 18c
Mark center of bolt on plate

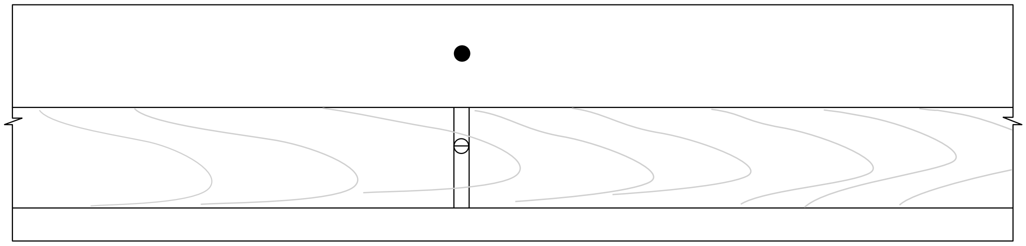


Figure 18d
Drill hole for anchor bolt

Alternative Method for Marking Sill Plate

You can make a simple device to locate the center of the anchor bolt on the sill plate for drilling. Follow these instructions to make a center locator:

- First, grind half of a $^1/_2$-inch diameter hole in the end of a strap. When this is placed against an anchor bolt, the strap will go half way around the bolt. See Figure 19a.
- Measure back from the end of the strap $3^1/_2$ inches for a 2 × 4 plate or $5^1/_2$ inches for a 2 × 6 plate and drill a hole the diameter of a 16d or larger nail as shown.
- Cut off the end of the nail so when you place it through the hole in the strap, $^1/_4$ inch of it will be exposed (Figure 19b).
- Braze the nail to the strap using a liberal amount of brazing on the top of the nail. The brazing will protect the hammer if you use a checker-faced hammer.

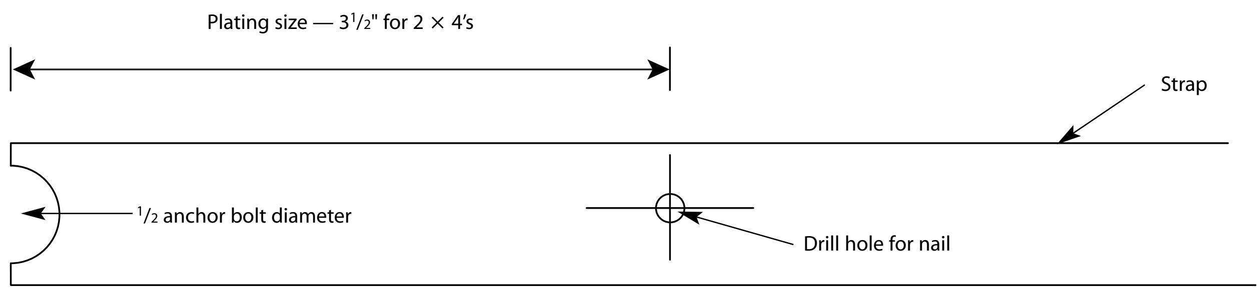


Figure 19a
Grind hole in strap

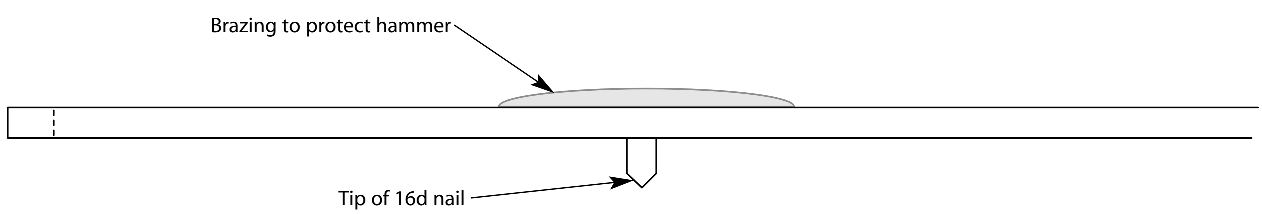


Figure 19b
Place cut-off nail in hole

- Leaving the end with the cutout to 1 inch behind the nail flat, you can bend the other end of the strap into a comfortable position for holding.

After you've made the locator, here's how to use it instead of Steps 5 through 7 above.

- With the sill plate on the chalk line, place the cutout on the end of your locator device tight against the anchor bolt.
- Square up the strap; "eyeballing" is usually adequate.
- Strike the brazing at the nail location as shown in Figure 20. This will leave an indentation on the plate.
- Drill a hole corresponding in size with the anchor bolt, using the indentation you just made as its center.

The plates are now cut, marked and drilled for the anchor bolts, and ready for placing. Use fiberglass or foam sill seal to seal up voids in the top of the foundation wall caused by irregularities in the surface. Roll it out over the top of the foundation wall, allowing the anchor bolts to punch through. This will prevent air as well as insects from infiltrating any spaces between the sill plate and foundation. Place the plate over the anchor bolts and attach the washers and nuts.

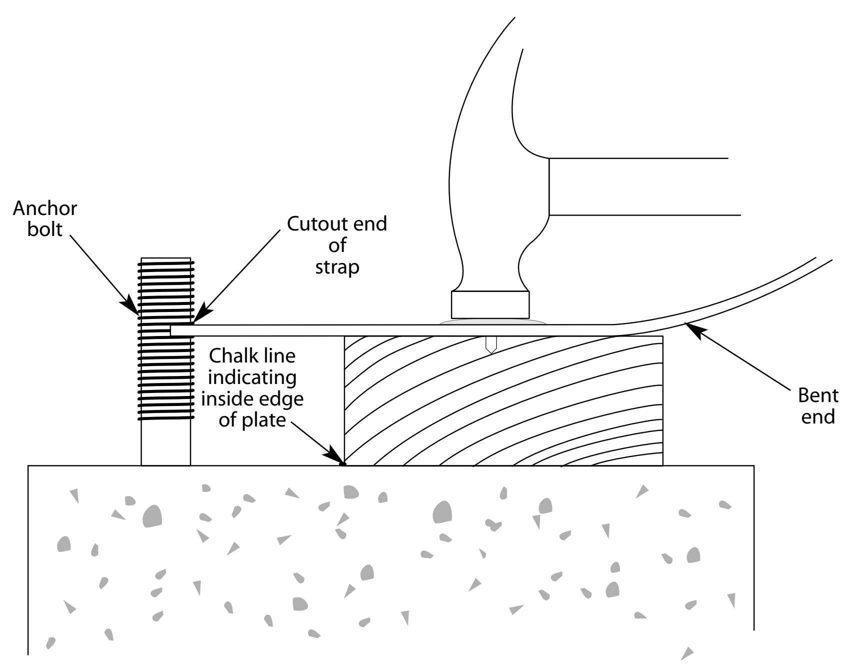


Figure 20
Mark the location of the anchor bolt using center-locator device

In some areas, you may need to place a sheet metal termite shield between the plate and the sill sealer. The effectiveness of a termite shield is disputed by some companies specializing in termite eradication, but it may still be required. If you use a shield, it must be continuous and you must overlap it at the joints. A more effective method of termite protection is ground poisoning, involving the preparation of the surrounding soils.

Placing the Sill Plate in the Concrete During Formwork

To make sure that the bolt patterns are correct, as well as to make the foundation pour easier, you may prefer to have the foundation crews place the sill plates inside their forms as part of their bracing (Figure 21), and then "pour" them into place (Figure 22). Using this method, the sill plate replaces the top outside brace of the form system, which is placed on the inside instead. Drill holes in the plate for the anchor bolts at the proper intervals, and hang the bolts in place. Consolidate the concrete with a vibrator after placing to ensure that it comes up under the plate and partially up the side as well.

Using this method, the foundation crew doesn't need to pay much attention to ensuring that the top of the foundation is level. A $1^1/_4$-inch variance in the top of the foundation can be tolerated without it being above the plate and interfering with the floor joists. Once the forms are stripped, give a final torquing to the anchor bolts in the sill plates, and you'll have a very level base to start the framing from.

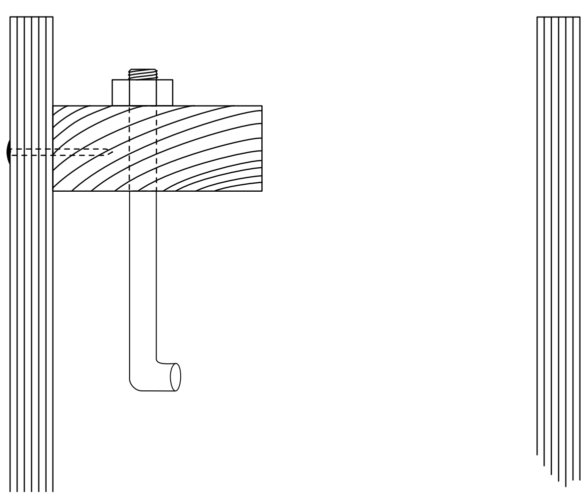


Figure 21
Fasten sill plate to form

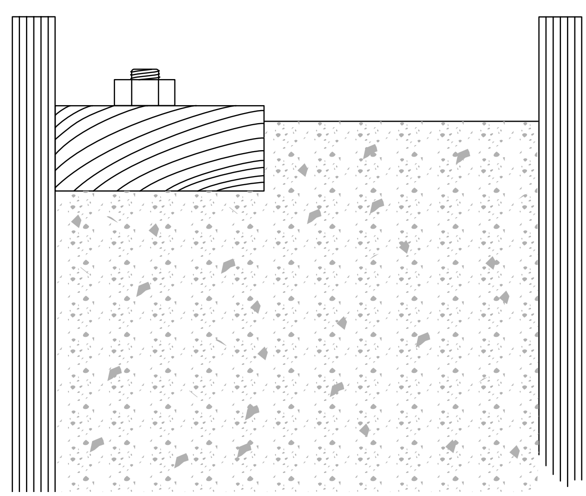


Figure 22
Pour concrete around sill plate

There are several advantages of placing the plates this way:

- Accurate placing of the anchor bolts
- Easier erection of the forms for the foundation crew
- Easier strike off and finish for the foundation crew
- A level plate that requires almost no shimming for the framers
- A plate already in place and ready for the framing crew when they start

The disadvantage of this method is that the concrete is difficult to place in the forms if you use a plate wider than a 2 × 4 in 8-inch-wide forms.

Floor Joists

You can begin installing the floor joists once the sill plates and any necessary girders are in place. You must select, size and install these components to provide a stable, squeak-free floor system, capable of supporting the design loads. Figure 23 shows the major floor framing components.

The floor system includes:

- The sill plate, which attaches the structure to the foundation
- The rim or header joists, floor joists and their hangers and fasteners
- The plywood subfloor or single floor systems

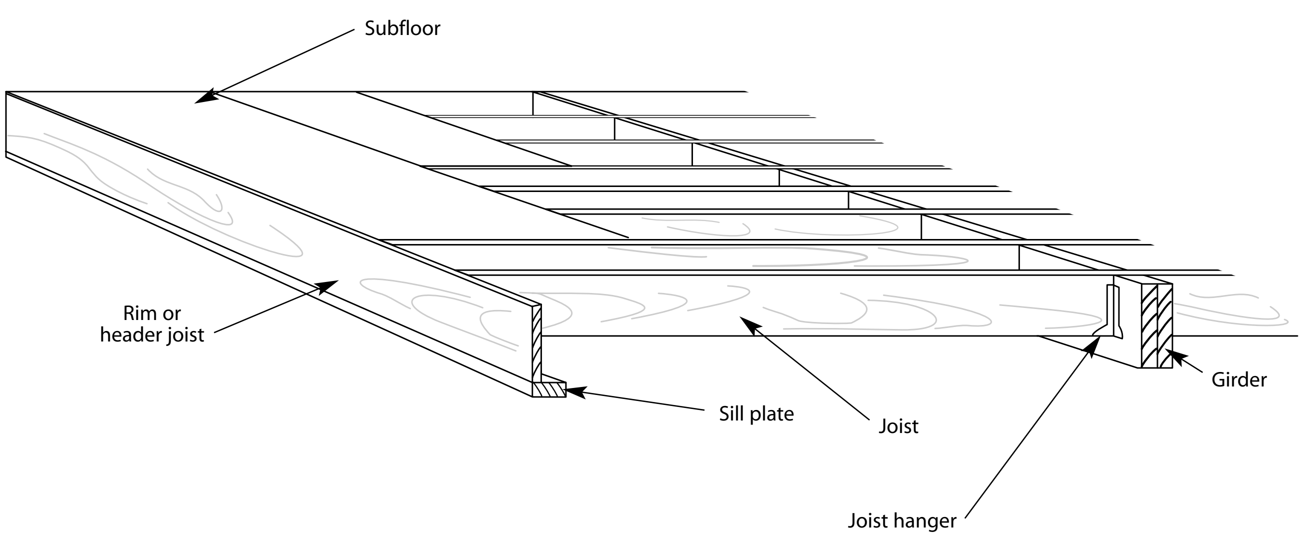


Figure 23
Floor framing components

Material for Floor Joists

Dimensional lumber and I-joists are the most frequently used materials for basic residential floor joists. In dimensional lumber, 2 × 8s through 2 × 12s are the common choice. I-joists are often preferred over lumber because they offer greater spans and stiffer floors than dimensional lumber with equal depths. I-joists are also considered more resistant to twisting and shrinkage.

Other joist materials include bar joists and truss joists, both similar in their truss design. Floor trusses are laid out with parallel top and bottom chords. They can be designed for use with either the top or bottom as the bearing chord, which provides great flexibility.

Selecting the Proper Joist Size

In most cases, the engineer or architect will specify the type and size of the joists, along with the spacing, necessary doubling, and any special notations, in the plans. There may be times, however, when the contractor or framer has to size the joists for a small project, or even for a large residential project in an area with a lenient or nonexistent building department. Many contractors choose to oversize the joist to be safe or "just use what they always use." There's certainly an incurred responsibility, not to mention potential liability, in choosing to make this type of engineering decision. Even if you're not worried about lawsuits, your reputation can be ruined by a poorly-designed floor system that springs, sags, or squeaks.

To size the joists, you must know the distance of the span and the species of wood available for joist material. You also need a resource, accepted by the local building department, that has structural information about the species and tables with allowable spans. The most commonly used reference has been the *Uniform Building Code* (UBC) published by the International Conference of Building Officials (ICBO). Two other building codes, used mostly in areas east of the Mississippi River, are put out by the Building Officials Conference of America (BOCA) and the Southern Building Code Congress. To simplify things, all three got together to publish unified codes in 2000, called the *International Residential Code* (IRC) and the *International Building Code* (IBC). That makes it more important than ever to make sure what code your area is using, get a copy, and follow it faithfully.

Example 5 — Use the following steps to determine the proper joist size for a basement spanning 28 feet with one intermediate girder as shown in Figure 24.

1. First determine the actual span. According to the UBC, the joist must bear on a minimum of $1^1/_2$ inches of wood or metal. This lets you use a 2 × 4 sill plate. Using a 2-by rim joist, the joist will bear a full 2 inches.

2. To figure the span you need to know the distance from face to face of supports, plus one half the required length of bearing at each end. With a $3^1/_2$-inch intermediate girder, figure the span as follows:

Basement, outside to outside	28'0"
Distance on one side to center of girder	14'0"
2-by rim joist minus $1^1/_2$ inches	$13'10^1/_2"$
Required bearing at each end	$1^1/_2"$
$1^1/_2" + 1^1/_2" = 3" \div 2 = 1^1/_2"$	
$13'10^1/_2" - 1^1/_2" = 13'9"$	
Total span	13'9"

We'll use hem-fir as the species most available for dimensional lumber for joists. To find what size and spacing you'll need for a 13-foot 9-inch span using hem-fir #2, look at the 2000 International Residential Code Table No. R502.3.1(1) (or whatever code is being used in your area). Nothing under 2 × 6 will work. Looking at 2 × 8, you can see that at 12 inches on center, your 2 × 8 joist will span 14 feet 6 inches. Or you could use a 2 × 10 spaced 16 inches on center, which will span 16 feet 10 inches. Since either choice would work, you can make the decision based on availability and cost.

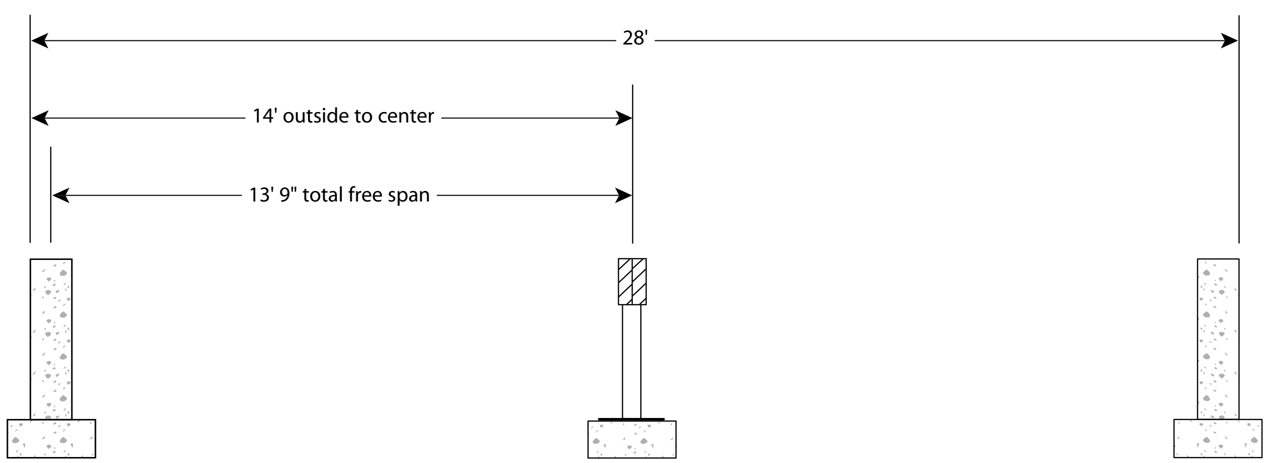


Figure 24
Determining joist size

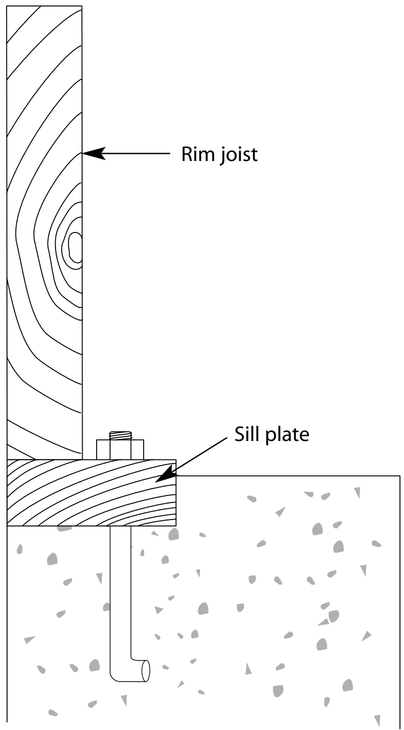


Figure 25
Rim joist

Rim Joists

Rim joists or header joists (see Figure 25) are the perimeter joists. They're usually placed before the installation of the floor joists. In some cases, primarily with I-joists, the floor joists are installed prior to the rim joist. Attach the rim joist to the sill plate with 10d nails at 16 inches on center.

Joist Spacing

As a rule, standard floor joist layout is 16 inches on center. However, based upon the proposed loads and desired stiffness, you can also lay out joists at 12 inches, 19.2 inches, and 24 inches on center. With tongue-and-groove dimensional decking, you can use even greater spans.

Figure 26 shows the difference in joist spacing for layouts 12, 16, 19.2, and 24 inches on center. Note how the different spacing affects the number of joists used. For a short run, this difference might not be significant. But what would be the difference between 16 inches on center and 19.2 inches on center in a 48-foot run? On a span with a girder down the center, two runs would be needed, doubling the number of joists and making the cost difference in labor and joist materials significant. At a glance, you can see the difference between 12 and 24 inches on center to be even more significant. In Figure 27 the differences are laid out for you. On a 24-foot run, you would need 24 joists for a 12-inch layout, 18 joists for a 16-inch layout, 15 joists for a 19.2-inch layout, and 12 joists for a 24-inch layout.

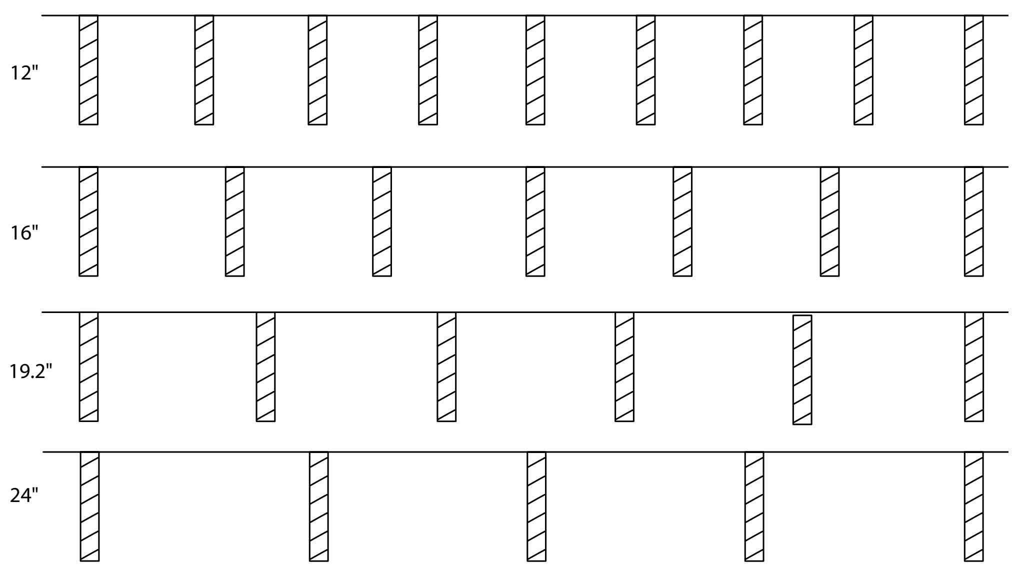


Figure 26
Joist spacing for different on center layouts

Joist Layout for 12" On Center Spacing			Joist Layout for 16" On Center Spacing		
	Space	Measurement		Space	Measurement
	1	12"		1	16"
	2	24"		2	32"
	3	36"		3	48"
	4	48"		4	64"
	5	60"		5	80"
	6	72"	8'	6	96"
	7	84"		7	112"
8'	8	96"		8	128"
	9	108"		9	144"
	10	120"		10	160"
	11	132"		11	176"
	12	144"	16'	12	192"
	13	156"		13	208"
	14	168"		14	224"
	15	180"		15	240"
16'	16	192"		16	256"
	17	204"		17	272"
	18	216"	24'	18	288"
	19	228"			
	20	240"			
	21	252"			
	22	264"			
	23	276"			
24'	24	288"			

Figure 27
Joist spacing

Floor Joist Layout

Plan your floor joist layout with saving materials, and therefore cost, in mind. Usually this means using a standard spacing layout. Before starting the layout, however, review the plans and foundation to see if there are details that would preclude starting the layout so that a complete sheet of plywood lays out on center without any cutting. There are several items that could require you to change the layout, including double joists at bearing points or headered areas such as stairwells. It'll save joists if you lay these out on module. You should also check for mechanical conflicts, such as toilet locations, to see that they don't fall on the joist layout. Often a slight layout shift can avoid the problem.

Joist Layout For 19.2" On Center Spacing			Joist Layout for 24" On Center Spacing		
	Space	Measurement		Space	Measurement
	1	$19^{3}/_{16}$"		1	24"
	2	$38^{3}/_{8}$"		2	48"
	3	$57^{5}/_{8}$"		3	72"
	4	$76^{13}/_{16}$"	8'	4	96"
	5	96"		5	120"
	6	$115^{3}/_{16}$"		6	144"
	7	$134^{3}/_{8}$"		7	168"
8'	8	$153^{5}/_{8}$"	16'	8	192"
	9	$172^{13}/_{16}$"		9	216"
16'	10	192"		10	240"
	11	$211^{3}/_{16}$"		11	264"
	12	$230^{3}/_{8}$"	24'	12	288"
	13	$249^{5}/_{8}$"			
	14	$268^{13}/_{16}$"			
24'	15	288"			

Figure 27 (continued)
Joist spacing

Spacing a Standard Layout

If you don't find any framing conflicts to justify a shift in the layout, use a standard layout with your chosen spacing (see Figure 28). When you start the layout, the first space should be $^{3}/_{4}$ inch shorter than the standard spacing. This allows the first sheet of floor panel to lie flush with the outside of the rim joist and still splice in the middle of the joist at the opposite end of the sheet, as shown in Figure 29. Your subsequent sheets will then also splice in the center of the joist.

In laying out the joists, start at the first short spacing, and stretch a tape to mark the remaining joist positions. *Remember, these measurements always represent inside to inside measurements*. It's important to have the joist in a squared vertical position to prevent twisting. If necessary, use a square to square up your markings. Some framers use a framing square to measure and mark from space to space, but avoid this on longer runs because it's entirely too easy to run off a fraction of an inch at a time.

Complete the layout in the same manner on the opposite side, as well as on any intermediate girders. If you run the joists through or butt them together at the girder, the spacing should be identical. However, if you lap the joists at the splice as shown in Figure 28, the layout on the opposite side will change by $1^{1}/_{2}$ inches.

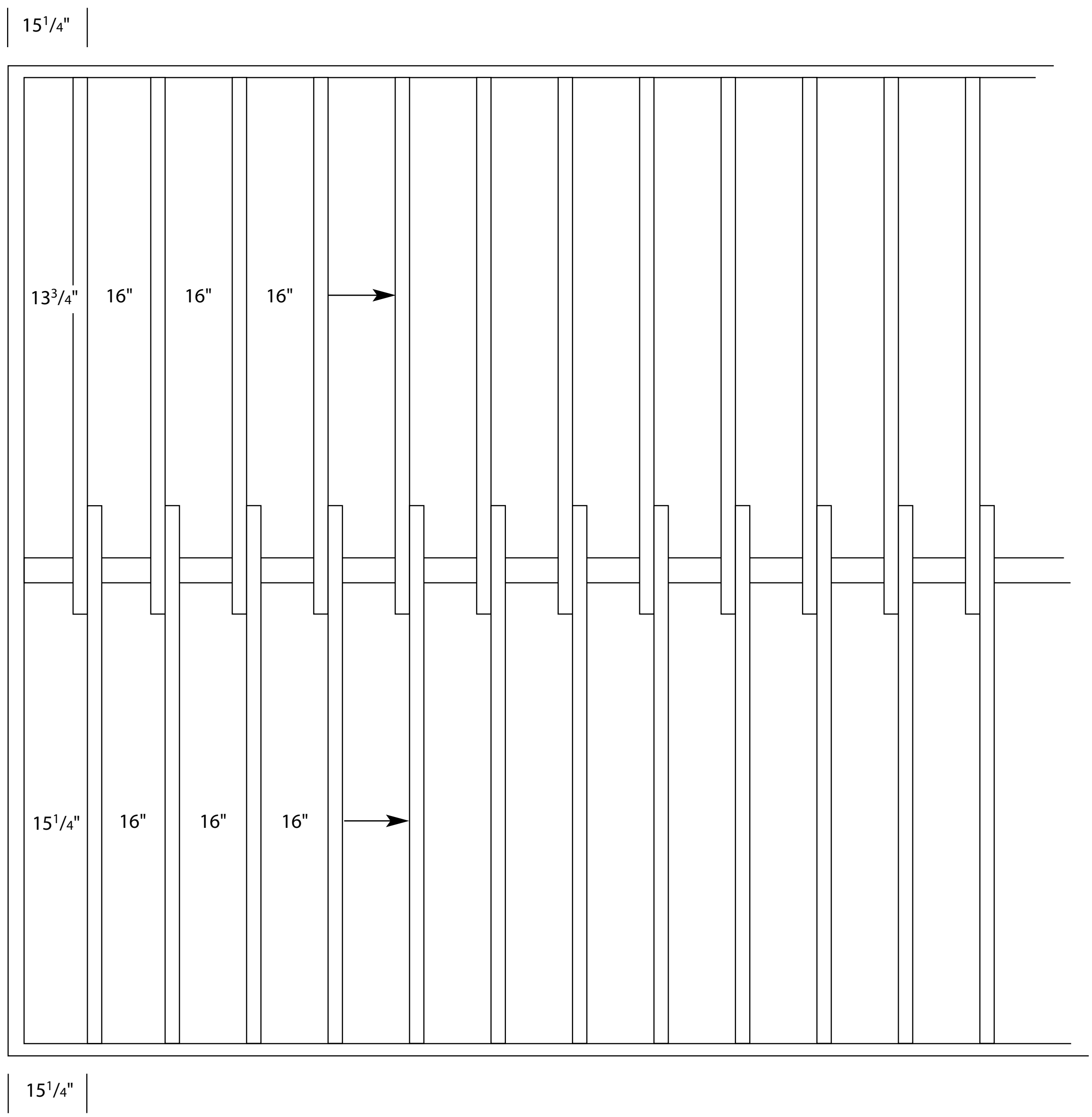


Figure 28

Standard joist layout with lapped joists

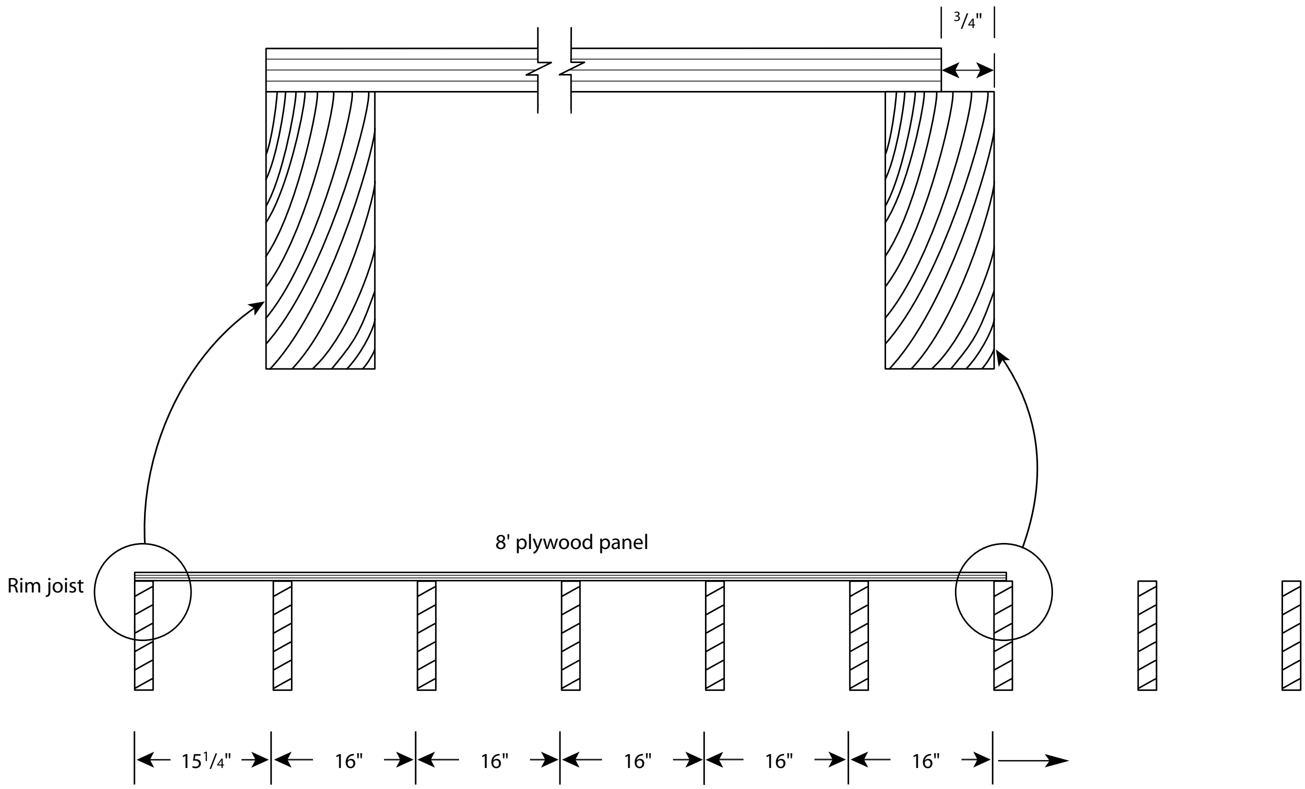


Figure 29
Splice floor panels in middle of joist

Doubling Joists

Double the joist when you need more bearing capacity than a single joist can provide. You may need additional bearing capacity for bearing wall partitions or to help carry the load of a companion joist that is headered off. Lay out doubled joists at the same time as single joists. Don't allow a doubled joist, or out of sequence joist, to run off the spacing of the standard joists. Figure 30 illustrates a joist layout which includes a doubled, out of sequence, joist.

Joist Openings

You may need to install headers for crawl space access, a stairwell, a chimney chase or other floor openings. You must double the joists that support the header and the intermediate joist that's cut for the opening. Use joist hangers to attach the header to the intermediate and doubled joists. Figure 31 shows a joist opening.

Make crawl space access openings a minimum of 18 inches by 24 inches. Coordinate openings for masonry fireplaces or other specialty items with the mason or subcontractor handling that area of construction. Frame stairways for the width required, plus the width of the drywall.

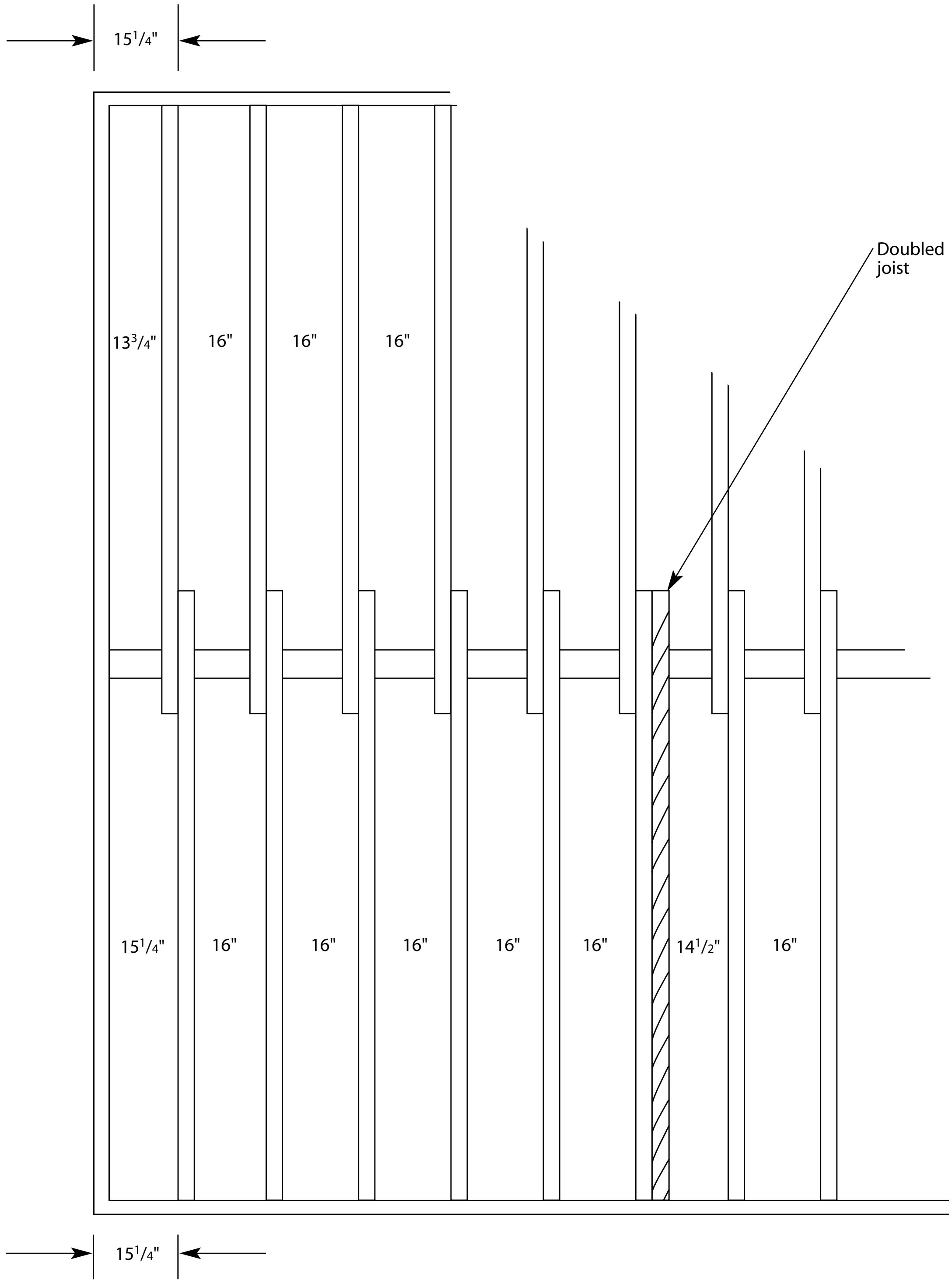


Figure 30
Layout with doubled joist

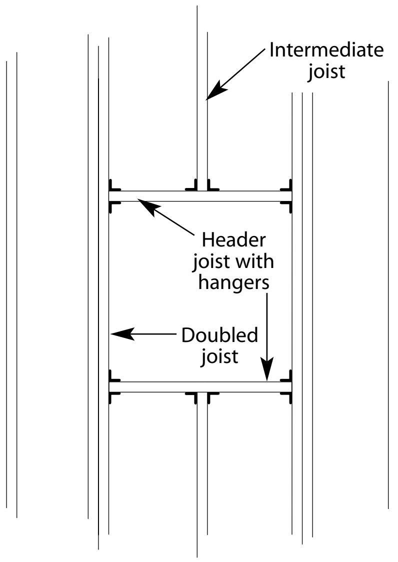


Figure 31
Joist opening

Double the header and trimmer joists for any openings where the span of the header joist exceeds 4 feet. Use joist hangers when the header exceeds 6 feet, as well as on tail joists over 12 feet. Refer to Figure 32.

Laying Out the Joists

We've already discussed most of what's involved in laying out joists. To do your layout, you'll need a steel tape (fiberglass tapes stretch), a framing square, and, of course, a pencil. You'll also need a set of plans showing the spacing and measurements for any floor openings, such as stairways. For the following steps, let's assume that the spacing is 16 inches on center, the most common spacing used.

1. Check to see that there are no mechanical problems that could be avoided by shifting the joist layout.
2. Measuring from the outside of the rim joist, mark the layout for the first joist $^3/_4$ inch back from the center. For 16-inch on center spacing, this is $15^1/_4$ inches.
3. Hook the tape on this first joist, and mark the remaining joist locations using the 16-inch oc markings, which are on most tapes. If your tape doesn't include these markings, refer to the layout chart included in this section.
4. Remembering that these marks always represent outside to outside measurements, square up the layout marks on the rim joist, using a framing or speed square.
5. Referring to the plans, mark any double joist or joist out of the standard layout needed for necessary floor openings.
6. Mark joist locations with an × on the joist locations that will receive a standard length single or doubled joist. Be sure to mark the × on the correct side of the squared location mark. Figure 33 shows the correct location of the ×.
7. Use an **O** to mark joist locations that are on standard spacing but due to header placement will be omitted until after the header is placed. Again, make sure the **O** is on the correct side of the line.
8. If the foundation is narrow and spanned by a single joist or if the joists are butted over a center girder, mark the opposite side using the same measurements and markings as in steps 6 and 7.
9. If the foundation has a central girder with the joists splicing on it, use the same measurements on the opposite side of the girder as used on the first, but mark the joist position on the opposite side of the measurement mark. Mark the girder with an × on both sides of the measurement mark.

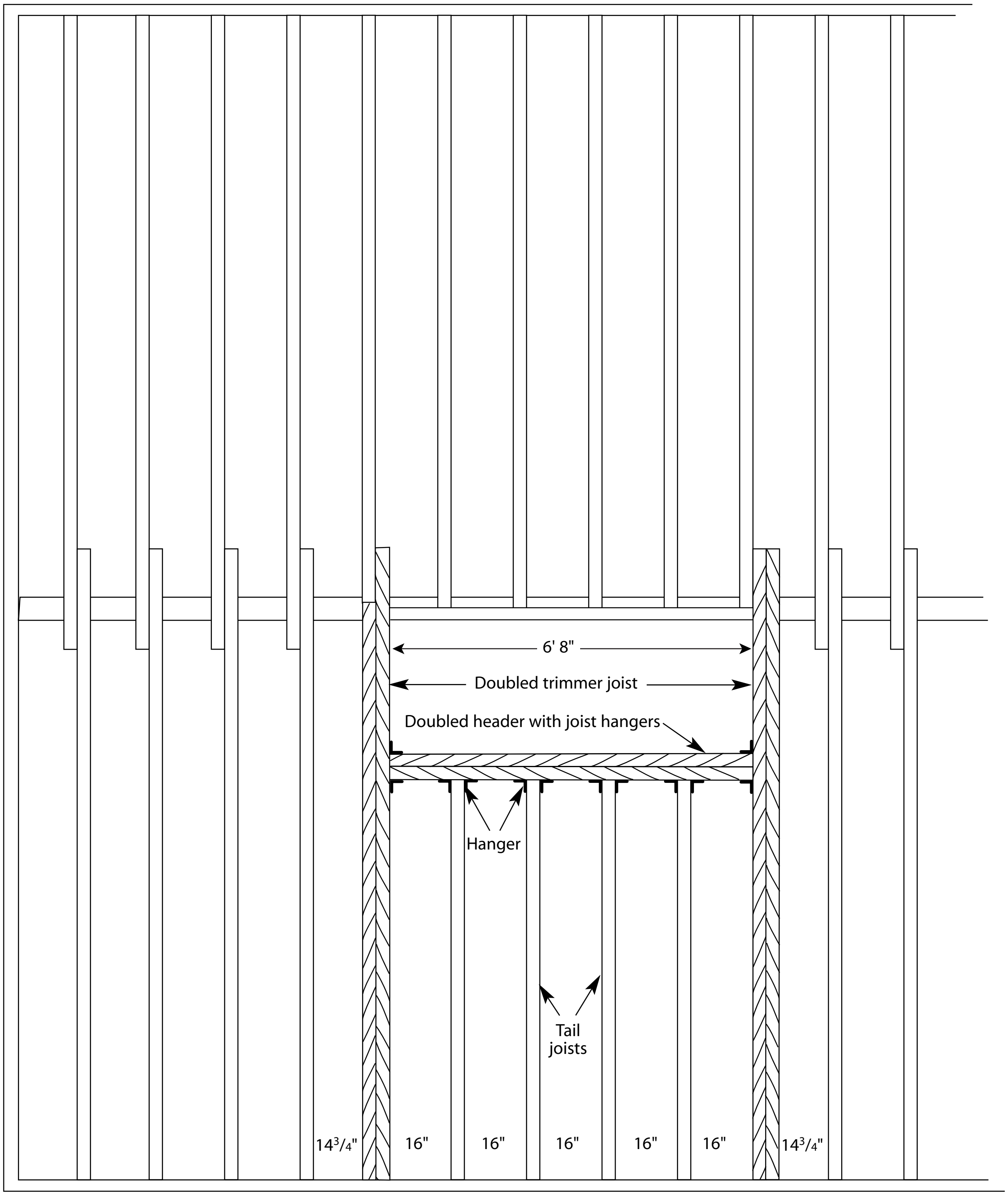


Figure 32
Doubled header with joist hangers

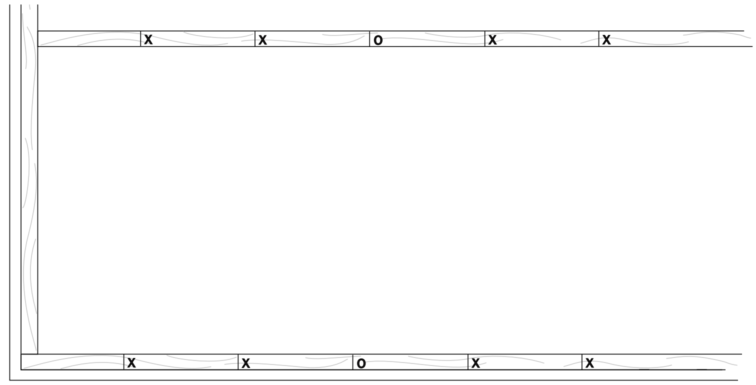


Figure 33
Joist layout marked for installation

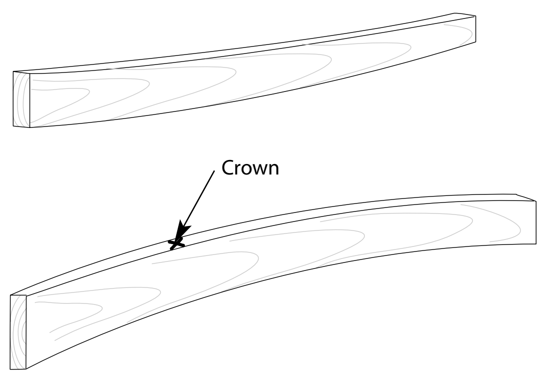


Figure 34
Crowning

Floor Joist Installation

Crowning involves identifying any bow in the lumber that's within an acceptable range. Install joists with the "crown up," so that the height of the bow is on the top side (see Figure 34). In this position, the joist is likely to straighten as the floor is loaded. Cull or discard any lumber that's unacceptably bowed. These can be cut up into short lengths and used for blocking. Return any excess culled material to your lumber supplier.

With your layout marked, cut the joists to length, crown them and lay them into position flat with the crowns all in the same direction. It eliminates confusion during installation if the same edge can be lifted to the top for every joist. If you were to lay two joists side by side with the position of the crown reversed, it would create a noticeable dip in the floor.

Lay any joist that's straight, but has large knots, with the knots to the top. Don't use lumber for joists if the knotholes would be structurally damaging. Here are the kinds of holes or notches that that would make a piece of lumber unacceptable for use as a joist:

- Any hole whose diameter exceeds $^1/_3$ of the depth of the joist
- Holes within 2 inches of the top or bottom of the joist
- Notches on the end of a joist that exceed $^1/_4$ the joist depth
- Notches in the top or bottom of a joist that exceed $^1/_6$ the joist depth
- Notches located in the middle $^1/_3$ of the joist span

Joist Installation Steps

After you mark the joist layout, cull the joists, and mark the crowns, you can begin installation:

1. Lay the joists flat near their marked positions (see Figure 33) with the crowns all facing the same direction. Again, this makes it easier during actual installation to routinely place the crown side up.
2. Place the joist in the marked position with the crown up.
3. Nail the joist in place, starting with the end against the rim joist. Be certain the joist is tight against the rim joist before nailing the opposite end to the girder. The rim joist should be nailed to the joist using three 16d nails. The joist should be nailed to the sill plate and the girder using three 8d nails, toenailed at each location.
4. Repeat steps 1, 2 and 3 on the opposite side.

Fastening the Joist to the Girder

The object of fastening the joists over the girder is to have the joists fastened to each other where they lap, as well as to the girder, in a squared, vertical position. If they're on the layout on the girder, but are out of square, the layout spacing for the plywood will be off (Figure 35). Furthermore, if the joists are nailed to each other in an out-of-square position, when they're brought vertical, the tops won't be level.

Fastening the Joists with Solid Blocking — If you need blocking over the joist, you can square the joist, install the blocking, nail the lapped joists together and fasten them to the girder all during the same process. For lapped joists, follow this sequence:

1. Cut the appropriate number of blocks out of the same dimension material as the joist. Cut the blocks 3 inches shorter than the joist spacing being used for standard spacing, making sure that the blocks are cut square.

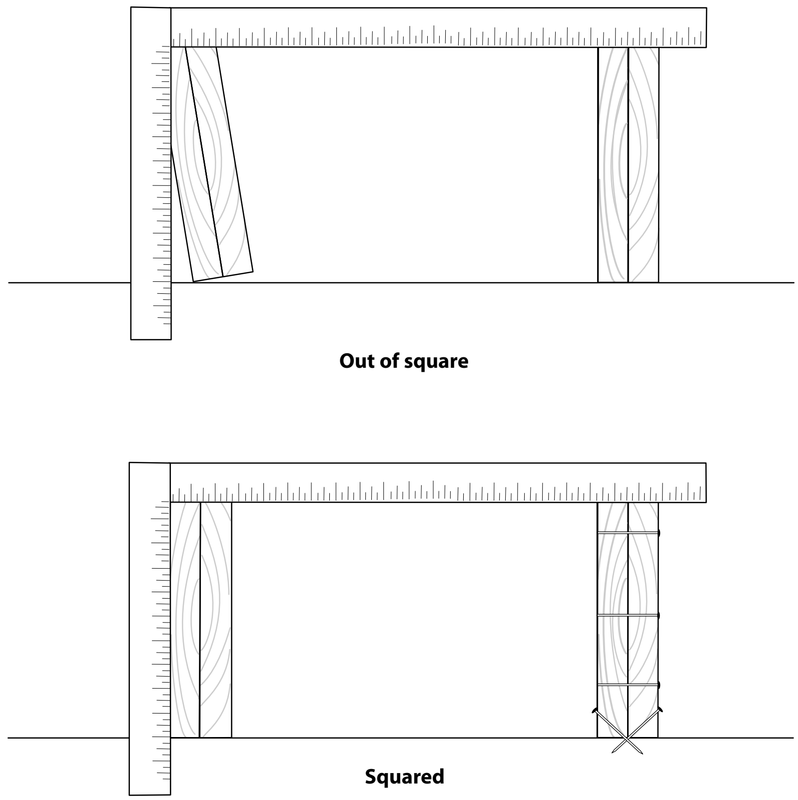


Figure 35
Square and level joists when fastening to each other and the girder

2. Place the first block between the first joist and the rim joist. Fasten the block to the rim joist by nailing through the rim joist into the block with two 16d nails.
3. Nail through the first joist into the blocking again using two 16d nails.
4. Toenail the first joist to the girder with three 8d nails, drawing the joist snugly against the block.
5. Place the lapped joist next to the first joist that you have nailed in place. Toenail it to the girder with three 8d nails. The toenailing will draw this joist tightly against the joist it's lapping and the block the first joist is nailed to.
6. Fasten the lapped joists together by nailing them with three 16d nails.
7. Repeat steps 2 through 6 for the remaining openings.

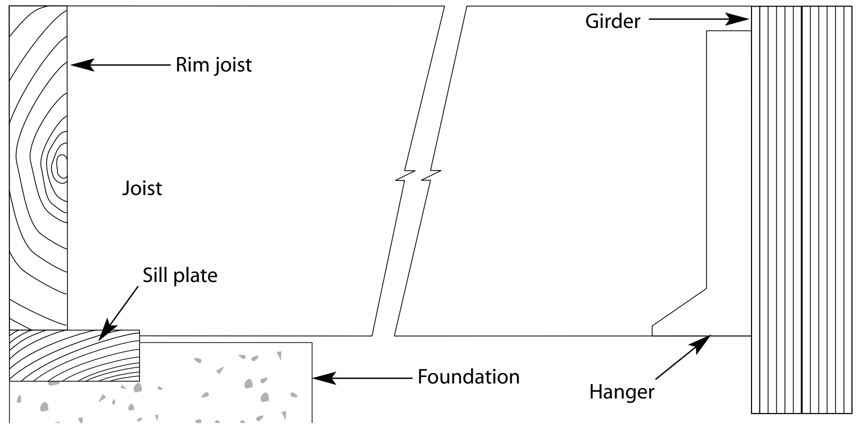


Figure 36
Box sill

***Fastening the Joist Without Solid Blocking* —** If you're not using solid blocking, use this sequence to fasten and square the joists:

1. Mark temporary bracing material with the same layout as that on the girder.
2. Toenail the joists into position without nailing them to each other. Use three 8d nails for each joist.
3. Nail the lapped joists together with three 16d nails at each splice. Make certain that when you're nailing the joists together, the joists are vertical so that the tops will be flush when brought vertical.
4. Using the temporary bracing material from Step 1, temporarily nail the joists on the marked layout. This will keep the joists vertical until the plywood flooring is in place.

Optional Joist Construction Styles

The box sill style of joist construction, shown in Figure 36, is probably the most common method in current construction and platform framing. You use a rim joist the same dimension as the joist, with no cutting or notching, making it the least labor-intensive method. The box sill method is the style we'll be discussing throughout this section on joists.

In addition to the box sill, you may encounter several alternative methods of joist installation. These you'll come across less frequently, usually on remodeling projects involving older homes, in special use situations, or perhaps because of some regional preferences.

Figure 37 illustrates a stepped sill. You use two sills with this method. The outside sill is at grade and supports the wall framing. The inside sill is dropped down the depth of the floor joist. This lower sill carries the floor joists at a lower level and is effective in situations that require a minimal rise between ground and floor level. Often the code only requires a 6-inch separation between the ground and wood framing members. With a box sill, the floor is 10 inches above the concrete if you use 2 × 10 joists, making the floor level 16 inches above the ground. Using a stepped sill, the floor level will be 6 inches above ground. While a slab on grade is often used in this situation, you can use a framed floor over a basement or when crawl space access is required.

You may sometimes find a double sill, like the one shown in Figure 38. Note the notch. If you're working with a double sill, cut the notch so that the joist rests on the bottom sill and not on the second smaller sill. You can do this by slightly overcutting the notch and creating a small space between the notch and the top sill. This space will allow for any possible shrinkage. If you allow the joist to rest on the top sill instead of the bottom, it will split. The *International Residential Code* specifies that any notching on the ends of joists shall not exceed 1/4 of the joist depth. This is especially important to remember if you use the variation of this style shown in Figure 39, in which the bottom plate of the wall framing is notched into the joist and rim joist as well.

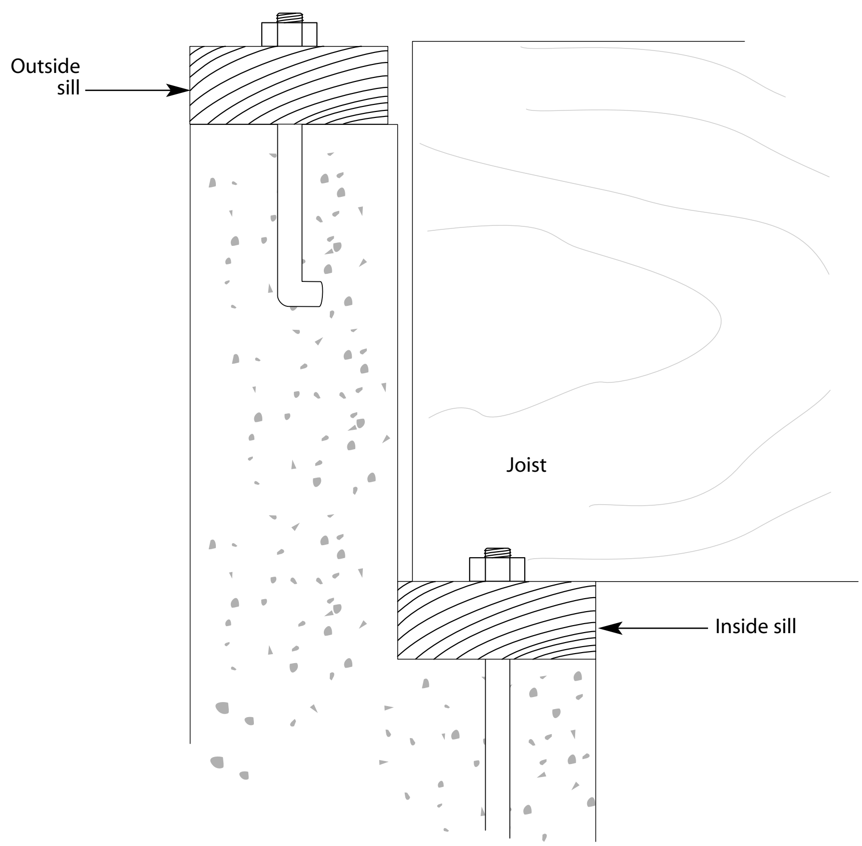


Figure 37
Stepped sill

Joist Hangers

Using framing anchors or, in the case of joists, joist hangers, provides you with additional possibilities for positioning joists. If you're using I-joists, hangers offer an alternative to the stepped sill shown in Figure 37. Figure 40 illustrates how you can hang the joist from a full-width sill plate, giving the same top of floor elevation as seen in Figure 37. Using hangers in this situation, you eliminate the need for the foundation blockout and a difficult double row of foundation bolts.

You can also use joist hangers at the girder. This location provides more headroom in a basement and greater ground separation in a crawl space, porch, or deck. In addition to the girder location, you can use the hangers against the structure, such as a porch or deck. When you use hangers in this location, place a band joist against the structure and lag bolt it to the studs or rim joist of the structure. Then place the hangers on the band.

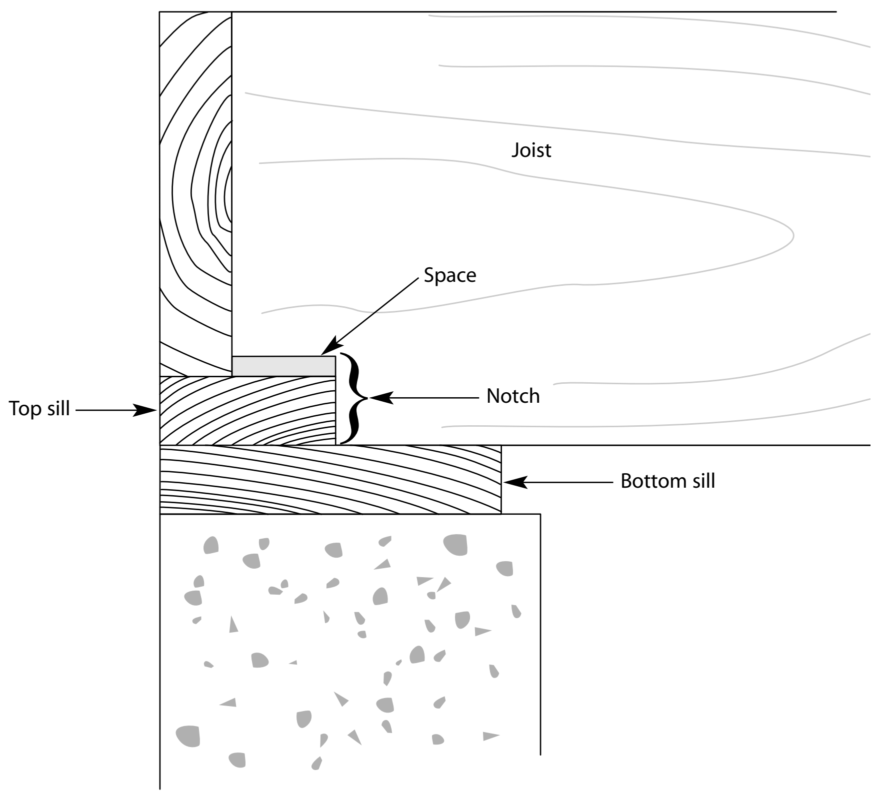


Figure 38
Double sill

When you use framing anchors, it's important to also use the nail designed for that particular hardware. Nails are available in several diameters and lengths as well as in galvanized finishes. The manufacturer will recommend the proper diameter and length to correspond with the size of hanger. Always use galvanized finishes for exterior applications.

Installation of Joists with Hangers

There are two methods you can use when installing floor joists with hangers. With the first, you establish the layout and nail the hangers into position. Then place the joists into the hangers and nail them in place. You may prefer to use the second method when the joist width seems irregular. With this method, you toenail the joists into place with the tops flush with the top of the girder or ribbon joist that you're attaching them to. After you have them in position, place the hangers tight against them and nail the hangers to both the joists and their supporting member.

Ledgers

Ledgers are most often used on the second floor of balloon style framing. When you use a ledger, it must be a minimum of a 1 × 4 inch ribbon strip cut into the stud. Rest the joists on the ledger and face nail them into the stud with three 16d nails as shown in Figure 41.

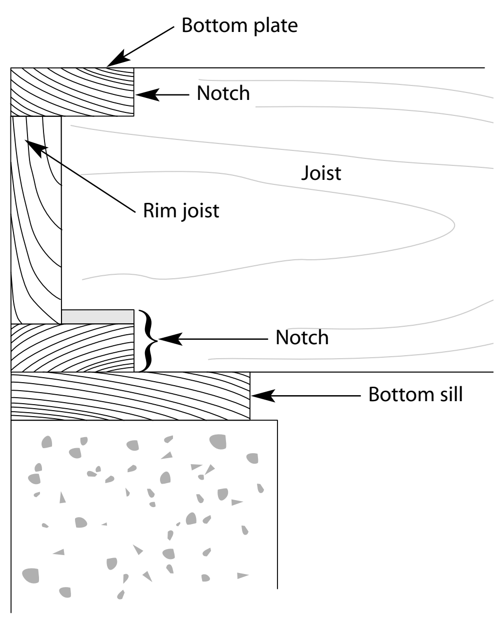


Figure 39
Double sill variation

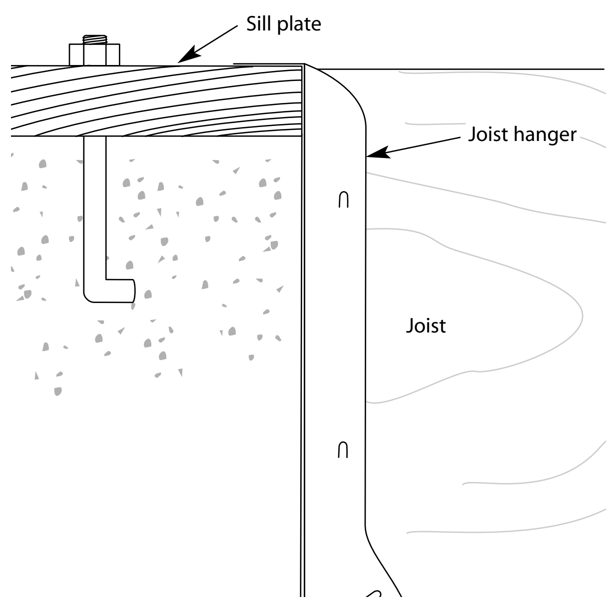


Figure 40
Joist hanging from sill plate

You can also use ledgers against the girder. In this case, the ledger must be a minimum of 2 × 4 inches. Fasten the ledger to the girder using three 16d nails near each joist location. Depending on the depth of the girder, you may need to notch the joists over the top of the girder. Make sure that the joists rest on the ledger and not on the notch to provide full strength and prevent future splitting and failure.

Cantilevering Joists

You may need to project the floor joists beyond the perimeter of the foundation to accommodate design considerations such as a wall projection, full-length bay window or a zero clearance fireplace. As a general rule, for every foot that the joist projects over the foundation, there should be at least 2 feet of joist inside the foundation. You shouldn't make projections of more than 2 feet without proper engineering. Figure 42 shows a cantilevered projection running with the floor joists and Figure 43 illustrates a right-angled cantilevered projection.

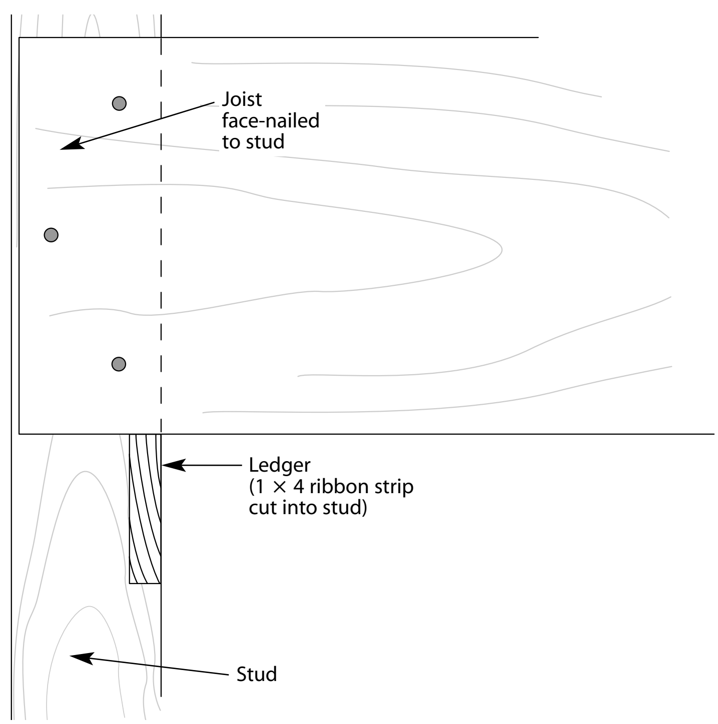


Figure 41
Installing joists with ledgers

Bridging

Bridging is cross bracing made of 1 × 3s or 1 × 4s and installed between the joists. The purpose of bridging is to prevent the floor joists from twisting and warping as well as to stiffen them. Check your local codes for bridging requirements. Some areas don't require bridging at all. There's some debate over its effectiveness when plywood subflooring is also used, since the plywood sheets also prevent joist movement. Install bridging spaced according to local code requirements. Where the spacing isn't specified, place bridging so that unbridged spans don't exceed 10 feet.

Bridging is available from some suppliers in precut lengths. Since the angle and the length of the bridging are different for every joist size, even at the same spacing, it's necessary to purchase bridging for a specific joist and layout, such as 2 × 10s at 16 inch on center spacing. If bridging isn't available precut, you can easily cut it from 1 × 4 boards. Using a radial arm saw or a trim saw, set up a stop using the measurements from the chart in Figure 44 for the appropriate joist size and spacing. Set the angle of the saw using the angle given for the size that you've chosen.

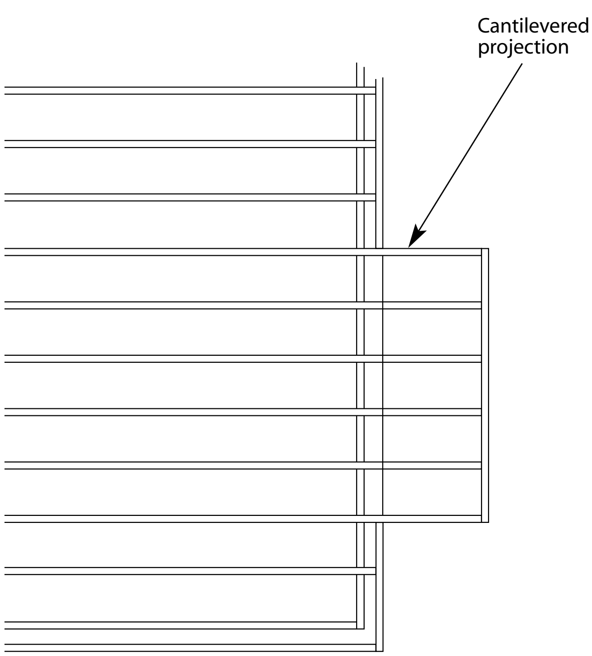


Figure 42
Cantilevered projection parallel with floor joists

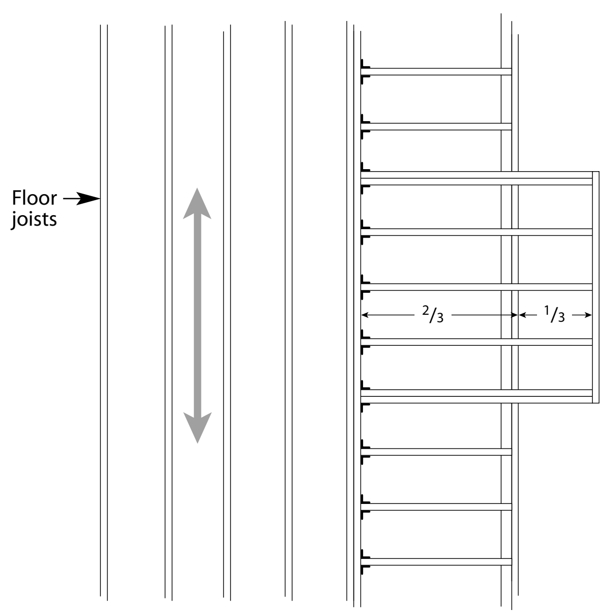


Figure 43
Cantilevered projection at right angle to floor joists

Bridging Lengths and Angles

	2 x 8	2 x 10	2 x 12
16" oc	15 3/4"	16 5/8"	17 3/4"
Angle	22 1/2	28	33
19.2" oc	18 3/4"	19 1/2"	20 3/8"
Angle	18	24	29

Measurements are from point to heel of cut.

Figure 44
Bridging lengths and angles

Installing Bridging

This bridging installation is based on a 24-foot span with an intermediate girder. The joists already have solid blocking over the girder.

1. Find the center of the span from the foundation wall to the girder. With the girder centered on a 24-foot span at 12 feet from either foundation wall, the center on both sides of the girder is 6 feet.
2. Snap a chalk line across the joist the entire length of the run.
3. Start two 8d nails into each end of the bridging.
4. Place one piece of bridging on one side of the chalk line, nailing the top only. Follow this by placing another on the opposite side at the opposite angle so that the bridging forms an ×, again nailing the top only (see Figure 45).
5. Repeat this procedure for the remaining openings, with the bridging on either side of the line, always making an ×. Always keep the top against the top on the opposite side of the joist and the bottom against the bottom of the following piece.
6. After nailing all the tops (only the tops), install the plywood flooring. Nail the bottom of the bridging only after you install the subflooring (see Figure 46). This allows the joists to move and be further aligned as you apply the plywood. If you nail the bottoms before you place the plywood, a joist that may be high won't be pulled down into alignment by the plywood but will remain high and cause a hump in the floor.

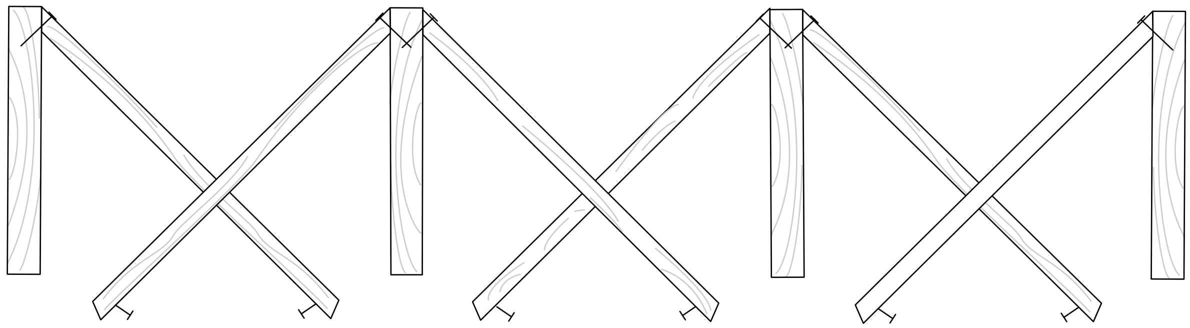


Figure 45
Nail tops of bridging into place

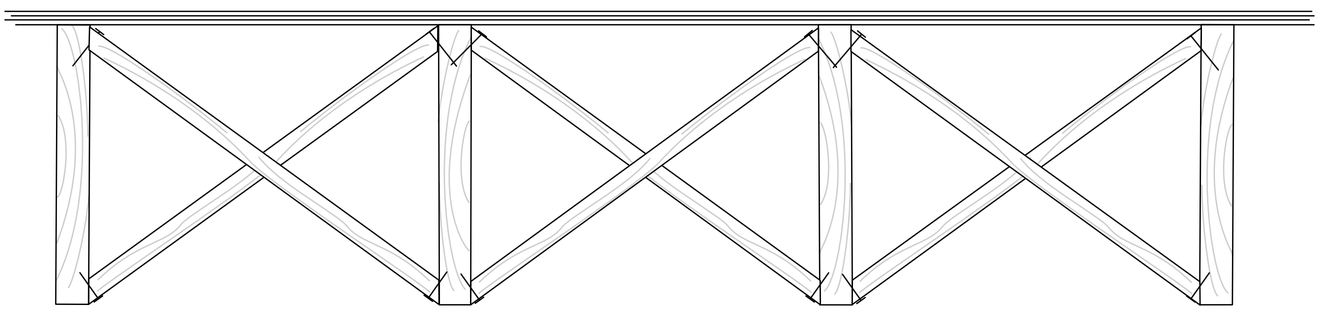


Figure 46
Nail bottom of bridging after subflooring is installed

Drilling and Notching Joists

In most cases, you won't be drilling and notching joists during framing but rather during the installation of electrical and mechanical systems. Framing inspections are made after the mechanical systems are in place to insure that the structural members weren't damaged by drilling and notching.

It's important that the contractors installing these systems be aware of the framing codes adopted in the area where the work is being performed. The requirements in the *International Residential Code* state that "notches on the ends of joists shall not exceed one fourth the joist depth. Holes bored in joists shall not be within two inches of the top or bottom of the joist, and the diameter of any such hole shall not exceed one third of the depth of the joist. Notches in the top or bottom of joists shall not exceed one sixth of the depth and shall not be located in the middle third of the span."

If you have any question about your mechanical contractor's understanding of these requirements, make a chart like the one in Figure 47. It visually illustrates the meaning of the code and makes the interpretation of the code requirements easier on the job site. If you're using plywood I-joists, the manufacturer will provide guidelines for cutting and drilling. Their charts are available from suppliers to display on the job site.

Subflooring

Use plywood or oriented strand board (OSB) over the floor joists for subflooring. At one time, it was common for a finish floor of tongue-and-groove oak, yellow pine, or other regional woods to be placed over the subflooring for the finish floor. However, as carpeting came to dominate the flooring market, the finish floor has been replaced in many areas with an underlayment over which carpet or vinyl can be installed, providing a double floor system throughout the house. The subfloor was usually $^1/_2$-inch plywood with a $^1/_2$-inch underlayment over it. In most areas today, it's more common to install a single $^3/_4$-inch tongue-and-groove plywood subfloor (see Figure 48) with a $^1/_4$-inch underlayment only under the areas where you'll be installing vinyl flooring. We'll be discussing underlayment shortly.

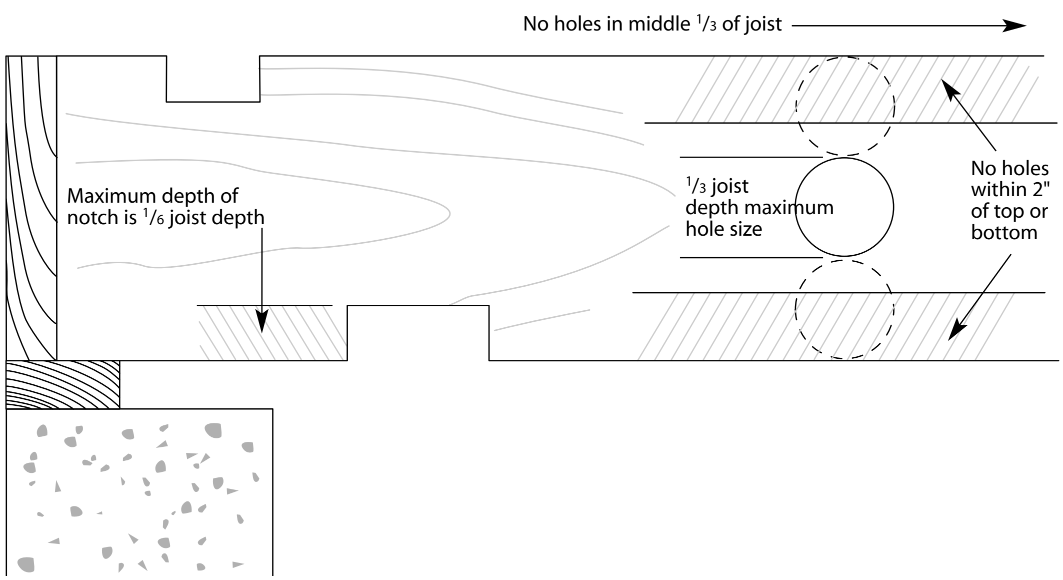


Figure 47
Drilling and notching joists

You may come across solid wood subflooring if you're remodeling older homes. Solid wood subflooring was installed diagonally to the floor joists and the finish floor was perpendicular to the joists. The total floor thickness would have started out being $1^{1}/_{2}$ inches but may be less now if the finish floor was sanded and refinished several times over the years. You won't usually find solid wood subflooring used today unless you're working on a residence being constructed for an occupant who is suffering from severe allergies associated with the glues used in plywood, OSB, and particleboard. Even if you're building for persons suffering from these allergies, plywood still remains the predominant choice of subflooring and sheathing. You can use products made with the offending glues if they're purchased well in advance of construction and stacked with spacers to allow the glues to air out. In all but the most severe cases, these precautions are adequate for solving allergy problems.

Installing Plywood Subfloor

Use glue and glue-coated nails, or in some cases ring-shanked or other nails resistant to pulling, to install plywood subflooring. This isn't just a sound construction procedure, it's also important in reducing the chance having squeaky floors and potentially costly callbacks. Of course you must also install the floor joists correctly to have a floor that's free of squeaks. Before you place the plywood, check the joists to see that the tops are level and in line. If you ignore crowning or a joist is mistakenly inverted with the crown down, you'll end up with a hump or sag in the floor. Take the time to correct any errors of this type before you install the plywood.

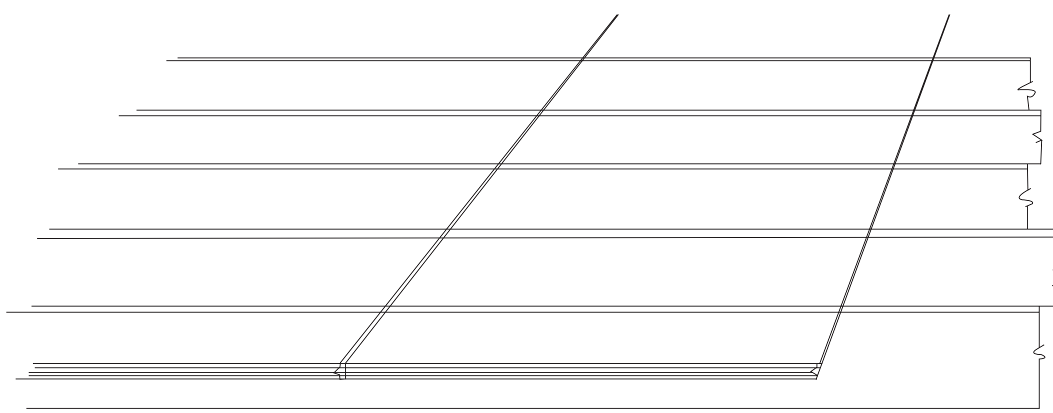


Figure 48
Tongue and groove plywood subflooring

If you fail to make these repairs, you may have a slight gap between the plywood and joist. This can easily occur, especially if you use air nailers. Air nailers have the power to shoot the nail in, but they lack the weight provided by hammer blows to pull the plywood down tight. If there's a gap, a squeak will follow. As the floor is walked on, the plywood depresses, causing movement between the flooring and the nail.

If you nail the plywood down tight but a joist is low, over time that too will result in a gap and a squeak. Vibration from movement in the house, along with the lifting pressure from the plywood trying to straighten itself out, will eventually loosen even a tightly-installed nail from a low joist.

Plywood Installation

If you don't use tongue-and-groove plywood subflooring, you're required to have solid blocking on all of the edge joints as shown in Figure 49. However, this blocking isn't necessary if you use 1/2-inch underlayment throughout for a double floor. If you use 1/4-inch underlayment only for areas receiving resilient flooring, you'll still need tongue-and-groove plywood or blocking.

After you've checked the joists and remedied any high or low spots, install the subfloor. The American Plywood Association recommends this procedure:

1. Snap a chalk line across joists 4 feet in from the wall for panel edge alignment and as a boundary for spreading glue.

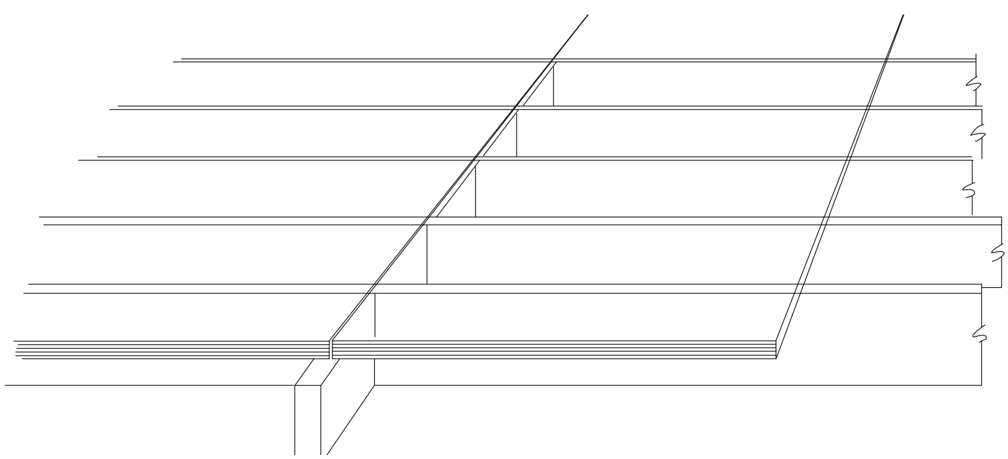


Figure 49
Plywood subfloor with solid blocking

2. Wipe any mud, dirt or water from joists before gluing. Then, spread only enough glue to lay one or two panels at a time, or follow specific recommendations provided by the glue manufacturer.
3. Lay the first panel with the tongue side to the wall and nail it in place. This protects the tongue of the next panel from damage when it's tapped into place with a block and sledgehammer.
4. Apply a continuous line of glue (about $^1/_4$-inch in diameter) to the sill and framing members. Apply glue in a serpentine pattern on wide areas.
5. Apply two lines of glue on joists where panel ends butt to assure proper gluing of each end.
6. After the first row of panels is in place, spread glue in the groove of one or two panels at a time before laying the next row. The glue line may be continuous or spaced, but avoid squeeze-out by applying a thinner line ($^1/_8$ inch) than on joists.
7. Tap the second row of panels into place, using a block to protect the groove edges.
8. Stagger the end joints in each succeeding row. It's recommended that you leave 1/8 inch between all the end joints and at all the edges, including T&G. (Use a spacer tool to assure accurate and consistent spacing.)
9. Complete all nailing of each panel before the glue sets. Check the manufacturer's recommendations for allowable time. (Warm weather accelerates glue setting.) Use 6d ring- or screw-shank nails for panels $^3/_4$-inch thick or less, and 8d ring- or screw-shank nails for thicker panels. Space the nails at 6 inches on center on panel edges and 12 inches on center on intermediate supports. Closer nail spacing may be required by some codes or for diaphragm construction. You can walk on the finished deck and it will carry construction loads without damage to the glue bond.

Underlayment

Install underlayment over the subfloor to provide a smooth, sound surface for vinyl flooring. Underlayment normally consists of $^1/_4$-inch sheet material. However, sometimes you may need to use $^3/_8$-inch material over an uneven base, such as a subfloor constructed of boards. Use sheet material of OSB, plywood, or tempered hardboard. For the purpose of underlayment, many of these products are available in 4 × 4 sheets instead of the standard 4 × 8.

It's very important that you only use sheeting products designed specifically for use as underlayment. You must also be sure that the product you use is approved by the manufacturer of the flooring that you'll be installing. Most manufacturers specify only certain underlayments, even though others are available. Failure to use the manufacturer's specified underlayment, in most cases, will void the warranty of the flooring.

If you have a flooring contractor install the flooring, it's usually a good idea to have the same person or company install the underlayment. That way there'll be no question about who's responsible for flooring problems in the future. While installing the underlayment seems simple enough, the chemical reaction of flooring glue with various products can create unforeseen problems. Some glues used with vinyl generate heat while they dry and can cause underlayment that isn't properly fastened to lift and bubble.

Underlayment Layout

Install the underlayment just prior to installing the resilient flooring. This is generally after the drywall and, in most cases, the painting work is complete. Scrape away any hardened drywall compound, and smooth off rough edges or other protrusions from the subfloor. Follow up with a thorough sweeping to clean the subfloor before you begin the installation. Once you have a clean, prepared surface, lay out the underlayment as follows:

1. Plan the floor layout for the least amount of cutting possible. Multiple pieces mean multiple joints, and you'll have to fill and sand each joint for a smooth finish. Many of today's no-wax, high-sheen vinyls are very unforgiving and show every irregularity, no matter how small.
2. In a kitchen, if your floor layout results in any cuts with lengths less than 24 inches wide, shift your layout so that these will be under the cabinets.
3. Adjust the layout where possible to keep joints away from high traffic areas such as a doorway leading into the kitchen.
4. Stagger the underlayment so that you don't place joints over subfloor joints.

Installing the Underlayment

1. Based on the layout that you've decided on, chalk a line to serve as a straight edge for the first row of underlayment.

2. When you cut the underlayment material, always cut so that you'll be laying the underlayment factory edge to factory edge. If possible, place new cuts against a wall.
3. Use ring-shank nails or staples to fasten the underlayment. Both should be long enough to fully penetrate the subfloor. Place the fasteners a minimum of every 6 inches; many installers prefer every 4 inches.
4. Staple the edges every $^1/_2$ to $^3/_4$ inch. Allow $^1/_{32}$ inch between joints for expansion.
5. Fill in the joints and nail holes with a floor leveling compound. This preparation is very similar to the compound used for drywall finishing. When the compound is dry, sand the edges for a smooth surface.

See *Resilient Flooring* for information on additional preparation and installation procedures for placing resilient or vinyl flooring.

Manhours

Manhours to Install Floor Framing

Item	Unit	Manhours	Suggested Crew
Columns or posts, wood, 8' long without base or cap			
4" × 4"	LF	.060	2 carpenters
4" × 6"	LF	.064	2 carpenters
4" × 8"	LF	.069	2 carpenters
6" × 6"	LF	.076	2 carpenters
6" × 8"	LF	.082	2 carpenters
6" × 10"	LF	.089	2 carpenters
8" × 8"	LF	.096	2 carpenters
8" × 10"	LF	.108	2 carpenters
Girders or beams, wood			
4" × 6" (2.15 BF per LF of girder)	LF	.034	1 carpenter, 1 laborer
4" × 8" (2.85 BF per LF of girder)	LF	.044	1 carpenter, 1 laborer
4" × 10" (3.58 BF per LF of girder)	LF	.057	1 carpenter, 1 laborer
4" × 12" (4.28 BF per LF of girder)	LF	.067	1 carpenter, 1 laborer

Manhours to Install Floor Framing (continued)			
Item	**Unit**	**Manhours**	**Suggested Crew**
6" × 6" (3.21 BF per LF of girder)	LF	.051	1 carpenter, 1 laborer
6" × 8" (4.28 BF per LF of girder)	LF	.067	1 carpenter, 1 laborer
6" × 10" (5.35 BF per LF of girder)	LF	.083	1 carpenter, 1 laborer
6" × 12" (6.42 BF per LF of girder)	LF	.098	1 carpenter, 1 laborer
8" × 8" (5.71 BF per LF of girder)	LF	.088	1 carpenter, 1 laborer
Sill plate			
2" × 3" (.53 BF per LF of foundation)	LF	.020	1 carpenter, 1 laborer
2" × 4" (.70 BF per LF of foundation)	LF	.023	1 carpenter, 1 laborer
2" × 6" (1.05 BF per LF of foundation)	LF	.024	1 carpenter, 1 laborer
2" × 8" (1.40 BF per LF of foundation)	LF	.031	1 carpenter, 1 laborer
Floor joists, no beams, blocking, bridging			
2" × 6"			
12" centers (1.28 BF per SF on floor)	SF	.021	1 carpenter, 1 laborer
16" centers (1.02 BF per SF on floor	SF	.017	1 carpenter, 1 laborer
24" centers (0.73 BF per SF on floor	SF	.012	1 carpenter, 1 laborer
2" × 8"			
12" centers (1.71 BF per SF on floor)	SF	.023	1 carpenter, 1 laborer
16" centers (1.36 BF per SF on floor)	SF	.018	1 carpenter, 1 laborer
24" centers (1.03 BF per SF on floor)	SF	.013	1 carpenter, 1 laborer
2" × 10"			
12" centers (2.14 BF per SF on floor)	SF	.025	1 carpenter, 1 laborer
16" centers (1.71 BF per SF on floor)	SF	.020	1 carpenter, 1 laborer
24" centers (1.30 BF per SF on floor)	SF	.014	1 carpenter, 1 laborer

Manhours to Install Floor Framing (continued)			
Item	**Unit**	**Manhours**	**Suggested Crew**
2" × 12"			
12" centers (2.56 BF per SF on floor)	SF	.026	1 carpenter, 1 laborer
16" centers (2.05 BF per SF on floor)	SF	.021	1 carpenter, 1 laborer
24" centers (1.56 BF per SF on floor)	SF	.015	1 carpenter, 1 laborer
Subfloor, plywood sheathing			
$^5/_{16}$" or $^3/_8$"	SF	.011	1 carpenter, 1 laborer
$^1/_2$" or $^5/_8$"	SF	.012	1 carpenter, 1 laborer
$^3/_4$"	SF	.013	1 carpenter, 1 laborer

For more information on related topics, see:

Brick Masonry, page 51

Concrete, page 141

Concrete Block, page 189

Concrete Reinforcement, page 201

Fireplaces and Chimneys, page 291

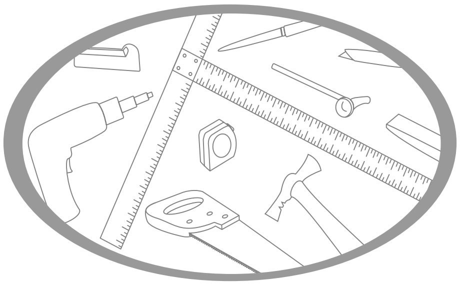
Flooring, page 359

Framing Materials and Planning, page 363

Insulation, page 395

Plumbing, page 471

Porches and Decks, page 485



Flooring

The right flooring creates a mood: carpet speaks of quiet luxury; wood of warm beauty; vinyl flooring of inexpensive convenience; and tile of colorful durability. Each has its purpose and strengths. But these flooring materials are only the last layer in a carefully designed system. (You'll find more information on flooring types covered in their individual sections.)

Consider the Subfloor

Every system begins with the subfloor, which may be concrete or wood. After the subfloor is in place, you may have to cover it with an underlayment. Finally, you'll install the flooring material itself.

Of the flooring materials, carpet allows for the most flexibility; you can install it over either concrete or wood. Above grade, you can also install wood flooring directly over concrete or wood. But on or below grade, it should only be placed on wood. Tile is most durable when you lay it over level, cured concrete, but it, too, can be placed over a properly prepared wood subfloor. Although you can lay resilient flooring directly over concrete, it's best to lay it over wood. Even then, if there are flaws in the subfloor, you may need an underlayment to increase rigidity or even up the surface of the subfloor. (For more information, see *Floor Framing*, *Subfloor* on page 350 and *Floor Framing*, *Underlayment* on page 353.)

Concrete Subfloor

Don't lay any flooring over concrete until it's completely cured. As long as any moisture remains in the concrete, adhesives won't bond. Even if the concrete cures adequately, ground moisture can still seep up and loosen the adhesive bond. Concrete that's been in place for several years, should still be tested for residual moisture before proceeding with any flooring job. To do this, tape pieces of 1-foot square polyethylene film over several different patches of the concrete. Seal the edges with plastic moisture-resistant tape. Leave the film in place for 24 to 48 hours. If no "clouding" from moisture appears on the plastic, the concrete is dry enough for your flooring installation.

An additional problem with concrete is that it will draw any alkaline salts in the soil up through itself in a capillary action. The salt also affects the adhesive bond. There are several things you can do to decrease or prevent moisture and salt problems.

Polyethylene vapor barrier: For concrete slabs on or below grade, install a vapor barrier on the soil before you place the concrete. Use 4 or 6 mil polyethylene film.

Two layers of membrane asphalt felt: Spread asphalt primer on a clean slab. When it's dry, apply cold cut-back asphalt mastic with a notched trowel at the rate of 50 square feet per gallon. Allow it to dry for two hours. Then roll out 15-pound asphalt felt or building paper over the entire floor. Butt the ends and lap the edges 4 inches. Spread a second layer of mastic and cover with another layer of felt or building paper. Lay the paper in the same direction as the first layer, but stagger the overlaps.

Avoid curing and parting compounds: Curing compounds sometimes contain soap, wax, oil, or silicone, which affect the adhesive bond. These must be removed before you apply the adhesive. Remove by wet grinding or using a trisodium phosphate and water wash followed by a thorough rinse. Better yet, check with the adhesive manufacturer for curing compounds that won't interfere with the adhesive you'll be applying.

Tools and Materials

- *Chalk box*
- *Construction adhesive or Asphalt primer and asphalt mastic*
- *Concrete nails*
- *4d and 8d nails*
- *1 x 2 inch random length (18 to 48 inches) furring strips, treated with wood preservative*
- *1 x 2 inch random length (18 to 48 inches) furring strips, untreated*
- *4 mil polyethylene film*
- *Strip or plank flooring or Plywood or particleboard*
- *Safety glasses*

Suspended Flooring

Another option is to build up a suspended floor. See Figure 1. You can attach screeds or sleepers (furring strips) to the concrete, lay plywood or particleboard over the sleepers, and cover it with underlayment. Some flooring manufacturers don't recommend installing resilient flooring on suspended subfloors when the concrete is on or below grade.

Installing a Suspended Floor

1. Make sure concrete is clean, dry and free of flaking paint or alkaline salts. Snap chalk lines 16 inches on center parallel with the length of the room.

2. Spread a $^3/_8$-inch bead of adhesive on the chalk lines. Place the wide side of treated furring strips on the adhesive. (Furring strips should be chemically treated with wood preservative, but not creosote or an oil-based preservative).

   Or, prime lines with asphalt primer and allow them to dry. Then apply hot (poured) or cold (cutback) asphalt mastic along the primer lines. Embed the sleepers, making sure each one is 100 percent covered with mastic.

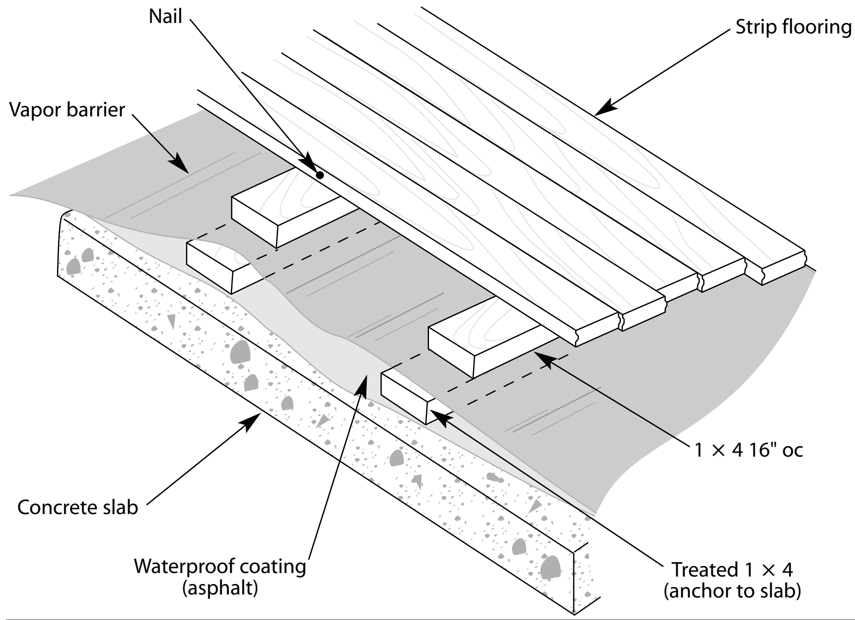


Figure 1
Installing suspended flooring over a concrete slab

3. Stagger the joints and lap the ends of the sleepers at least 4 inches. Leave small gaps between the ends for expansion. Shoot concrete nails to anchor the strips more securely. (Wear safety glasses to protect your eyes from flying chips.) Allow the adhesive to set for 24 hours. You can place insulation between the sleepers to reduce squeaks as well as provide insulation and protection against moisture.
4. Spread polyethylene vapor barrier over the furring strips, overlapping at the seams. Place the wide side of the untreated furring strips on the treated strips. Secure the top layer to the first with 4d nails.
5. Lay the planking or plywood perpendicular to the furring strips, staggering them so that you don't have splices next to each other. Attach them to the sleepers with 8d nails. Allow $^1/_2$ inch where the wall meets the floor for expansion.

Wood Subfloor

For carpet and wood flooring, a standard built subfloor is generally all the preparation you need, although it’s not recommended to install wood flooring below-grade. As stated earlier, you can lay tile on a wood subfloor, but only if it’s been properly prepared. Tile needs a strong, rigid surface that’s at least $1^1/_4$ inches thick; also, you’ll need to install a waterproof membrane to prevent the wood from swelling when you apply the mortar or mastic. (See *Ceramic Tile*.)

When you lay resilient flooring over a wood subfloor, you need a minimum of at least 18 inches of well-ventilated space between the subfloor and the ground.

Covering Existing Flooring

In remodeling, you'll often find a surface covered with another layer of flooring. As they are with subfloors, carpet and wood are fairly forgiving when laid over other flooring surfaces. The texture or flaws in the previous flooring generally won't be visible.

Tile and resilient flooring are more demanding. Tile will tolerate a wide range of surfaces as long as they're rigid, perfectly smooth, and resistant to moisture. You can lay tile over other tile, noncushioned vinyl, and clean, grease-free concrete. But if you want to set it over a hardwood surface or indoor-outdoor carpet, you'll need to first install backerboard. The alternative is to remove the original flooring and put in a new substrate.

You can install resilient flooring over existing flooring if the material is smooth, not embossed, and firmly bonded. You'll need to remove all wax and other finishes where adhesive will go, and make sure no moisture or salts are present. You can't install resilient flooring over existing flooring if it has a cushioned backing.

Manhours

Manhours to Install Flooring, per SF

Type	Manhours	Suggested Crew
Subflooring, board sheathing		
1" × 6" #3 & Btr (1.28 BF per SF)	.020	1 carpenter, 1 laborer
Add for diagonal pattern	.001	1 carpenter, 1 laborer
Subflooring or underlayment, plywood sheathing		
5/16" or 3/8"	.011	1 carpenter, 1 laborer
1/2" or 5/8"	.012	1 carpenter, 1 laborer
3/4"	.013	1 carpenter, 1 laborer
Underlayment, 40lb. particleboard		
3/8", 1/2", 5/8" or 3/4" thick	.016	1 carpenter, 1 laborer
Furring strips		
1" × 4", 12" oc	.014	1 carpenter, 1 laborer
1" × 4", 16" oc	.012	1 carpenter, 1 laborer

For additional information on related topics, see:

Carpet, page 107

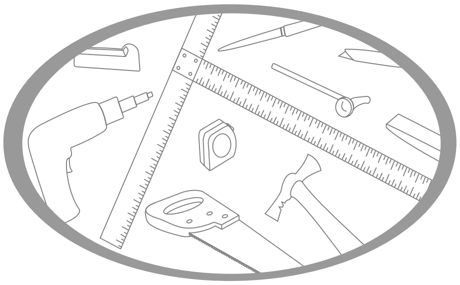
Ceramic Tile, page 125

Floor Framing, page 299

Resilient Flooring, page 503

Trim, page 673

Wood Flooring, page 759



Framing Materials and Planning

The frame of a building is like the skeleton of a person. It's the supporting structure that gives shape to the mass of the structure. The frame supports the dead load of the structure, or the nonmoveable permanent parts, such as the siding, flooring and roof. It must also be designed to support the live load of the structure, or the moveable objects such as furniture, appliances and people.

Framing is a trade in itself, often referred to as rough carpentry. While the term rough may be descriptive (as opposed to fine), it can never be used in framing to indicate a lack of accuracy or detail. A good framer or rough carpenter needs to understand the structural capacity of wood, fasteners, and connectors. A good framer also knows that a poor framing job can never be totally covered up by even an expert trim carpenter. A framing crew leader must thoroughly understand workmanship, as well as the materials they're working with.

As with most aspects of construction, there are regional differences in framing techniques. And as always, the local building code has the ultimate jurisdiction over any new techniques or methods you may wish to incorporate.

New Framing Materials

Framing materials are continually evolving. It hasn't been too many years since the supply of timber, including old growth timber, seemed to be never-ending. High quality framing materials, even Douglas fir studs, were commonly available from the mills. In the eastern states, where hardwoods are common, older structures were often framed with oak and other hardwoods.

Today, the high demands on our forests have brought a wider range of species into common use. New engineered wood products, as well as these additional wood species, have changed the way we build. The most significant changes in the building industry began with the use of plywood products and continued with the development of waferboard, particleboard, and fiberboard. We now routinely use engineered floor joists, beams, and roof trusses. These products provide greater flexibility in design, ease construction labor, and enable us to better utilize our forests.

Grading and Classification of Framing Materials

In many areas, local code requires all structural lumber to carry a grading stamp. The stamp shows the species of wood and the structural capacity of the framing member. There's good reason for that grade requirement. While it may seem to be restrictive, it's actually the opposite. By grading lumber and distinguishing between structural and nonstructural grades, less expensive alternative products are graded and made available for nonstructural uses.

Lumber is categorized into three types: board, dimension, and timber. All lumber starts at 8 foot lengths and is available in 2-foot increments beyond 8 feet. Its thickness and width determine which category it's in.

Board Lumber

Board lumber is also called 1-by lumber. Boards are generally available in the following sizes:

Classification	True size
1 × 4	$^3/_4 \times 3^1/_2$
1 × 6	$^3/_4 \times 5^1/_2$
1 × 8	$^3/_4 \times 7^1/_4$
1 × 10	$^3/_4 \times 9^1/_4$
1 × 12	$^3/_4 \times 11^1/_4$

Here are the board grades:

- Appearance grades
  - Clear
  - B & Better
  - C Select
  - D Select
- Sheathing boards
  - No. 1 Common *or* Select
  - No. 2 Common *or* Construction
  - No. 3 Common *or* Standard
  - No. 4 Common *or* Utility
  - No. 5 Common *or* Economy

Dimension Lumber

Lumber from 2 inches up to (but not including) 5 inches thick is known as dimension lumber. This is the size lumber we use almost exclusively for typical framing work and it's referred to as 2-by lumber. Dimension lumber is commonly available in the following sizes with the actual measurements (see Figure 1) shown below:

Classification	True size
2 × 4	$1^1/_2 \times 3^1/_2$
2 × 6	$1^1/_2 \times 5^1/_2$
2 × 8	$1^1/_2 \times 7^1/_4$
2 × 10	$1^1/_2 \times 9^1/_4$
2 × 12	$1^1/_2 \times 11^1/_4$

Here are the dimension lumber grades:

- Studs
  - Stud
  - Economy stud
- Light framing
  - Construction
  - Standard
  - Utility

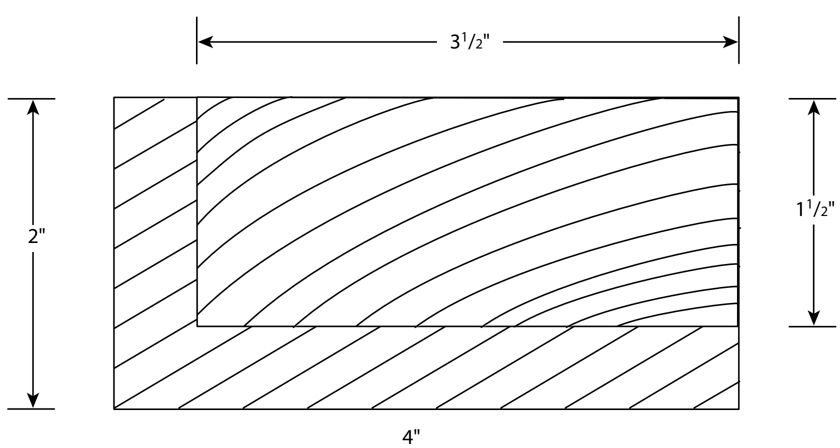


Figure 1
2 × 4 — true size

Economy

or

Select structural

No. 1

No. 2

No. 3

Economy

Structural joists and planks

Select structural

No. 1

No. 2

No. 3

Economy

Timber

Lumber 5 inches thick by 5 inches wide and larger is known as timber. Timber is used for support posts in standard framing or as the primary framing material in post and beam or timber frame construction.

Timber is sized as follows:

Classification	True size
By even inches	1/2 inch smaller than classification

Timbers grades are:

Beams and stringers

Select structural

No. 1

No. 2 (No. 1 Mining)

No. 3 (No. 2 Mining)

Posts and timbers

Select structural

No. 1

No. 2 (No. 1 Mining)

No. 3 (No. 2 Mining)

Figure 2
Lumber grade stamp

The Grade Stamp

Dimension lumber, sheathing boards, and timbers have a stamp on them that identifies the species of wood, its classification, the moisture content of the wood and the mill that the lumber came from. Figure 2 shows a typical lumber grade stamp from the Western Wood Products Association.

- *Mill* — The mill is designated by the use of a number, such as 12.
- *Classification* — The classification is designated with a number such as 1, 2, or 3, or an abbreviation such as SEL STR (select structural) or STAND (standard).
- *Species* — The species is also abbreviated. HEM FIR identifies the lumber as hemlock or fir. S-P-F stands for spruce, pine or fir. D-FIR or DOUG identifies the lumber as specifically Douglas fir.
- *Moisture content* — The moisture content of the wood is specified as follows:

S-GRN	moisture content over 19 percent
S-DRY	moisture content 19 percent or less
MC 15	moisture content 15 percent or less

Engineered Wood Products

Engineered wood products can be divided into two categories: glued and laminated products, and trusses. Glued and laminated products include plywood in its many forms, and glued-laminated beams.

Framing Plywood

The introduction of plywood brought about a significant change in the building industry. In rough carpentry, plywood is used primarily for sheathing and decking. Plywood replaced 1 × 8 and 1 × 10 sheathing boards, lowering both labor and material costs.

Veneers

Plywood is made from thin veneers peeled from logs on a large lathe-type veneering machine. The veneer plies are glued together in diagonal layers for strength and stability. Veneers are graded A through D with various combinations on the two sides. The grades are:

- *N* — Smooth surface "natural finish" veneer. Select, all heartwood or all sapwood. Free of open defects. Allows not more than six repairs, wood only, per 4 × 8 panel, made parallel to grain and well matched for grain and color.

- *A* — Smooth, paintable. Has not more than 18 neatly-made repairs, boat, sled, or router type, and parallel to grain. May be used for natural finish in less demanding applications. Synthetic repairs permitted.
- *B* — Solid surface. Shims, circular repair plugs and tight knots to 1 inch across grain permitted. Some minor splits permitted. Synthetic repairs permitted.
- *C plugged* — Improved C veneer with splits limited to $^1/_8$ inch width and knotholes and bored holes limited to $^1/_4 \times {}^1/_2$ inch. Admits some broken grain. Synthetic repairs permitted.
- *C* — Tight knots to $1^1/_2$ inch. Knotholes to 1 inch across grain and some to $1^1/_2$ inch if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed. Stitching permitted.
- *D* — Knots and knotholes to a $2^1/_2$ inch width across grain and $^1/_2$ inch larger within specified limits. Stitching permitted. Limited to Interior Exposure 1 and Exposure 2 panels.

Exposure Ratings — The type of glue used to laminate the veneers determines the exposure rating for the finished product. The American Plywood Association gives the exposure durability four classifications:

- *Exterior* — Panels have a fully waterproof bond and are designed for applications subject to permanent exposure to the weather or to moisture.
- *Exposure 1* — Panels have a fully waterproof bond and are designed for applications where long construction delays may be expected prior to providing protection, or where high moisture conditions may be encountered in service. Exposure 1 panels are made with the same exterior adhesives used in Exterior panels. However, because other composition factors may affect bond performance, only Exterior panels should be used for permanent exposure to the weather.
- *Exposure 2* — Panels (identified as Interior type with intermediate glue under PS 1) are intended for protected construction applications where only moderate delays in providing protection from moisture may be expected.
- *Interior* — Panels which lack further glueline information in their trademarks are manufactured with interior glue and are intended for interior application only.

Grade Stamps

Plywood is stamped with its grade designation on the back of the panel, except for panels with B-grade or better veneer on both sides. These are stamped on the panel edge.

Structural panels such as sheathing, floor panel, and siding have stamps that provide the following information:

- Intended use (sheathing, siding, etc.)
- Span rating
- Thickness (given in fractions of an inch)
- Exposure durability (Exterior, Exposure 1, etc.)

Two numbers separated by a slash designate the span rating for sheathing. The first number indicates the maximum spacing of the supports if the panel will be used for roof sheathing. The second number indicates the maximum spacing of the supports if the panel will be used for flooring. Both numbers are based on the panel being installed with the long dimension or strength axis of the panel over three or more supports.

The span rating for floor panels designed for a single layer floor system are stamped with a single number designating the span rating with the panel laid out with the strength axis spanning a minimum of three supports.

Siding panels are designated as either 16 or 24 inch spans for 16 inch or 24 inch stud layout

Grade Stamps for Grade B or Higher — Panels with at least one of the veneers a grade B or higher are sanded. These panels are classified as "sanded" and "touch-sanded" plywood. The stamps on these panels provide the following information:

- Veneers are designated by two letters for the two sides as discussed earlier. For instance, A-C designates an A quality veneer on one side with a C quality veneer on the other.
- Classification of species is designated as Group 1-5.
- Exposure durability is designated as Exterior, Exposure 1, Exposure 2, and Interior.

Other Sheathing Types

Plywood isn't the only choice for wall sheathing. There are other panel materials available that offer cost savings or better insulation.

Oriented Strand Board

OSB is a wood product similar to plywood that can often be used interchangeably with plywood. OSB is made of large wood wafers or strands glued and pressed together. The wafers are oriented much as plywood, with alternating layers of wafers or strands in three or five layers. OSB is rated in the same manner as plywood sheathing with the stamp designating the thickness, spacing, and exposure durability. OSB is available as T&G floor panels and sheathing for walls and roof.

Asphalt-Impregnated Sheathing

Asphalt-impregnated sheathing is a nonstructural wall panel often selected for use because of its low cost. It offers a slightly higher R-value than plywood.

Foil-Faced Foam Sheathing

Foil-faced foam sheathing is a nonstructural wall panel chosen for its energy-saving properties. Foil-faced foam sheathing provides higher R-values than plywood and the foil acts as both an air barrier and vapor barrier. (See *Insulation*, page 395.)

Structural Glued Laminated Timber (Glulam) Beams

Glulam beams are structural members used for a variety of framing applications. Because of their attractiveness, designers often incorporate them into the design of the structure in such a way that they can be left exposed (see Figure 3).

Glulam beams are engineered and laminated using dimensional lumber for specific applications such as arches, S-curves, and other configurations specified by designers. They are laid out using large gluing clamps that are positioned on special laminating floors. Glulams are made up in project-specific sizing, ranging from 2 × 4s laminated into 4 × 12s to 8-inch or wider arches for churches or other public buildings.

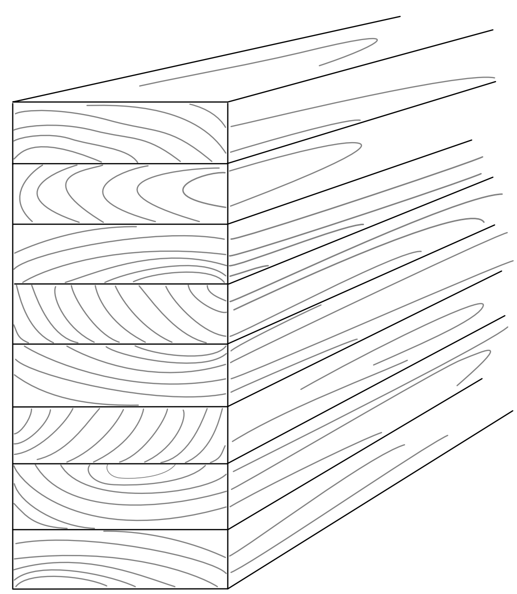


Figure 3
Glulam beam

Laminated Veneer Lumber (LVL)

LVL beams are made of multiple plywood veneers, to a thickness of $1^3/_4$ inches as shown in Figure 4. Since they aren't as attractive as glulam beams, they're almost exclusively used as covered structural framing members. They're designed $1^3/_4$ inch thick so that a doubled beam used for a header is a full $3^1/_2$ inches thick with no spacer required.

Because they are engineered using multiple veneers, they're stronger than standard dimensional lumber of the same size. This strength allows for more flexibility in structural design as well as easier installation in the field. LVL beams are often used instead of steel beams. Their strength can provide no-sag support for openings such as large windows or wide garage doors.

Besides the $1^1/_2$-inch-thick widths, you can purchase LVL beams in widths of $5^1/_2$, $7^1/_4$, $9^1/_2$, $11^7/_8$, 14, 16 and 18 inches as well. They come in lengths up to 60 feet.

Plywood Web Joists

Plywood web joists or plywood I-joists are shaped like steel I-beams but constructed of plywood (Figure 5). As with LVL beams, the engineered veneers used in plywood I-joists create a product that provides a stronger floor than comparable dimensional lumber. This straight

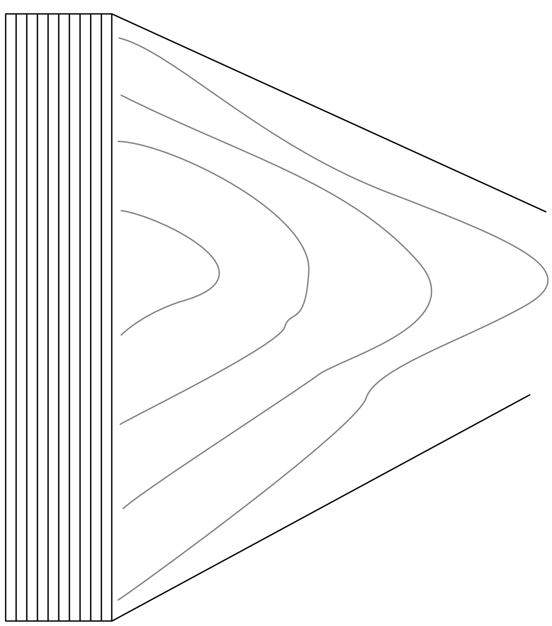


Figure 4
LVL beam

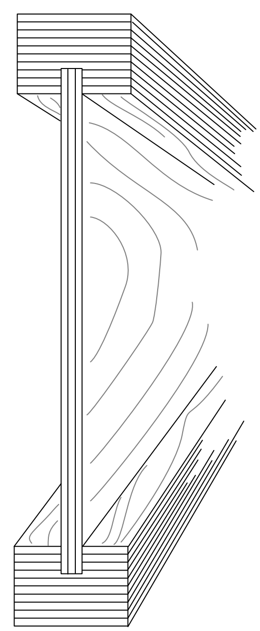


Figure 5
Plywood I-beam

and uniform product is also significantly lighter than the comparable dimensional lumber. Since they consist of multiple veneers, plywood I-joists are much more stable than dimensional lumber and resist twisting or warping. As a result, you don't need cross bracing with this product.

Plywood I-joists are available in widths of $9^1/_2$, $11^7/_8$, 14 and 16 inches, and lengths up to 60 feet.

Trusses

Trusses are designed to carry heavier loads using less material than dimensional lumber. They are also able to span greater distances than joists made of dimensional lumber. Trusses are made from dimensional lumber, but they have added external support members known as top or bottom chords, and internal members known as webs. These members are attached to one another with metal connecting plates called gussets. By engineering different arrangements for the webs, along with the sizing of the chords, both floor and roof trusses can be designed to carry a variety of loads.

Framing Procedures

Planning and preparation for framing, like most areas of construction, begin on the drawing board. Planning saves labor and materials, which in turn, saves dollars and creates profits. Traditionally, planning starts with the estimate you do when you bid the project. The two most common methods of estimating are *unit pricing* and *stick pricing*.

Estimating Costs

Unit pricing involves pricing by a unit, such as per square foot of floor area, which is then multiplied by an "average" square foot cost for framing. Square feet of wall framing is a more accurate unit price because it accounts for all of the wall framing on a particular house. Lineal feet of wall is in the same accuracy range as square feet of wall.

In contrast, estimating by the stick counts every piece of material. Then you add in your labor to get a firm project cost. Of the two methods of estimating, unit pricing is considerably faster than stick pricing and it's generally just as accurate.

Almost all building supply centers do material "take-offs." You can use these quantity estimates to put together a stick-priced estimate or you can do one once the contract is in hand if you base your bid on unit pricing. If you want to receive the most accurate estimate possible, provide your supplier with the most complete drawings and specifications you have available.

When you begin to deal with new suppliers, use caution when ordering directly from the material take-offs that they provide. You'll find that some suppliers are very accurate while others just don't seem to do things the same way you do. Cross reference your own take-offs with the supplier's until you have a feel for how your framing style matches their take-off. Then proceed to order with a degree of caution reasonably matched with the degree of liberty their return policy provides.

Modular Planning

While material stacked in bunks at the start of a project looks like random sticks and panels, it isn't. Framing is modular. The basic module of construction is a 4-inch cube, and building components have all been milled to fit that standard. And because framing is modular, estimating framing materials as well as looking for ways to save framing materials, is modular based.

All modular dimensions are multiples of 4 inches, such as 48- × 96-inch sheathing and drywall or stud layouts at 16 or 24 inches on center. While floor joists laid out at 19.2 inches on center are "off" module on their individual spacing, they're "on" for 8-foot (96-inch) floor panels.

Understanding the modular components of framing is important, not only for the framing phase, but for the building trades that follow. Drywallers, cabinet setters and trim carpenters all rely on modular framing to fit and install their components or to aid in locating the framing members used for attachments.

Well-planned framing centers around the predictability of modular layout. Lay out joists so that the first sheet of plywood fits uncut. Stagger your rows by starting with half sheets of plywood to eliminate waste. Compile your material lists with the layout in mind.

By taking the time to design the structure so that the doors and windows also lay out on a modular scale, you can save studs and consequently make higher profits. This involves placing windows and doors so that at least one of the sides is on a 16-inch or 24-inch on center stud layout. On paper, it looks nice if both sides are on the layout, but door and window rough openings don't always fit inside multiples of 16-inch or 24-inch stud spacing.

In tract home developments, you can generate substantial savings using modular framing because of the volume of studs used. If 250 houses are being built, and the designer coordinates the layout with the framers so the studs are laid out with the windows and doors on module, the savings adds up. Cutting just $50 per unit off your costs with that volume would save $12,500 overall. You can see the advantage of good planning.

For individual designs such as custom homes, eliminating studs through modular layout of window and door openings hardly justifies the time put into planning it out. Most custom home consumers would almost certainly prefer to give you the $50 they might save in order to keep their freedom of design and choice of layout.

Framing Loads

Buildings are built from the ground up. But the loads must all be calculated from the roof down to the component that's being designed to support each part of the structure. To design the roof trusses, the roof load and snow load must be taken into account. To design a girder, the roof loads, partition loads, floor loads, and potential live loads must be considered. We'll include information on design loads in each of the individual component sections. As you review the design of the components, you may find it necessary to refer to other component sections to understand how those loads are being transferred down through the structure.

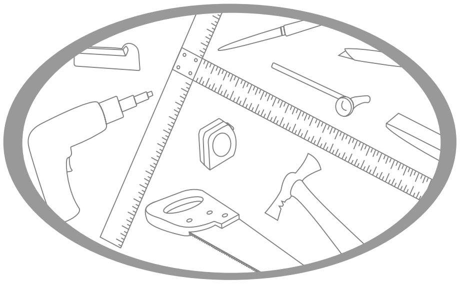
For more information on related topics, see:

Floor Framing, page 299

Insulation, page 395

Roof Framing, page 513

Wall Framing, page 709



Glass Block

Glass blocks are formed by fusing two glass shells together to create a hollow block. Not only do they provide thermal and acoustical insulation, they also resist moisture and condensation better than regular glass. Their most attractive feature however, and the reason most people choose glass block, is that they allow natural light into the structure like a window but provide privacy by distorting visibility. This makes them ideal for bathroom windows, shower walls, room dividers, or even exterior walls.

Estimating for glass block is easy. They come in squares and rectangles that are either $3^{1}/_{8}$-inch thick or $3^{7}/_{8}$-inches thick, with the thinner sizes being reserved for light commercial or residential uses. The nominal sizes (allowing $^{1}/_{4}$ inch for mortar joints) for squares are 6, 8, and 12 inches. The rectangles come in 4 × 8 inch and 6 × 8 inch sizes.

Mortar Formulas

Here are three formulas you can use for the mortar to lay glass block:

1:$^{1}/_{4}$:3
- *1 part portland cement*
- *$^{1}/_{4}$ part hydrated lime*
- *3 parts sand*

or

1:1:4
- *1 part cement*
- *1 part lime*
- *4 parts sand*

or

1:1:6
- *1 part cement*
- *1 part lime*
- *6 parts sand*

Laying Glass Block

Although glass block is sometimes laid in large sections, it's not a load-bearing material. It shouldn't be used in sections larger than 144 square feet without extra bracing. With reinforcement added, you can lay it in sections up to 250 square feet. However, at no point should glass block panels be longer than 25 feet or higher than 20 feet.

Mortar for Glass Block

Unlike other types of masonry, glass block doesn't absorb moisture. This makes laying the block more complicated. Since moisture from the mortar won't be partially absorbed by the block, it takes longer for the mortar to set. And while it's setting, the weight of the glass block tends to squeeze out the wet mortar. You can prevent this from occurring by using special plastic spacers between the blocks that hold them in place until the mortar is firm.

You'll need to mix the mortar for glass block to a stiffer consistency than for other masonry since none of the water will be absorbed into the block.

Tools and Materials

- *Level*
- *Tape measure*
- *Brick trowel*
- *Glass block*
- *Mortar*
- *Joining tool*
- *Spacers*
- *Anchors or reinforcing wires*
- *Asphalt emulsion*
- *Putty knife*
- *Expansion joints, $1/2 \times 4\,1/8 \times 25$ inches*

Guidelines for Laying Glass Block

1. Mark each level of block on the wall, allowing for 1/4-inch mortar joints between each course. Dry lay the first course, again leaving a space for 1/4-inch mortar joints. Mark the joint locations.
2. Spread an unfurrowed mortar bed 3/4 inch thick. Butter the wall end of the first block. Butt it against the wall. Butter the end of the next block and push it against the first. Set spacers between the blocks as you work.
3. Carefully level each block as you lay it. When the first course is finished, check to make sure that it's level and plumb.
4. Use panel anchors on every other course. Screw the ends to the wall and embed the panel in mortar.
5. As the mortar sets, twist off the ends of the spacers and fill the holes with mortar. When the mortar is thumbprint hard, tool the joint. Carefully wipe the excess mortar off the glass with a damp cloth.

Spaces Larger Than 25 Square Feet

Follow the steps above for laying the block, except for the second step. Instead of using mortar, spread a layer of asphalt emulsion on the sills, jambs, heads, and mullions of all openings. Place expansion joint strips at the jambs, heads, and mullions.

Tools and Materials

- *2×4 stop block*
- *Wedges*
- *Oakum*
- *Putty*

Installing Glass Block Panels

You can also order glass blocks in preassembled panels. When ordering, allow an extra 1/2 inch for width and 3/8 inch for height. The mortar joints themselves are still 1/4 inch.

To install glass block panels:

1. Prepare the opening by nailing a 2×4 stop block to the header on one side. Place two wedges on the sill. Carefully push the panel into the opening.
2. Level the panel by tapping the wedges around until the panel is level and plumb. Leave a 1/4-inch space at the top. Push mortar into the spaces around the panel.

3. When the mortar has set, remove the stop block and wedges and fill the gaps with mortar. Force oakum into the joints between the blocks and the sills, jambs, heads, and mullions of all openings. The oakum should be pushed in at least $^3/_8$ inch.
4. Caulk over the oakum with a nonhardening waterproof caulk.

Manhours

Manhours to Lay Glass Block, per SF		
Block	**Manhours**	**Suggested Crew**
Plain, 4" thick		
6" × 6"	.284	1 bricklayer, 1 bricktender
8" × 8"	.194	1 bricklayer, 1 bricktender
12" × 12"	.129	1 bricklayer, 1 bricktender

For more information on related topics, see:

Brick Masonry, page 51

Ceramic Tile, page 125

Concrete Block, page 189

Stone Masonry, page 655

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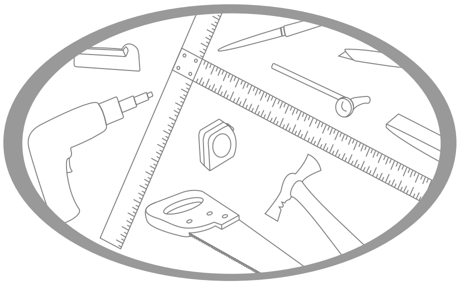

Heating and Air Conditioning

The temperature of a building is handled by heating and/or air conditioning units controlled by a thermostat. There's a broad selection of mechanical systems for providing heat. Choosing a system for a building is usually determined in part by its regional location. Forced-air systems are popular in areas that require both heating and cooling. In areas where air conditioning isn't necessary, hot-water heat is a good choice. Figure 1 shows the major methods of heating and some of the advantages and disadvantages of each.

Selecting a System

Choosing a heating system is usually fairly easy. If air conditioning is a requirement, you can immediately look to forced-air systems. If you don't need air conditioning, consider the fuels required by each type of system, the cost and availability of those fuels in your area, and then look at which system is the "standard" for your area. Choosing the local standard usually makes it easier to have the system serviced, as well as making the home or building more attractive for resale or renting. If you have questions about the various systems, obtain detailed information from manufacturers or consult with specialists in your area.

Sizing the System

With any system you choose, you'll need to determine the heat loss for the building before you can decide what heating capacity you'll need. The system should be capable of maintaining a temperature of 72 degrees when the outside temperature is 0 degrees. The heat loss is the rate that heat leaves the building. To determine the loss, you must first identify the R value of the walls, floors and ceilings facing the outside, as well as the windows and doors. Once you determine how much cold air replaces the warm air in the building per hour, you can

Type of System	Fuel	AC?	Advantage/disadvantage
Hydronic (hot water)	Gas, oil	No	Clean and efficient.
Electric baseboard	Electric	No	Easy and inexpensive to install. Clean. Easily zoned. Expensive to operate.
Radiant	Gas Oil Electric	No	Clean, efficient and unseen. Punctured or broken wire or tube imbedded in concrete or plaster difficult to repair. Slow response time to thermostat.
Forced air	Gas Oil Electric	Yes	Humidifiers and air filter easily added. The only choice where air conditioning is required. Cumbersome ductwork takes up space.

Figure 1
Heating systems

figure the heating capacity required to maintain the desired temperature in the building. The heating capacity of a system is given in Btu's or British thermal units and is provided by the manufacturer. A well-designed heating system must be capable of replacing the Btus lost with an efficient use of the energy available in your area. There are many calculations that go into figuring heat loss and gain for each climatic region in the country, as well as all the variables that can affect those calculations. Check with specialists in your area to help you determine your needs.

Heating System Types

Let's look with more detail at the various types of heating systems, their operation, ease of installation, and the advantages they offer.

Hydronic or Hot Water

Hydronic heating systems provide heat by circulating hot water through pipes, which then radiate the heat to the desired areas. These systems consist of a boiler with an expansion tank, a circulating pump, finned heating elements (typically in a baseboard-type arrangement), pressure regulating valve, and a thermostat.

Hydronic systems can have multiple zones with a thermostat for each zone. This allows hot water to be circulated only through the zones or areas specifically requiring heat. For instance, bedrooms can be kept cooler than the main living areas, and guest rooms or other areas not occupied every day can be heated only as needed.

Hydronic heat provides quiet, clean heat. There are boilers available for a variety of fuels, including natural gas, oil, and electric. You can run the small diameter piping (usually 3/4 inch for residential use) in existing floor and wall space, so no chases are required for ductwork. Hydronic systems must be protected from freezing, as freezing can result in extensive damage. Using glycol as antifreeze will prevent freezing, but it also cuts down the efficiency of the system.

Hydronic System Operation

A hydronic system cycles heat using these simplified steps, which are interconnected in most systems:

- The thermostat signals the zone control that heat is required.
- The zone control opens, allowing hot water to circulate.
- The signal also triggers the pump to begin circulating hot water.
- If the water isn't hot enough, the boiler fires to bring the system to temperature.

Installation

Most localities require that a licensed professional install hydronic systems. In any case, the installation should be done under the guidance of a professional. You'll need to determine the heat loss for each zone to indicate the lineal feet of finned heating elements required to provide adequate heat for the zones. Then you must size the boiler so that it can provide hot water to all zones. You must also properly vent the boiler.

The following are generalized steps that you or a homeowner would expect a heating subcontractor to follow when installing hydronic heating. They are not how-to steps for a do-it-yourselfer to work from.

A) Planning: Determine the lineal feet of fin elements required for each room or zone to receive heat. A detailed heat loss is your most accurate source. A supplier may also provide a take-off that's adequate.

B) Rough-in: The installation follows the completion of the framing, but before installation of the insulation or drywall.

1. Lay out the finned element lengths and locations.
2. Leaving room for fittings at ends, drill through the floor where the element will tie into the zone loop.

3. Rough the piping for each zone. This involves running copper pipe loops for each zone starting and ending at the boiler location. Run the piping through floor or wall cavities (outside wall cavities should be avoided) and stub it up through the floor where the finned elements will be placed.
4. Run the thermostat wires for each zone from thermostat locations to the boiler room.
5. Place the boiler in its designed location near a floor drain.
6. Install the venting with proper clearances as per local and national governing codes.

C) Trim: The trim follows the drywall installation.

1. Attach the finned element enclosure back piece to the wall.
2. Install the finned elements.
3. Attach the enclosure front pieces and end pieces.
4. Complete the installation of the boiler by installing the expansion tank, circulating pump, relief valves and zone controls.
5. Complete all necessary low voltage wiring. You'll need an electrician to provide the 120/240v wiring for the system.
6. Charge the system by filling it with water or a water/glycol mixture.

Electric Baseboard

Electric baseboard heat is used primarily where high installation costs prohibit other heating types. The advantage of electric baseboard heat is its relatively cheap installation costs. Its disadvantage is the high operating costs. Electric baseboard heat is typically used for small additions to supplement the incidental heat from adjoining living areas. It's also used by some to circumvent local codes that require a permanent heating system in instances where the user intends to heat primarily with wood, passive solar, or other alternative heating methods that aren't considered permanent in that jurisdiction.

You size baseboard electric heat by wattage, which correlates to the length of the units. The units are available in lengths from 2 to 12 feet. You need to do a heat loss for the area to be covered to determine the amount of wattage/feet of baseboard you'll need.

Installation

Do the rough installation of these units as part of the electrical rough. The units are operated by a thermostat, either installed directly on the unit or mounted on a wall. If you use a wall thermostat, it requires the same 120/240 wiring as the unit. Typical rough installation involves running a power supply from the service panel to the location of the junction end of the baseboard unit. Trimming and completing the job simply involves attaching the unit to the wall following drywall and finishing the wiring inside the junction box in the unit.

Radiant Heat

Radiant heat is heat that's transmitted by heat waves rather than by the forced movement of air. Free standing steam radiators, hot-water baseboard systems as well as electric baseboard heat are forms of radiant heat. When you use the term radiant heat for heating systems, however, you're usually referring to a system of cable or piping that's placed in a ceiling or floor that radiates heat into an area or room. Free hanging space heaters placed above working areas also fall into the category of radiant heat.

Residential radiant heating primarily involves burying hot water polybutylene tubing in concrete floors or in placing electric cable or panel systems in plaster ceilings. The hot-water floor system operates on the same concept as the hydronic system except that the concrete floor is heated and acts as the radiator instead of the finned baseboard elements. The boiler room is indistinguishable from the boiler room for a hot water baseboard system; it also has zones, pumps, boiler and expansion tank. However, instead of zone loops circulating through the baseboard finned elements, the loops are placed in the concrete floor. Floor radiant systems are slow to respond to changes in the thermostat. The mass of the concrete must either heat up or cool down in response to control signals.

Ceiling systems consist of wire cables or panels placed in the ceiling. You control each zone, or in this case circuit, with a thermostat. Radiant heat placed in a ceiling acts like the heat of the sun, except that it feels cooler than direct sunlight. It's more like the diffused heat you feel when sitting under an umbrella. As with all types of electric heat, this type of system is one of convenience rather than cost efficiency.

The advantage of both of these radiant systems is a quiet, pleasant, and invisible heating system. Both floor and ceiling systems, however, are susceptible to damage and expensive repair. A misplaced nail or staple during the construction process and you'll have to replace an entire circuit since you can't make splices outside of a junction box. To repair ceiling cables requires rewiring and replastering the ceiling. And for flooring systems, it can be even worse. A crack in the concrete floor may mean a crack the heat tubing as well. To repair the tubing, the concrete has to be removed, the tubing repaired or replaced, and then the concrete and floor coverings replaced. These repairs are big jobs.

Forced Air

Because of their versatility, forced air systems are the most common heating systems installed today. You can easily incorporate humidifiers, air cleaners, and air conditioners into the same system. A forced air furnace may be fueled by natural gas, oil, or electricity, with gas being the most economical.

Forced air systems are also called central heating systems because they use ductwork to transport heated air from a central heating unit to the desired points of use. The predecessor of the forced air system was the gravity system, which you can still find being used in many older homes today. Gravity systems, like forced air, use ductwork to carry the heated air to the point of use. The difference between these two systems is that in the forced air system a fan forces the hot air through the ductwork. In a gravity system, the heat flows up through the ductwork and pushes the cold air out through cold air returns.

Because the air is fan-forced through the system, you can size the ductwork smaller in a forced-air system than in gravity systems. You can easily recognize old gravity systems by their oversized components. The furnaces are large appliances, sometimes even converted coal burners, and the ductwork is very large in diameter. The combination of furnace and ductwork can take up a sizable portion of a basement. Modern forced-air furnaces are considerably smaller. Because the fan moves the heated air quickly through the ductwork, the furnace doesn't become as hot as a gravity furnace, so it can be placed in smaller, closer areas — even in hall closets.

The Forced-Air Heating Cycle

Forced-air furnaces are fairly simple pieces of machinery. The air is heated by gas or oil-fired burners and then transported out through the duct systems. The furnace is composed of a fuel supply line, a fuel regulator, burners, igniter, heat exchanger, a limit switch at the furnace, and a thermostat to control the temperature in the area to be heated.

The forced air heating cycle follows these steps:

1. As the area cools below the setting on the thermostat, contacts close within the thermostat, completing an electrical circuit.
2. The completed electrical circuit sends a message to the furnace, which opens the fuel valve.
3. The fuel is ignited by either a standing pilot or electronic ignition.
4. The flames from the burners warm the heat exchanger.

5. The limit switch or "thermostat" in the heat exchanger sends a message to the fan control, indicating that the air in the exchanger has reached temperature.
6. The fan turns on and moves the hot air through the supply ducts, which forces the cooler air back through the return ducts to the furnace where it passes through the heat exchanger and is sent out through the supply ducts again. The warm air cycles through the building until it reaches the appropriate temperature in the room where the thermostat is located.
7. When the room is heated to the desired temperature, the thermostat opens the circuit. This sends a message to cut off the supply of fuel to the burners.
8. The fan continues to blow until the limit switch in the heat exchanger indicates that the air temperature has dropped to acceptable levels.
9. The furnace is now "off" until the thermostat once again calls for heat.

A forced-air furnace utilizes two systems of air. The first system is for combustion. The combustion air is brought into the furnace, supplies the flames, and then is vented out of the building. The second system is air that's carried through the supply ducts to the rooms to be heated, and then brought back to the furnace through the return air system. The air in this system passes through a heat exchanger, which is heated by the air in the first system.

The Furnace

Furnaces are rated in Btu's per hour. Use the heat loss for the building to select a furnace with a sufficient Btu output. You may often find two Btu ratings for the same furnace. One is the input rating and the other the bonnet capacity. The input rating is used to determine fuel consumption. The bonnet capacity measures the heat output, and is the measurement you'll need to use to select the furnace size.

Placement — Hot air rises and cold air drops. This simple sentence presents a problem when installing a forced air system with air conditioning.

If you only need heat, you'll get the best efficiency by placing the supply at floor level and the return at the ceiling. If you only need cooling, the reverse is true. When you need both, you must make a choice. Theories aside however, most registers are placed at floor level. That's because most furnaces are placed in the basement, if there is one, and the ductwork run to all the first floor rooms under the floor. By placing the ductwork below the floor, you can avoid having to build chases and soffits to cover the ductwork.

There are many different types of furnace designs, allowing you many options for placement. Upflow furnaces blow the hot air up. Downflow furnaces blow the hot air down. You can install both of these types vertically, and they look very similar in place. A horizontal furnace can force the air either up or down and can be installed in either a crawl space or an attic.

Installation **—** Your first step in installation design is to check the code as well as the specific furnace clearance requirements for your choice of furnace. These are given as side, back, and front clearances to combustible surfaces. Also, make sure you choose a placement location close to a chimney or in an area where you can run a vent through the roof.

Use the following steps as a guide for furnace installation:

1. Select a code- and manufacturer-acceptable site to place the furnace.
2. Place the furnace in position.
3. Install the supply and return heating and cooling ductwork (see Ductwork below).
4. Run a vent to the chimney or through roof.
5. Run ductwork to supply the combustion air.
6. Run the electrical supply to the furnace control box along with low voltage thermostat wire.
7. Install the gas or oil supply lines.
8. Inspect gas, electrical, and furnace installations as required by codes.
9. Fire up the furnace.

Ductwork

Air moves both to and from the furnace through ductwork. The furnace fan forces heated air through the supply ducts into the space to be heated. Return air ducts circulate air back from that space to the furnace. Ductwork is commonly fabricated from galvanized sheet metal. Standard sizes are manufactured in both rectangular and round sizes.

Prefabricated rectangular duct is sized to fit inside standard construction sizes, such as the wall cavity created by standard 16-inch on center stud spacing. Round sheet metal pipe is used in crawl spaces, between joists, or overhead through the truss framing. Some custom sheet metal fabrication is necessary for all installations. You'll often need to have a plenum to fit a furnace, though stock plenums are available from some suppliers for the furnaces they handle. A plenum is a large volume duct to which you attach the smaller duct branches. The branches are usually made up from prefabricated duct. From this large duct, sometimes called a trunk line, you make final distribution runs to the point of use by means of sheet metal piping.

In addition to metal duct, you can also use "vinyl" flexible ductwork for heating systems. Because it's flexible, vinyl duct is easy to install. Flexible vinyl duct does have one major disadvantage, though. Because of the wire support that spirals around the duct giving it shape, it's less efficient than metal duct. The wire creates a rippled texture that impedes the flow of air. You should only use vinyl duct for the branches; the plenum should always be metal.

Bring all the branch ductwork into metal "boots" at the point of air delivery. The boots provide strength, rigidity and shape, as well as providing a backing to which you can attach a grill or register.

Most heating and air conditioning companies have their own sheet metal fabrication shops. Some installers, however, may subcontract the custom fabrication portion of the job to an outside sheet metal shop to cut down on their overhead, especially if they are just starting a heating and air conditioning business.

Insulate all ductwork that's placed in cold air spaces such as crawl spaces and attics. Preassembled insulated vinyl pipe, as well as insulated sleeves, are available for all standard duct sizes. You can easily insulate custom sizes as well.

***Installation* —** The first step in ductwork installation is laying out the supply and return air openings. You may have a heating design prepared by a mechanical engineer that gives the location of the openings. However, in some cases, you may have to make slight shifts in the layout of the openings to accommodate structural framing.

Template for Floor Openings

You can make a simple template for tracing floor openings. Cut out the desired opening on a $^1/_4$-inch or $^3/_8$-inch piece of plywood. Make the cutout 4 inches, or the distance you choose, from the edge of the plywood. By placing the edge of the template against the wall, you will only have to trace the cutout to have the opening consistently placed.

Supply Air Runs —

1. With the floor layouts marked and checked for clearance from structural framing, make the cutouts using a reciprocal saw. (Some installers prefer a lightweight chain saw for making cutouts.)
2. Place the boot in the opening and nail it in place.
3. Use a hanger to place boots in wall and ceiling openings. "Hangers" are made of straps of sheet metal bent to provide rigidity. They suspend the boot in the middle of ceiling joists or stud spaces.
4. Attach the plenum to the furnace.
5. Attach the trunk line(s) to the plenum. Make the supply lines as tight as possible to prevent losing heated air.
6. Run the sheet metal pipe from the trunk line to the boots.

Return Air Runs — The layout and placement of openings, hangers, and boots are the same for return air lines as supply air lines. A plenum-type duct, called the return air drop, feeds the return air into the furnace. Return air lines only bring back cold air, so their tightness isn't as critical as the supply lines. Where possible, pans are typically used in return air systems. You can create a pan by nailing flat sheet metal to the bottom of a joist space. You can then use the box created by the joist space as a return air duct. Use duct, or in most cases pipe, to bring the return air from the pan to the return air drop at the furnace.

Temperature Control

Thermostats are the one furnace control that's familiar to almost everyone. Though most people will also recognize the registers that the heated air comes through. Registers, grills and diffusers are the types of covers you find on ductwork openings. The grill is the most basic cover. It allows air out but can't be adjusted. A register is like a grill except that it has a movable portion that allows you to adjust the amount of the airflow. Diffusers are similar to registers, but they're usually used just with dropped-tile ceilings.

These two controls, the thermostat and the registers, can provide even heat throughout a building. If the thermostat is working properly, you can assume that the room it's placed in will be the temperature indicated on the thermostat. If you have any question about the accuracy of the thermostat, bring in a thermometer to compare readings.

People are sometimes confused by what a thermostat can do. When they check into a cold motel room, for instance, they throw the thermostat up to 90. But a thermostat is nothing more than a switch controlled by temperature. It controls the temperature of the room, not the speed it takes to reach temperature. When a room is below indicated temperature, the switch turns on the furnace. When the room is up to temperature, the switch turns off the furnace. If you want to bring the temperature of a room up from 50 degrees to 70 degrees, set the thermostat at 70 degrees. Setting it at 90 won't help the temperature come up to 70 any faster.

You can achieve even heat from room to room by balancing the registers. The basis for this is fairly simple. If a second room is too cool and its register is wide open, adjust the register in the room with the thermostat slightly to allow less heat to enter. This will cause the furnace to run longer to bring the thermostat up to temperature, and at the same time, send more heated air into the second room. Adding more rooms makes balancing more difficult, but the principal to use in making the adjustments is the same.

Air Conditioning with a Central Air System

One of the beauties of central air is its versatility. Air conditioning is the feature that's made central air systems the primary choice for installation in new homes. As an addition to an existing forced air heating system, the components required for air conditioning are: a condensing unit, a cooling coil, refrigerant tubing, and a thermostat which will handle cooling as well as heat.

The Condensing Unit

The condensing unit is also sometimes referred to as the compressor or the compression cooling system. This is the cooling method most often used in residential air conditioning. The condensing unit is the core of the air conditioning system. It's where the cooling mechanics actually take place. The refrigerant lines and cooling coil only transport the cooled refrigerant gases. The condenser unit does the actual cooling by compressing refrigerant gases to a liquid inside the condenser, and then changing the liquid back into a gas in the evaporator. The gas is compressed from 70 psi to 300 psi before it's expanded back to 70 psi. This is a continuing process in the same manner that water being heated by a boiler in a hot water heat system is a continuous process.

Installing the Condensing Unit

Installing a condensing unit consists of placing the unit on a concrete pad and connecting the electrical wiring.

Place the condensing unit outside of the building on a concrete pad. Check with manufacturer's installation guidelines for the required clearances. These vary from manufacturer to manufacturer, as well as with the orientation of the unit if it's a rectangular unit. Typically, the two refrigerant lines and the electric hook up point come from the same corner of the unit. Orient the condenser so that these connection points face the building.

Connect the condensing unit to the cooling coil with the refrigerant lines (refer to the information under Refrigerant Lines to follow), and attach the electric hook up to power the compressor and fans. Both the refrigerant lines and the electric line need to be protected from damage. Use BX cable for the electric feed.

The Cooling Coil

The air in a forced-air system is heated by blowing it over the heat exchanger. Likewise, the air is cooled by blowing it over a cooling coil. The cooling coil is a radiator type device consisting of tubing and radiant fins. Refrigerant circulates through the coil, which cools the air blowing past the tubing and fins. The coil has an inlet and outlet to attach the refrigerant lines, and a condensate pan that requires a line routed to a proper drain.

Cooling Coil Installation

Place the cooling coil directly above the furnace inside the plenum. You'll have to cut an access hole in the plenum if one hasn't been provided. Use the instructions provided by the manufacturer for the specific sizes and steps. You need to install the coil with a tight fit for optimum cooling. Be sure you use a $^{3}/_{4}$-inch condensate drain line, made from copper or PVC tubing, to complete the installation. The purpose of the line is to carry away moisture that condenses from the cooling process.

Refrigerant Lines

Two refrigerant lines run from the condensing unit to the cooling coil. These lines come with a partial charge, that is, they are partially filled with refrigerant. When ordering the lines from your supplier, you'll need to select a standard size in the length you need or longer. Because the line is filled with refrigerant, you can't simply cut it to length and add a new end piece. You'll have to coil it up or loop it around in the crawl or attic space that you're feeding it through if it's too long.

Refrigerant Line Installation

The refrigerant lines are two different sizes, as are the connections on both the cooling coil and condensing unit. Both lines come coiled and boxed from the supplier. When you remove the line from the box, check for any damage. If it's kinked, return it to the supplier. If it appears to be fine, follow the installation instructions provided with the compressor and cooling coil. They should be similar to the following:

1. Unroll the line, being careful not to damage it.
2. Feed the line from the condensing unit to the cooling coil. Make no bends tighter than a 6-inch radius.
3. Unless otherwise instructed by the manufacturer, remove the protective caps from the ends and attach to the condenser and cooling coil in the following sequence:

    a) Connect the large tube to the cooling coil.

    b) Connect the small tube to the cooling coil.

    c) Connect the large tube to the condensing unit.

    d) Connect the small tube to the condensing unit.

The Cooling Cycle

A central air conditioning unit works in the following manner. When the thermostat calls for cooling, the condensing unit comes on and sends cooled refrigerants through the cooling coil. The fan then blows air over the cooling coil and through the ducts to the point of use. When the temperature is down to the desired level, the thermostat switches off, which in turn shuts down the condensing unit and then the fan.

Manhours

Manhours to Install Ductwork for Forced Air Heating Systems, per SF of living area		
House Size	**Manhours**	**Suggested Crew**
1,200 SF or less	35.8	1 HVAC installer
1,200 to 1,900 SF	43.9	1 HVAC installer
1,900 to 2,400 SF	53.7	1 HVAC installer
2,400 to 2,900 SF	69.9	1 HVAC installer
2,900 to 3,400 SF	100.0	1 HVAC installer
3,400 to 3,900 SF	130.0	1 HVAC installer
3,900 to 4,500 SF	162.0	1 HVAC installer

Manhours to Install Heating Systems, per each		
Unit	**Manhours**	**Suggested Crew**
Hydronic (hot water) heating assembly; includes insulated supply and return mains, insulated branch piping, radiant heat baseboard convectors, hot water boiler, circulation pump and electric controls (based on 1,200 SF of heated space)		
Distribution system, first floor	46.0	1 plumber, 1 laborer
Second floor	16.0	1 plumber, 1 laborer
Boiler, pump and controls	16.0	1 plumber, 1 laborer
Radiant baseboard and valves, first floor	16.0	1 plumber, 1 laborer
Second floor	12.0	1 plumber, 1 laborer
Electric-resistance heating cable (radiant heat)		
Ceiling installation, copper inner resistance wire embedded in gypsum	.036	1 electrician, 1 helper
Floor installation, copper inner resistance wire core sheathed with aluminum, with a cross-linked polyethylene outer layer. Per SF of exposed floor space.	.60	1 electrician, 1 helper
Electric baseboard heater, standard grade (3 LF minimum, 188 watts per LF)		
Includes up to 18 LF #18/2 thermostat wire, box and line thermostat	.512	1 electrician, 1 helper
Remove and replace	.716	1 electrician, 1 helper
Forced air heating system, includes connection only. Does not include wiring run, plenums, ducts, or flues (see table for ductwork following)		
Electric furnace		
10,200 Btu	10.8	1 HVAC installer
34,100 Btu	13.8	1 HVAC installer
Remove and replace	5.20	1 HVAC installer
Gas furnace		
45,000 Btu	11.3	1 HVAC installer
100,000 Btu	15.0	1 HVAC installer
Remove and replace	5.08	1 HVAC installer

Manhours to Install Heating Systems, per each (continued)		
Unit	**Manhours**	**Suggested Crew**
Oil furnace		
56,000 Btu	12.4	1 HVAC installer
134,000 Btu	17.8	1 HVAC installer
Remove and replace	5.44	1 HVAC installer
Double wall furnace flue (all fuels)		
4" diameter	.318	1 HVAC installer
8" diameter	.533	1 HVAC installer
Air conditioning unit, through-wall		
5,000 Btu	8.83	1 HVAC installer
18,000 Btu	11.8	1 HVAC installer
Remove and reinstall	4.96	1 HVAC installer
Combination AC and heat unit, through-wall		
6,000 Btu	10.2	1 HVAC installer
11,300 Btu	12.2	1 HVAC installer
Remove and reinstall	5.37	1 HVAC installer
Thermostat, electric line		
Heat only	1.53	1 HVAC installer
Heat and air conditioning	2.38	1 HVAC installer
Remove and replace	.623	1 HVAC installer

For information on related topics, see:

Electrical Installations, page 269

Fireplaces and Chimneys, page 291

Insulation, page 395

Radon and Other Pollutants, page 499

Ventilation, page 701

Wall Framing, page 709

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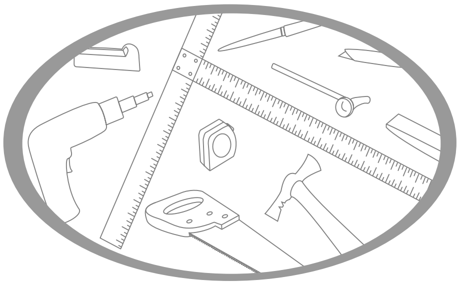


Insulation

Prior to the energy crisis in the mid-1970s, little attention was given to efficiently heating and cooling homes. Energy costs were a minor part of an owner's expense, so most homeowners didn't consider spending money during construction to save money later. All that has changed. Now a new home buyer understands that a well-designed insulation system is as essential as an efficient floor plan.

The Movement of Heat

Heat travels from warm areas to cool areas. Practically speaking, this means that in winter the warmth of a house flows out, resulting in heat loss and driving up the cost of heating a house. During the summer, the opposite happens; the heat flows into the house, resulting in a heat gain and increasing the cost of cooling the house.

This movement of heat occurs in three specific ways — conduction, convection, and radiation — which combined can make the process of effectively insulating a structure far more complicated than just filling the spaces between studs with insulating material.

Conduction

Conduction occurs when heat passes through a solid material. The more solid or dense the material, the more efficiently it conducts heat. If you hold a steel rod in a fire long enough, the heat will travel, or be conducted, the length of the rod and into your hand. Likewise, heat on a brick wall passes through the brick to the other side of the wall.

Convection

Convection conveys heat by moving it through air or water. Most common home construction designs utilize air for convection heating. Warm air rises while cool air falls, creating a constant, if imperceptible, air movement. In a house, air leaking through spaces around windows and doors are a common source of convected heat loss.

Radiation

Heat radiation occurs when an object is so hot that heat radiates from it. The sun's heat is a form of infrared rays, as is the heat from a stove.

Preventing Heat Transference

Because all three of these means of heat movement interact to raise utility bills, you should use insulation where the heat transference is the greatest. Install insulation in ceilings under unheated spaces, around ductwork in unheated spaces, in exterior walls, and under floors over unheated spaces. These will produce the biggest savings in heating and cooling bills. Plugging air leaks also helps, although a house that's too airtight can create additional problems, particularly in areas where radon gas is a problem. To solve interior pollution problems, you need a good air exchange system to bring fresh air in without compromising the airtightness of the house. (See *Radon and Other Pollutants* for additional information on this subject.)

Insulation is designed to prevent all three types of heat flow by the following means:

- Insulation materials don't conduct thermal energy, or heat.
- Infrared rays are absorbed or scattered by insulating materials to stop heat transfer.
- Insulating materials stop convective heat movement by trapping air in thousands of tiny air pockets.

Insulation Ratings

In order to compare the values of various types of insulation, you'll need to understand what the different ratings mean. The simplest and most common way to rate an insulating material's effectiveness is by how well it resists the transfer of heat. Its resistance factor is denoted by the letter *R* and a number. The higher the number, the more effective it is as an insulator. This is true regardless of whether you're comparing similar types of insulation made by different manufacturers or completely different types of insulation. An R-value of 10 is always a better insulator, regardless of the material, than an R-value of 8.

All components of a structure — the drywall, studs, insulation, and siding — have an R-value, and by adding them together, you get a total number. For example, 8-inch concrete block is rated R-2 and 3/8-inch drywall is rated R-32. However, when an architect specifies an R-value, it will be for the insulation material alone.

A less common and more complicated rating system is designated by the letters *C*, *U*, or *k*. These refer to the number of Btus that are transmitted in 1 hour through 1 square foot of material that's 1 inch thick with a temperature difference of 1 degree Fahrenheit across the material. The lower the number, the better the insulating value. Specifically, *k* is used when the material being tested is 1 inch thick; *C* or *U* are used with materials that are other than 1 inch thick. C- and U-values don't correlate equally to R-values. To find the R equivalent to one of these values, divide 1 by the given C-value or U-value. The result is the material's R-value. For example, a $^1/_4$-inch window has a C-value or U-value of 2. When you divide 1 by 2 you get 0.5:

1/C- or U-value = R-value

or

$$1 \div 2 = 0.5$$

Thus the R-value of the window is 0.5.

The R-value is used almost exclusively for all insulating materials. C- or U-values are used only for glass, and you'll very rarely find k-values referred to at all.

Insulation requirements vary with the climate and region you're working in. Figure 1 gives some general recommended R-values for different areas of the country. Refer to your local building code for specific numbers.

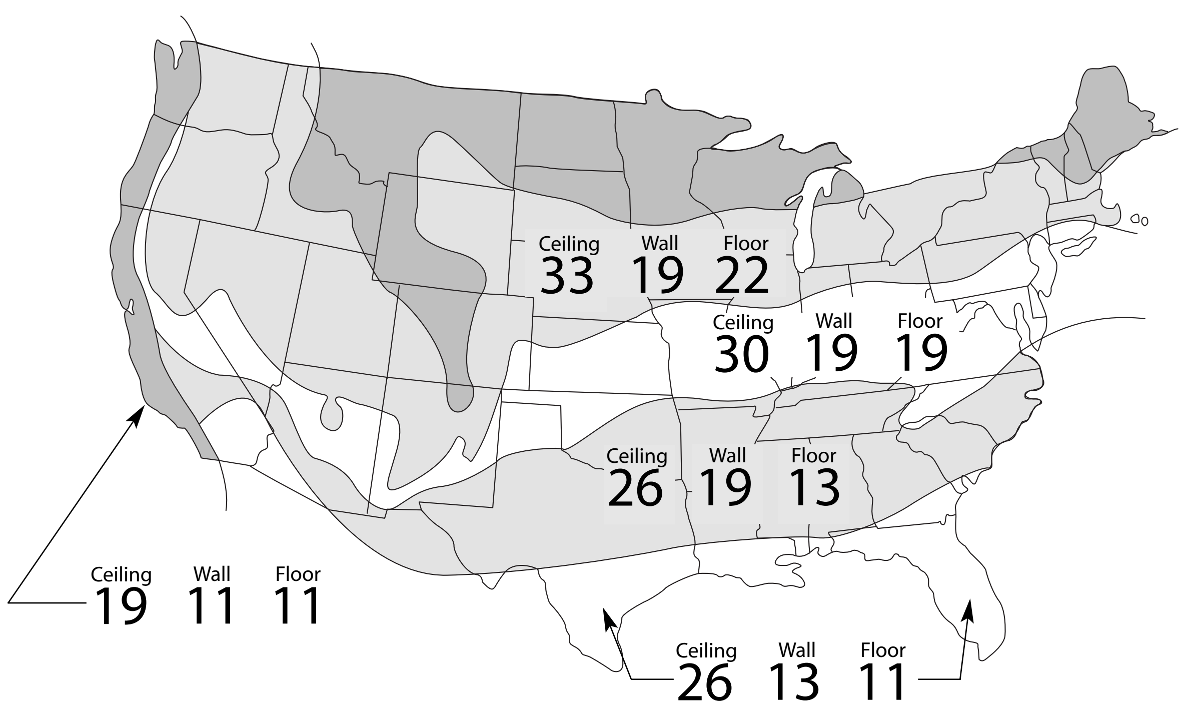


Figure 1
Recommended R-values

How Much Insulation Do You Need?

Is more better? It depends on the type of insulation and whether you're talking about thickness or density. Generally, if you double the thickness of insulation, you're doubling the R-value. With low-density insulation, though, there seems to be a slight, perhaps 5 percent, diminishing of return.

Density versus value is more complicated. Batt insulation that's stuffed into a space half as thick as it should be will result in a higher R-value per inch than if it were in a less cramped space. But you'll also have fewer inches of thickness, ultimately decreasing the overall R-value.

For blown insulation, the question of whether more is better takes a slightly different turn. Blown fiberglass increases considerably in R-value as its density increases, although twice as much fiberglass doesn't translate into twice the R-value. With blown cellulose, on the other hand, increasing the density actually decreases the R-value.

Remember that one of the keys to effective insulation is to have thousands of tiny air pockets to prevent air movement. If some of the air pockets are eliminated, so is some of the insulating value. Another factor to keep in mind is that wood is a better heat/cold conductor than insulation. So if you use 6-inch studs placed 24 inches on center rather than 4-inch studs placed 16 inches on center, the insulating value will be higher because you've reduced the square footage of the conductor (the wood) and raised the square footage of the insulation.

Estimating Insulation

Batts and Blankets

Batt insulation comes in a variety of widths, lengths, thicknesses, and R-values to fit the space between studs, and the specific needs of the job. The insulation is packaged in rolls or bundles, either faced or unfaced.

Unfaced rolls are slightly wider so they can be pressure fitted. The faced batts or blankets have a vapor barrier facing of either aluminum foil (0.5 perm) or asphalt-impregnated paper (0.1 perm). (Perm values will be explained in detail later in the chapter.) The R-value is listed on the facing, or on labels or coded strips on unfaced insulation. You can place batts and blankets in layers to reach a higher R-value.

The rolls have the square footage marked on the package. To estimate how many rolls you need, first find the square footage of the area to be insulated, then divide the square footage by the amount stated on the insulation roll.

For example, you need 1,285 square feet of insulation, and you're buying rolls with 86 square feet per roll. Divide 1,285 by 86 and you get 14.6, so you'll need 15 rolls. Some estimators deduct 5 percent to allow for studs and joists, but we've found that except for very large jobs, it really isn't necessary. Besides, you can always return unused material.

Secure the edges, or flanges, of the insulation to the stud or joist — usually with a staple, but they can be nailed — at least 6 inches on center. Allow 160 fasteners per 100 square feet of insulation.

Rigid Insulation

Rigid insulation comes in 4 × 8 or 4 × 9 sheets. The sheets are usually perforated so you can snap off the size you need. Rigid insulation is used primarily against concrete and is usually held in place by backfilling dirt, although in some instances you might want to use fasteners or adhesives to hold it. Again, figure the square footage of the area you're going to cover and divide by either 32 or 36 square feet to determine the number of sheets to buy.

Loose-Fill or Blown Insulation

Loose-fill insulation is sold by the bag. The label on the bag should have a coverage chart listing the number of bags needed to cover 1,000 square feet. You can find the number of bags you need to meet a specified R-value of loose fill with two measurements: the minimum thickness of the installed insulation and the minimum weight per square foot of the installed insulation. Since actually measuring the thickness and weight isn't practical, the way you ensure that you have the correct coverage is to use the recommended number of bags for the minimum amount of coverage.

Types of Insulation

Although R-value is extremely important in choosing an insulating material, other factors may have more impact. For instance, although fiberglass batt insulation is a cheap and efficient insulation material for new construction, it's expensive and impractical for remodeling.

The chart in Figure 2 has information to help you select the proper insulation material for various areas of construction.

Radiant Barriers

Research suggests that in cold climates radiant barriers are of little use because they appear to work best to prevent heat gain rather than prevent heat loss. In warm climates, though, a radiant barrier is often installed on top of regular insulation in the attic to reduce heat gain in the summer. It does this by reducing the amount of warm air that's

Type	Cost per R*	R-value per Inch	Perm Value	Common Uses	Flame Resistance	Water Damage Resistance	Advantages	Disadvantages
Fiberglass batt, blanket, or roll	1	3.5	Unfaced: more than 100 Faced: depends on facing	New construction; walls, floors, ceilings	Medium; fibers nonflammable but resins binding fibers will burn if hot enough	High	Easy installation; nonsettling	Doesn't resist air leakage; may gap; can't be used in remodeling; growing questions about possible health hazards
Rock wool batt, blanket, or roll	1	3.2	Unfaced: more than 100 Faced: depends on facing	New construction; walls, floors, ceilings	High	High	Easy installation; nonsettling	Can't be used in remodeling
Blown fiberglass	1	2.2	More than 100	Flat ceilings that have access; retrofitting	Medium	High	Good coverage over trusses, ceiling joists and hard to reach areas	Growing questions about possible health hazard; must be carefully installed to avoid voids
Blown rock wool	1	3.1	More than 100	Flat ceilings that have access; retrofitting	High	High	Good coverage over trusses, ceiling joists and hard to reach areas	Must be carefully installed to avoid voids
Blown cellulose	1-2	3.7	High	Flat ceilings that have access; retrofitting	Treated, high; Untreated, dangerously low	Low; once wet has no insulating value	Good coverage over trusses, ceiling joists, and hard to reach places; requires simple equipment to install; uses recycled material	Standards vary, particularly with small manufacturers; messy to install; may settle
Blown urea formaldehyde (UF foam)	2	4.2	9	Flat ceilings that have access; retrofitting	High	High	Nonsettling; smoke less toxic than plywood	No longer used due to potential health hazard
Polystyrene beadboard	2	3.9	4	Walls; foundations; attics	Low; smoke is highly toxic	High	Easy to install; good for below grade walls	Not a vapor barrier
Extruded polystyrene (Styrofoam)	4	5.25	6	Walls; foundations; attics	Low; smoke is highly toxic	High	Excellent vapor barrier	May contain CFC's**; should be covered with fire-rated sheathing
Polyurethane U-thane Urethane	5	9.0	1	Concrete; roof decks	Very low	Very high	High R-value	Produces cyanide gas when it burns; banned in some areas; may contain CFC's**
Radiant barrier (reflective foils)	N/A	N/A; doesn't replace exsisting insulation	0.1 to 0.3	Stapled to rafters in hot climates	High	High	Works better than additional insulation	Requires air space of 3/4 inch or more in front of it; not proven for use in colder climates; well designed ventilation very important

*The cost per R is given on a scale of 1 to 5, with 5 being high. These are material costs only and don't include installation. Costs will vary from year to year and from region to region; these are only a general guide.

**Chlorofluorocarbons: Formerly a component in insulation material, most manufacturers have stopped using CFC's because of the damage they do to the ozone layer.

Figure 2
Types of insulation

radiated across a space. Made up of foil-coated materials such as kraft paper, plastic films, or plywood sheathing, radiant barriers depend on an air space of at least $^3/_4$ inch to be effective. If the surface of the barrier touches another surface, it loses its reflective quality.

You can install radiant barriers vertically or horizontally. The easiest way is to lay it horizontally over the ceiling insulation. Initially, this is a fairly effective method. However, as dust in the attic settles onto the barrier, it loses its reflective quality. Within a matter of three or four years, it can lose up to 50 percent of its effectiveness.

Vertical installation is called draping and is done by stapling the barrier to rafter bottoms or truss top chords. It can also be stapled to roof sheathing near the rafters or top chords, allowing it to drape, or hang in channels, between rafters.

Moisture Problems

The R-values listed in Figure 2 are accurate as long as the insulation isn't exposed to any moisture. All insulation loses some of its thermal performance value when it gets wet. Even after the material dries out, there may be permanent damage. This is particularly true with a material like cellulose. When it gets wet, it turns into a paper-mache like substance, losing all of its insulating properties. Insulation also swells when it gets wet and shrinks as it dries, which leaves gaps. And a gap is a gap, whether it's due to a failure in the installation or created by a moisture problem affecting the insulation.

The most obvious sources of moisture and water problems are things like ice dams, driving rain, or leaky pipes. If water from these penetrate the insulated areas of a building, it will cause damage to the insulation, as well as the rest of the structure. Usually the problem makes itself known, either in the form of leaks or stains.

A more difficult moisture problem, and one that often goes undetected, is water vapor. Water vapor is created by cooking, bathing, high humidity in the air, or even from people. Warm, moist air travels through walls, gets trapped, and condenses as it cools. To prevent moisture problems, place an airtight vapor barrier on the warm side (interior) of the wall, in between the insulation and the wall. Leave the cool side (exterior) unsealed. This will prevent moisture from getting trapped in the insulation. All structures in areas with an average winter temperature of 35 degrees Fahrenheit or below require a vapor barrier.

Vapor Barriers/Vapor Retarders

Some types of insulation, such as some fiberglass batts or rigid foam, are designed with one side faced as a vapor barrier or retarder. If you install two layers of this faced insulation, remove or tear holes in the vapor barrier of the second layer.

Fiberglass batts with vapor barriers have flanges along each side. Staple these flanges to the edge of the stud, even though installing them this way will make it harder to finish the wall. If you staple the tabs inside the stud, there'll be gaps where moisture can creep in. Theoretically, stapling the tabs to the stud correctly will provide a good vapor barrier. Realistically, though, moisture can still permeate through the seams, which are difficult to seal completely.

Let me add a little note here about the term vapor barrier. It's technically incorrect since even the best material allows a small amount of moisture through. The term *vapor retarder*, which suggests that vapor is slowed rather than stopped, is more accurate but is much less commonly used.

If you're not using fiberglass batt insulation, you can paint the interior wall with a low-permeation primer as a way to create a barrier. Regardless of the type of insulation you use, however, the best insurance is to seal the walls with polyethylene sheets. Use the following as a guideline: Install the insulation, do the rough wiring, install ductwork and window frames, and then staple 4- to 6-mil polyethylene onto the studs or joists before you hang the drywall or lay the subfloor. Overlap the vertical joints of the polyethylene by one stud, covering everything completely (including window and door headers, top and bottom plates, outlets). Hang the drywall, and then use your utility knife to cut away the excess polyethylene. Caulk all the cracks, and finish by installing the wood trim.

Perm Values

A vapor barrier's effectiveness is rated according to the permeability of its surface, or its *perm value*. That's the amount of water, measured in grams, that passes per hour through a square foot of material per inch of mercury difference in vapor pressure. The lower the perm value, the better the vapor barrier. Under 1.0 is a barrier or retarder; above 1.0 is a breather and shouldn't be used as a vapor barrier.

Ideally, the perm value of the exterior material should be several times higher than the perm value of the interior ones. A 5:1 ratio of cold side to warm side is commonly used. However, this isn't always easy to do because building materials vary considerably in their permeability. For instance, $^3/_8$-inch drywall has a perm value of 50.0, and a 4-mil polyethylene sheet has a permeability of .08. A $^1/_2$-inch sheet of exterior plywood has a low rating of 0.5, which could create a problem by trapping moisture. How do you follow the 5 to 1 rule of thumb? The only way to prevent problems is through adequate ventilation.

One final note of caution: Standard vapor barriers are highly flammable and shouldn't be left exposed. Code requires that they be covered with a material such as drywall even when they're installed in storage areas or garages or other areas that aren't used as living space but may be used for service work.

Air Infiltration

The infiltration of air also reduces the effectiveness of insulation. Air passes through a variety of places in a building, such as electrical outlets and fixtures, plumbing stacks, vent fans, and of course around windows and doors. A correctly installed vapor barrier also acts as an air barrier.

If you want to seal a structure completely, you can place an additional air barrier on the exterior side of the insulation. It will stop air from moving through, but still allow moisture to pass through. This is an important difference. Since the barrier is placed on the exterior, you want to keep moisture from being trapped inside the wall where it could do damage. Like vapor barriers, air barriers are commonly made of polyethylene, but the polyethylene in an air barrier consists of a spun fiber material rather than a solid sheet.

Placing Air/Vapor Barriers

It's extremely important to have a solid fit for an air/vapor barrier. In fact, you can lose so much heat from gaps that correctly installing an air/vapor barrier is actually more important than using additional insulation. The table in Figure 3 provides suggestions for the types of air barriers to use at various building locations. Keep these two guidelines in mind when placing a barrier:

- First, the barrier should be as close to the interior surface as possible. Logically then, for walls and ceilings, place the barrier just below the drywall or plaster. For floors, where you place the barrier is determined by whether or not there's an unheated crawl space. An unheated crawl space needs two barriers, one under the subfloor and a second on the ground. If you have a heated basement below, you can place the barrier between the subfloor and the finished floor.
- And two, the barrier should fit tight around all openings. Even small gaps will cause moisture problems. If a barrier is cut or torn, repair it with duct tape. You will also need to caulk around all openings.

Keeping the Customer Informed

Too many fly-by-nighters with too many undelivered promises have caused increased regulation in the insulation industry. If you install insulation, you need to follow the U.S. Federal Trade Commission guidelines listed below. If you hire a subcontractor to install the insulation, get the required paperwork from him to pass on to your client.

Area	Perm Value	Materials
Walls, ceilings, floors	0.25 or less	Asphalt coated or laminated papers; Kraft-backed aluminum foil; Polyethylene; Aluminum paint; Foil-backed drywall
Concrete slabs	0.50 or less	Polyethylene; Roll roofing; Asphalt laminated papers; Papers with laminated films
Crawl spaces	1.0 or less	Polyethylene; Asphalt laminated papers

Figure 3
Air/vapor barriers

1. Provide the customer with a fact sheet explaining the insulation, included in the explanation should be the wording "the higher the R-value, the greater the insulation power."
2. Provide a signed and dated contract or a receipt along with a sheet that lists the type, thickness, and R-value of the insulation installed in each part of the home.
3. Loose-fill insulation requires a contract or receipt identifying the coverage area, thickness, R-value, and number of bags to be used.

Installing Insulation

If you're working with new construction, install the insulation just before the drywall is hung. That means that the structure is enclosed, the windows and doors are set, the roofing installed, and all plumbing, wiring, and ductwork is in place. There are exceptions to this, such as architectural designs that include low-pitched roofs. In that case, it's almost impossible to wait on the insulation; you'll need to install it while the spaces are still accessible.

Batt and Blanket Insulation

Because insulation works on the principle of trapped air, whenever possible, you should install batt or rigid insulation so that it doesn't touch either the exterior or interior wall. (Of course with blown insulation this isn't possible.) With reflective insulation, leave at least a $^{3}/_{4}$-inch air space between the foil and the surface.

One dilemma installers often have is whether to staple the flanges to the face of the stud or the inside. Drywallers don't like the flanges or a vapor barrier on the face of the studs because the drywall adhesive only holds the drywall to the vapor barrier and not to the stud. However, as we said earlier, stapling the flanges to the inside of the stud leaves too many gaps. For good vapor barrier protection, the best solution is to place the vapor barrier properly and use screws, rather than adhesive, to attach the drywall to the studs. Staple the flanges, or tabs, to the exposed side of the studs every 6 inches on center. Then seal with an air/vapor barrier such as polyethylene.

Butt the joints as tight as possible. Overlap the facing at joints and ends by cutting back the insulation 2 inches on one of the ends. Fit insulation around all obstacles in the wall, but don't stuff it in too tightly or you'll lose some of the R-value. Be very careful to fill in all the space around pipes, electrical boxes, ductwork, and so on. Think of installing insulation the same as you would about sealing a roof. Even a small leak can result in a lot of damage, although proportionately the leak may be very tiny. Likewise, any spaces or voids in the insulation decreases the overall effectiveness of the insulation by an amount far greater than its size.

Insulation can create a fire hazard if you place it too close to recessed light fixtures or exhaust fans. Before insulating, place wood blocking between joists about 3 inches away from the fixtures. Also, remember to insulate around all pipes and ducts, especially on sides that are exposed to the cold.

CAUTION: Allow a 3-inch space around metal flues and recessed light fixtures. Keep air spaces free around metal chimneys and fireplaces. You can insulate around masonry chimneys, but only use unfaced mineral fiber insulation. When working with fiberglass, always wear protective clothing and a dual-cartridge respirator. Shower immediately after insulating to remove any particles from your skin.

Insulation for New Construction

Sill sealer insulation: Sill sealer comes in 50- to 100-foot rolls, up to 6 inches wide and 1 inch thick. Lay it on top of the foundation wall, and then fasten the sill to the wall. The insulation compresses to about $^{1}/_{32}$ inch in the process, sealing voids and air leaks.

Miscellaneous spaces: Cut the insulation about an inch wider than the space to be filled. Remove the facing material and pack insulation into all odd spaces, such as around doors and windows and between studs at the corners and where the interior and exterior walls meet.

Tools and Materials

You'll need the following materials for your installation:

- *Utility knife*
- *Tape measure or plumb bob*
- *Yardstick (to tuck or push insulation where you can't reach)*
- *Staple gun*
- *Protective clothing (hat, gloves, goggles, long sleeves)*
- *Dual-cartridge respirator*

Insulation for New Construction or Remodeling

Headers: Cut strips of insulation into blocks, and pressure fit or staple them between each joist.

Rim or band joists: Cut strips of insulation to width, and staple or nail them to the joists. For faced insulation, you can undercut the insulation slightly to create makeshift flanges for easier attaching.

Walls:

1. Work from the ceiling down. Install batts, facing out, between studs, leaving an air space between the exterior wall and the insulation. Staple the edges every 6 inches on center.
2. With unfaced batts, the insulation stays in place by friction rather than with fasteners. Batts should fit very snugly. With wood studs, the batts should be about $^1/_4$ inch wider than stud width; with metal stud framing, they should be 1 inch wider.

Double walls: Use unfaced batts for the exterior wall, or remove the vapor barrier if the insulation has one. Place the vapor barrier to the inside wall.

Ceilings: Either lay batts over finished ceiling or install it from underneath before you hang the drywall. Staple it to the face of the joists and install a vapor barrier on the interior side of the structure.

Cathedral ceilings: Work from the peak down. Staple the insulation in place, with the vapor barrier to the inside of the structure. Or, you can pressure fit the insulation between rafters. Allow at least an inch between the insulation and roof sheathing.

Attics: You can use two layers of insulation to achieve the recommended R-value. If the insulation comes with a vapor barrier, remove the vapor barrier from the top layer so moisture doesn't get trapped.

If the attic has pre-engineered trusses, install all the insulation between the bottom chords, whether you're using just one layer or two or more layers of insulation. In open attics where the joists and rafters are connected only at the sidewalls, place the second layer of insulation at right angles to the first.

Leave an inch of unblocked air space between the insulation and roof sheathing wherever there are soffit vents. Place foam baffles between the rafters to keep the insulation from blocking the vents.

Unheated attic:

1. Lay the batts between joists with the facing down. Work from the outer walls toward the center.
2. Weatherstrip around vents, windows, and access doors. Cut a batt or rigid insulation board the size of the access door and attach it.

Heated attic:

1. Install batts, facing to the attic interior, between rafters, leaving an air space between the exterior wall and the insulation. Staple edges every 6 inches on center.
2. Also insulate:

   (a) between collar beams

   (b) knee walls

   (c) ceilings with cold space above

   (d) dormer walls

   (e) dormer ceilings

Floors: You can use reverse-flange batts for floor insulation. These have a vapor barrier on the side that should go next to the subfloor and a breather paper on the other side that has stapling flanges. In highly humid areas, you should also use mesh or wire lacing.

1. Place batts, facing up, between joists. Fasten in place every 24 inches and not more than 6 inches from the ends of the batt.
2. Hold the batts in place with straight rigid galvanized wire fasteners. The pointed-end fasteners come in lengths to fit 12-, 16-, 18-, 20-, and 24-inch spans. As you place the batts, set the fasteners between the joists and bow them up to hold the insulation against the subfloor.
3. Another option is to staple or nail nylon mesh or galvanized wire to the bottom of the joists. You can also staple string or wire to the joists in a staggered, angled pattern.
4. At cross braces or bridging, cut the batt to length. Split it down the center 6 inches or so. Tuck one half into the lower opening of the bracing and the other half into the upper opening. Or, butt the insulation against the bracing, and pack insulation scraps into the gaps.

Foundation walls: Masonry wall insulation comes $^3/_4$ to $1^1/_2$ inches thick (R-3 to R-6). It's placed between furring strips and held in by pressure. For thicker insulation, build a separate frame wall. Set the framed wall up to an inch away from the masonry wall (see *Wall Framing*). Insulate as you would for a regular wall, with the vapor barrier to the interior.

Unheated crawl space:

1. Cover the ground with a vapor barrier.
2. Cut the batts so they hang the full length of the wall plus an extra two feet. Nail or staple insulation batts to the joists, with the vapor barrier to the inside of the crawl space. Or attach the

batts directly to the band joist, placing the insulation between the joist and a furring strip. Butt-joint the pieces so there isn't a gap.

Insulating around obstructions: You should tolerate the same number of insulation gaps or voids in a structure as leaks in a boat — zero. Pack insulation into all gaps and around obstructions. Likewise, keep in mind what you need to keep warm (or cool) within a wall — such as pipes and heating and air conditioning vents — and insulate to that purpose.

Electrical:

1. Stuff insulation between the exterior sheathing and the back of junction boxes for outlets and switches. Fit insulation tightly around the boxes.
2. If wiring is strung through the studs close to the inside wall, insulation can be tucked behind the wiring. If the wiring is centered in the studs or close to the exterior wall, cut the insulation to butt snugly above and below the wires.
3. Install insulation at least 3 inches away from recessed light fixtures. They need air circulation to keep from overheating.

Plumbing: Wedge insulation between pipes and the exterior sheathing. Never put insulation between the pipe and the interior wall.

Air ducts: Pack insulation behind ductwork and exterior sheathing.

Loose-Fill Insulation

Generally, you'll only be working with loose-fill insulation as part of a retrofit for an older structure. It's important that the installation crew know something about the carpentry in older homes in order to understand what kind of obstacles to expect, where to expect them, and how to patch after blowing the insulation.

In spaces that are easily accessible, such as an attic, you can pour or blow loose-fill insulation between rafters and then level it with a rake. To blow insulation into inaccessible spaces, you'll need a blowing machine. You can usually rent one where you buy the insulation. Different nozzles are available, so check with the supplier to make sure you have the right ones for the job you're doing. Sometimes you may need to use your hand to deflect insulation, but try to keep this to a minimum.

Blowing insulation into walls means that you have to cut holes in the exterior and patch them when you're done, but generally that's your only option when retrofitting. Blowing insulation takes two people, one to fill the hopper and one to handle the hose. Make sure both are wearing protective clothing and have dual-cartridge respirators.

One serious problem with blowing loose-fill is that you can't add a vapor barrier. The only alternative available for this situation is painting the interior walls and ceilings with a low-permeation primer. Although it's not as effective as polyethylene, it provides a barrier that's better than nothing at all.

Attic: When blowing an attic space, divide the area to be covered, and the specified number of bags, into four equal sections. It'll be easier to gauge and ensure that you're spreading the insulation evenly.

1. Cover vents to keep insulation from falling into them and to prevent air blowing through the vents from moving the loose insulation around. Remove the covers when the job is complete. Or shield the vent openings with prefabricated baffle boards or polyethylene.
2. Blow the insulation with, rather than across, the joists. Work a space of about three or four joists at a time, keeping the hose close to the floor. Let the insulation fall 4 to 10 feet in front of you. Rake or screed the insulation for an even distribution.
3. Check all around any obstructions such as wiring, cross-bracing, or chimneys to make sure the insulation is even and complete.
4. If it's too difficult to reach the ends of the joists, you can bounce the insulation off the underside of the roof. But be careful not to block vents.
5. Weatherstrip around vents, windows, and access doors. Cut a batt or rigid insulation board the size of the access door and attach it.

Floors:

1. You can only blow insulation about 4 to 6 feet under floorboards, so you'll have to remove the flooring about every 8 to 12 feet. If there's a lot of bracing or wiring, you may have to remove flooring even more often. Stick a steel tape measure into the space to find cross bracing.
2. Push the hose under the floorboard. As the machine blows the insulation, snake the hose slowly out of the hole, twisting and turning it as you do, in order to fill all the spaces.

Knee walls: Cut holes in the interior wall, blow the insulation, and then patch the holes.

Interior walls: Whenever possible, try to blow insulation from the interior rather than the exterior. This is especially important with stone, brick, and stucco exteriors, as they are difficult to patch (particularly stucco, which is hard to match in color). Drill through the plaster or drywall, following the guidelines listed below for exterior walls. Save the drywall plugs and reuse them when patching. (See also *Repairs* under *Drywall* or *Plaster*.)

Exterior walls: A more complicated and more expensive alternative is to drill through exterior walls to blow insulation. In older homes, you may be able to gain access into the space between studs by removing the eaves panels. Or you can expose the sheathing by taking off the exterior trim. You can drill holes in the sheathing, blow in the insulation, and then reinstall the trim without a lot of extra patching. But even if you do it this way, you'll still have to drill additional holes in the exterior to get good coverage.

To get the most even coverage, don't try to blow more than 4 feet down or 12 inches up. Be careful not to overfill cavities, or you may cause damage to the drywall inside. Use the following guidelines:

1. Turn off the electricity along the wall you're working. Open the soffit panels or drill holes every 16 or 24 inches between studs. Stick a tape measure or plumb bob into the hole to find out if there's cross bracing or any other obstacles. (Current code requires cross bracing every 10 feet; older homes may have bracing or fire stops more often.) Drill under the bracing as well as under all windows and other obstacles.
2. Begin by filling the lower holes. Push the hose into the cavity. As the machine blows the insulation, snake the hose slowly out of the hole, twisting and turning it as you work, in order to fill all the spaces.
3. When the hole is filled, hand pack batt insulation into the hole and patch the exterior.

Opening Up Exterior Sidewalls

Usually, getting into the sidewall is easy enough. Doing it without having to go back and do a lot of patching is more complicated. Basic carpentry skills are really useful at this point. If you have to get into brick or stone walls, first read the section on masonry repair so you can avoid potential problems.

Clapboard Siding —

Removal:

1. Free the vertical end joints of the clapboard on either side, or cut new vertical joints with a back saw if you only have to remove part of the board.
2. Using a chisel as shown in Figure 4, lift the bottom edge of the clapboard (1) that you need to remove, and cut the nail (A) that's holding it in place with the chisel or a nail saw.
3. Pry the bottom of the clapboard above (2) up with the chisel and cut the nail (B) in the lower edge. (You don't need to cut the nails if they come off with the clapboard when you pry it from

Tools

- *Back saw*
- *Wide-faced chisel*
- *Curved siding chisel*
- *Claw hammer*
- *Nail set*
- *Nail saw*
- *Drill*

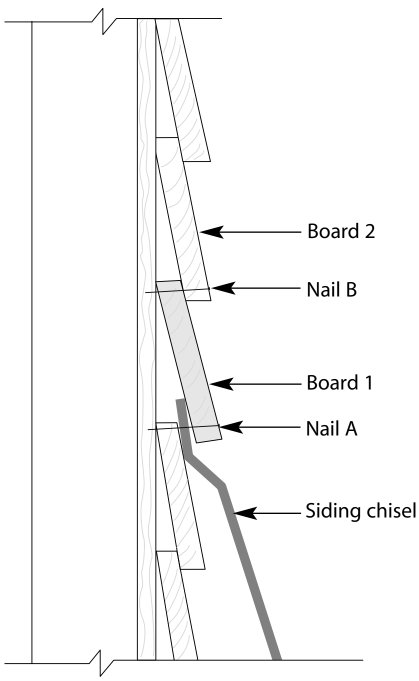


Figure 4
Removing clapboard siding

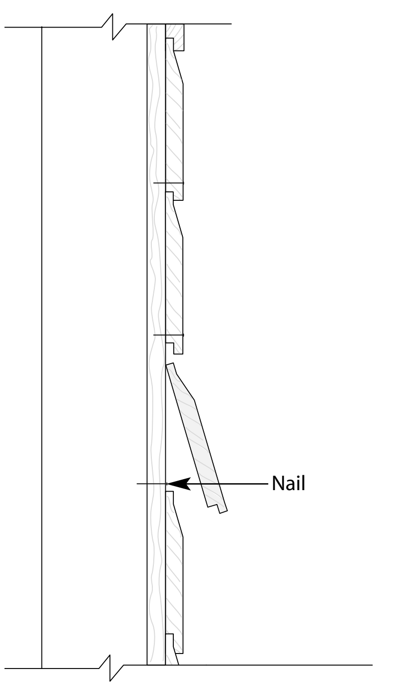


Figure 5
Removing shiplap siding

the wall. In rare cases, you might need to use a nail set or punch and set the nails through both clapboards and into the sheathing. However, you should avoid doing this, if possible, because it can create large holes or cause splits in the clapboard that are hard to repair.)

4. Carefully remove the clapboard (1) using a chisel, if it isn't free enough yet to fall out by itself.
5. Be careful to do as little damage as possible to the building paper when you remove the clapboard. The building paper is usually found between the clapboards and sheathing. Carefully cut the paper along the horizontal edge about 1 inch above the clapboard that's still in place.
6. Cut the paper vertically, bend it up, and tack it to the clapboard above, allowing free access to the sheathing.
7. Drill the hole.

Replacement after blowing:

1. After you've blown insulation into the wall section, push the building paper back into place, making sure the hole is completely covered.
2. Replace the clapboard. If possible, leave a very slight opening between the replaced clapboard and the ones on the house in order to allow the wall to breathe. Fill any nail holes or splits with putty.

Shiplap Siding —

Removal:

1. Follow the steps for clapboard siding, but instead of cutting the nails, set them directly through the siding (see Figure 5).
2. Use a chisel to remove the siding. Insert it under the lower edge of the board you're removing and pry it outward.
3. Follow the same preparations for blowing (treatment of sheathing, drilling, etc.) as you would for clapboard siding.

Replacement after blowing:

Follow the instructions given for replacing clapboard siding.

Tongue-and-Groove Siding — Tongue-and-groove siding is more complicated because you can't pry out a board without breaking either the tongue or an edge. Either of the following two methods will work, but where the boards are fitted very tightly, Method 1 is likely to split off the outer edge of the board.

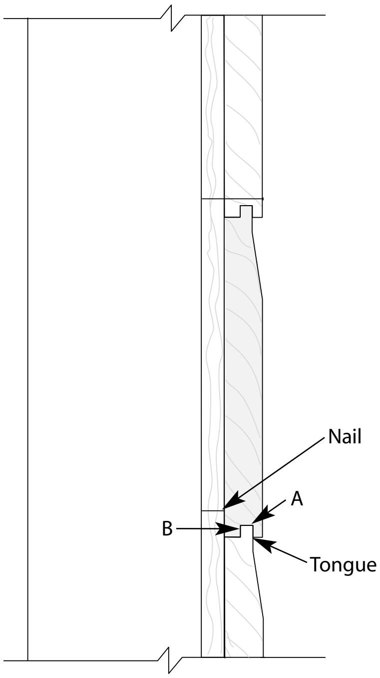


Figure 6
Removing tongue-and-groove siding

Method 1, Removal:

1. Set all nails directly through to the sheathing.
2. At the lower edge of the board you're removing, insert an electrician's chisel and pry out and down at point A shown in Figure 6. This usually causes the board to split off at the rear along line B, leaving the tongue of the board below intact.
3. By proper manipulation, the board to be removed will come away from the top groove in the board above so you can slip it out.
4. Once the board is removed, follow preparations for blowing (treatment of sheathing, drilling, etc.) as listed for clapboards.

Method 1, Replacement after blowing:

1. Set the edge of the tongue into the groove of the upper board and tap the board along the edges until the tongue is started in the groove along its entire length.
2. When the tongue has entered the groove far enough so that the bottom edges are level, knock the bottom edge straight in. You can now face nail the board into place.

Method 2, Removal:

1. Set the nails through the board.
2. You'll need a broad-blade knife, about 12 inches long, with a slight curvature to the blade face and a welded striking plate on the blade. Insert the knife blade in the groove at the top of the board you're removing. Drive in the knife blade to cut off the tongue. Repeat this process at the bottom of the board. Once the tongues are cut away at both the top and the bottom, the board should then be easy to remove.
3. If the board is toenailed at the top edge through the groove instead of straight-nailed, the procedure is the same except that it'll require slightly more prying to remove it.
4. The preparations for blowing (treatment of sheathing, drilling, etc.) are the same as for clapboards.

Method 2, Replacement after blowing:

Cover the sheathing behind the top and bottom edges of the board with mastic the full length of the cut and at least 1 inch on either side of the tongue and groove. The mastic should be sufficiently thick so that when you push the board back into position, the mastic will work into place between the upper and lower joints, serving to replace the tongue and groove as a protection against the weather. Since the board is absolutely free, you can easily put it back into position.

Tools and Materials

- *Utility knife*
- *Shingle or slatter ripper*
- *Nail saw*
- *Drill*
- *Replacement materials*

Wood Siding Shingles — There are two methods you can use when working with wood siding shingles. If the owner objects to cutting the shingles for access, use Method 2 instead of Method 1.

Method 1, Removal:

1. Using a sharp utility knife, cut upward at a 45-degree angle as far as possible under the butt end of the shingle course above the shingle to be removed as shown in Figure 7. Make a series of shallow cuts through the shingle that you're removing.
2. Cut the paint seal at the sides of the shingle and remove the shingle.
3. Drill through the lower course of shingles to the stud cavity.

Method 1, Replacement after blowing:

1. Tack pieces of asphalt paper over all holes.
2. Daub the back of the shingle you're replacing along the cut edge with mastic and drive it solidly up against the section of the shingle still in place.
3. Face-nail the shingle with 4d or 6d galvanized finishing nails or light-gauge aluminum nails. Use a minimum number of nails to fasten the thin upper edge of the shingle to reduce the possibility of splitting.
4. Touch up edges and other necessary spots with paint.

Method 2, Removal:

1. With a utility knife, free the edges of the shingle by cutting the paint seal.
2. Pry up the course above the shingle to be removed. Then pry up the shingle you're removing.
3. Running the ripper or saw above the shingle you're removing, cut the nails holding the course above to the shingle.
4. Inserting the ripper or saw under the shingle, cut or pull the nails holding it.
5. Holding the shingle by the butt, work the shingle loose and pull it out.
6. Drill through the lower course of shingles and through the sheathing.

Method 2, Replacement after blowing:

1. Tack pieces of asphalt paper over the hole.

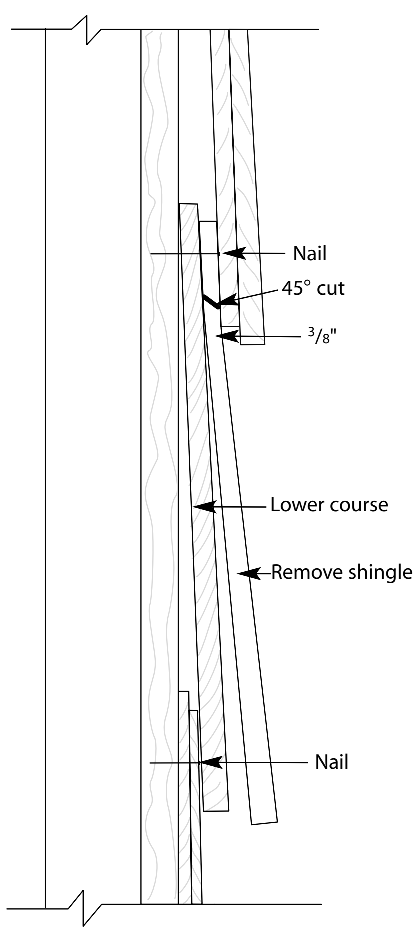


Figure 7
Removing wood siding shingle

2. Daub the back of the shingle you're replacing with mastic and drive it solidly upwards until the edge of the butt lines up with the rest of the course. Use a block of wood against the butt end in order to protect the shingle edge.
3. Follow steps 3 and 4 under Method 1 for replacing the shingle.

Rigid Insulation Board

When you use insulating board on exterior foundations, it's usually held in place by the backfill. The insulation should extend at least 1 foot below grade (at least 2 feet in colder climates). You should also run the insulation up past the header joist to prevent condensation around the joist and to seal air out between the sill plate and the foundation.

For interiors, you can attach the insulating board to concrete, masonry, or metal or wood studs with a mastic adhesive or fasteners. Apply the adhesive in a grid pattern or, better yet, a complete coat to avoid trapping moisture between the insulation and the foundation surface.

Spray Applied Polyurethane Foam

Unless you're working in small spaces, such as around windows or electrical boxes, spraying polyurethane foam requires special equipment and training. It's best done by a subcontractor who specializes in the field. They'll give you an estimate for materials and costs.

The effectiveness of spray polyurethane foam depends on the thickness of its application, the number of passes made, the temperature of the substrate, and the air temperature and humidity.

Because the material is so combustible, it's vital that no one smokes or does any open flame work, such as welding, while the polyurethane foam is exposed. The building code requires that the foam be covered by a minimum of a 15-minute thermal barrier. This should be installed the same day the foam is applied. A common barrier would be $^1/_2$-inch drywall. Other options (see Figure 8) are sprayed-in-place cementitious or fiber materials.

Since you'll most likely hire a sub to apply polyurethane foam for large jobs, the following general guidelines will help you make sure you get a quality job.

Electrical Guidelines

In residential applications, use either baseboard raceway, shielded cable, or one size larger wire than would normally be required for all electrical work. *Under no circumstances should you use aluminum* *wiring if you're going to have spray-applied polyurethane foam insulation*.

For recessed lighting, heat lamps, ventilation fans, and other recessed fixtures you need special insulation consisting of a drywall box-barrier surrounding the fixture, placed at least 3 inches out from the fixture. The sprayed polyurethane foam insulation may be applied up to the box surround, but under no circumstances should it come in contact with the fixture.

Vapor Barriers

Although polyurethane foam is resistant to water penetration, it has a perm value of 2 or 3. You'll need to place a vapor barrier on the winter warm side, usually the interior.

Surface Preparation

Polyurethane foam adheres well to most surfaces, but the surfaces must be clean, dry, and free from flaking or peeling. If a primer is required, use a primer that's compatible with the spray polyurethane foam, and allow it to cure completely before spraying the foam. Primers other than those listed below may work also. Check with the spray polyurethane foam sub or paint supplier for additional primer options.

Area	Surface to be Sprayed	Finish
Cathedral ceiling	Underside of plywood decking	$^1/_2$-inch drywall or code approved equivalent
A-frame roof	Underside of plywood decking	$^1/_2$-inch drywall or code approved equivalent
Exterior roofing	Exterior substrate	Approved protective covering
Masonry wall, interior	Install 2-inch furring strips on interior side of cement block wall, 24 inches on center; apply 2 inches of foam	$^1/_2$-inch drywall or code approved equivalent
Masonry wall, exterior	Exterior surface of masonry wall	Stucco or face brick
Basement/foundation exterior	Concrete block	Moisture retarder and then backfill
Footings and sill plates	Foundation wall and into area formed by sill plate	15-minute finish rated thermal barrier

Figure 8
Polyurethane foam insulation and recommended barrier finishes

Suggested primers:

Wood — chlorinated rubber, modified alkyds

Steel — modified alkyds, epoxy, acrylics

Galvanized steel — vinyl copolymer, “wash primer,” modified alkyds

Concrete/masonry — chlorinated rubber, vinyl copolymer, acrylic, asphaltic

Wood Surfaces —

1. Plywood should contain no more than 18 percent water.
2. Most untreated and unpainted wood surfaces don’t have to be primed. See the spray polyurethane foam manufacturer for specific details.

Steel Surfaces —

1. Make sure primed metal is free of loose scale, rust, weathered, or chalking paint. Clean it with vacuum equipment, hand or power tools to remove loose dirt. Remove grease, oil, or other contaminants with cleaning solutions.
2. Clean previously painted metal to remove loose scale and dirt. Remove grease, oil, and other contaminants by power washing.
3. Clean galvanized steel according to the recommendations of the primer manufacturer.
4. Clean unpainted steel according to the recommendations of the primer manufacturer.

Concrete and Masonry Surfaces — Both must be cured. Remove loose dirt and other contaminants before applying the foam.

Sheathing Board — Most sheathing boards don’t need to be primed before applying the foam.

Room Preparation

1. Mask the openings of all electrical boxes, telephone boxes, cable TV, and so on. Mark each masked area with a wire so you can find it again after spraying.
2. Cover the windows. But don’t mask beyond the window casings as that area should be sprayed with foam to seal it.
3. Mask or spread a release agent on the studs. The overspray can then be easily pulled loose or scraped off with a trowel or garden hoe.

Application

The foam should be sprayed in a "picture framing" motion. Outline the perimeter of the stud cavity. Let the foam rise along the stud face. After it rises, spray the middle of the cavity. By applying it in this way, the foam will seal all the cracks and crevices without folding over the stud face or creating voids.

Controlling thickness is critical to making sure you get the full insulation value. Mark a long ordinary needle or pin in half-inch increments. As the spray is applied, check the foam thickness by inserting the pin into the cured spray polyurethane foam and reading the depth on the needle.

Cleanup

Discard all scrap and unused liquids in the manner suggested by the manufacturer. Check the manufacturer's polyurethane foam data sheet and MSDS (Material Safety Data Sheet). These are an integral part of your procedures and should be read and followed in their entirety.

Superinsulation

The energy crisis of the 1970s was both a curse and a blessing. No one will argue the frustration of higher energy costs. But the sudden shift upward in prices also forced the construction industry to look at more efficient ways to cool and heat a home, and over the long run, preserve our natural resources for a while longer. Passive and active solar systems were quick to gain attention as viable alternatives, but with their advantages also came some serious disadvantages. These included the initial setup costs, maintenance expenses, design problems, and solar's dependence on clear, sunny days. Wind generators and other forms of energy were also developed with increasing frequency and continue to be used with varying costs and success.

Another method of energy savings that's been developed is *superinsulation*. The name suggests that this method involves an extra amount of insulation simply being packed into the walls and ceilings. While it's true that walls in a superinsulated house are usually insulated up to R-40, and ceilings up to R-65, the concept goes far beyond that. Superinsulation is an entire design system that incorporates controlled ventilation, efficiently placed insulation, and airtightness. By paying attention to each of these items, energy costs can be reduced dramatically. Some houses have been built with a superinsulation design that literally creates a heated environment produced solely by the people, the lights, and the appliances within the home.

The real beauty of a superinsulation system is that it's all done without exterior or interior design considerations. In other words, the superinsulated house can look pretty much like the standard house sitting next to it. It isn't necessary to add trombe walls, sunspaces, wall collectors or solar panels. The system requires very little alteration in the house itself whether it's in Georgia or Saskatchewan.

Most people assume that if a structure has a high enough R-value in the walls and ceilings, that's about all that can be done. While insulation is an important aspect of cooling and heating a structure efficiently, it's only one piece of the whole puzzle. For the highest efficiency, you must avoid four problem areas when designing and building a structure. Superinsulation takes these problem areas into consideration and then goes a step further.

Avoiding Thermal Defects

The problems areas you must take care of include the following:

- *Insulation voids* — places that should be insulated but aren't because of carelessness or inexperience. Wherever insulation is missing, cold air enters and warm air escapes. You'll find the most common voids are around electrical boxes and fixtures, ductwork, pipes, and between insulation batts or boards.
- *Thermal bridges* — places that have low R-value and "bridge" from the interior to the exterior. You may insulate your walls to R-31, but the overall R-value of the wall will be considerably less. The studs, which bridge through the wall, have an R-value of only 1.25 per inch. You can prevent thermal bridges in the framing stage in a variety of ways, such as by using exterior insulative sheathing or by building double walls.
- *Air leakage* — places where air moves through the shell, either from the outside to the inside or vice versa. Up to 40 percent of the heat lost in a typical house is due to air leakage. Air/vapor barriers are the first and most important step in stopping air leakage. You should also carefully seal around obvious places like pipes, windows and doors, as well as less obvious points such as the joints where walls and floors meet.
- *Convective loops* — places where heat is drawn by convection. The result is that warm air is pulled up and out of a space, cooling it in the process. You then have to reheat the cooled air as it sinks.

An additional design consideration included in a superinsulated house is the ventilation system. Good ventilation is important in any insulated structure. Without it, vapor can condense and cause dry rot in the framing members or damage the insulation. When a house is superinsulated, there's far less air exchange between the exterior and interior than in standard construction. This makes a well-designed ventilation system even more crucial. Part of this ventilation system should be an air-to-air heat exchanger, which allows fresh air to enter and stale air to go out, and in the process, recovers and reuses the heat in the outgoing air.

Designing a Superinsulation System

Although an actual superinsulated system isn't much more complicated to build than a regular house, it does have some specialized design needs and there are added costs. The bulk of the extra expense results from the additional framing and insulation you'll need, along with the material and labor costs for these. Air/vapor barriers and ductwork also raise costs slightly. Of course, some of these costs are saved in reducing or even eliminating the central heating system. For a 2,000 square foot house, you might spend as much as $5,000 extra on a superinsulated design. But that design will prevent up to 80 percent of the heat loss generally occurring in a conventional house. As a result, you can reduce energy costs by as much as 80 to 90 percent. The savings in energy costs over the long run, as well as the added resale value of the home, easily make up for the initial cost of the system.

For more information on advances in insulation systems, check the following Web sites:

Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
University of California, Berkeley
Berkeley, CA 94720
http://epb1.lbl.gov/EPB

National Institute of Standards and Technology
Building and Fire Research - Enhanced Building Performance
U.S. Department of Commerce
Washington, D.C. 20234
www.nist.gov

U.S. Department of Housing and Urban Development Guidelines
Energy Efficient Rehab Advisor
http://rehabadvisor.pathnet.org/index.asp

Manhours

Manhours to Install Insulation, per SF		
Type	**Manhours**	**Suggested Crew**
Batt or blanket, place and/or staple		
Joists		
16" oc	.011	1 carpenter
24" oc	.007	1 carpenter
Rafters		
16" oc	.016	1 carpenter
24" oc	.011	1 carpenter
Studs		
16" oc	.013	1 carpenter
24" oc	.009	1 carpenter
Loose fill — Insulating wood, granule or pellet		
Joists @ 7lbs/CF density		
16" or 24" oc, 4" thick	.017	1 carpenter, 1/2 laborer
16" or 24" oc, 6" thick	.023	1 carpenter, 1/2 laborer
Loose fill — Vermiculite/Perlite		
Joists		
16" or 24" oc, 4" thick	.012	1 carpenter, 1/2 laborer
16" or 24" oc, 6" thick	.017	1 carpenter, 1/2 laborer
Cavity walls		
1" thick	.005	1 carpenter, 1/2 laborer
2" thick	.009	1 carpenter, 1/2 laborer
Block walls (2 cores/block)		
8" thick block	.020	1 carpenter, 1/2 laborer
12" thick block	.026	1 carpenter, 1/2 laborer
Rigid insulating board		
Roofs, over wood decks, normal moisture conditions within building, nail one ply 15 lb felt		
2' x 8' x 1/2" T&G asphalt sheathing	.026	2 carpenters, 1/2 laborer
4' x 8' x 1/2" asphalt sheathing or building block	.019	2 carpenters

Manhours to Install Insulation, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Roofs, over wood decks, humid moisture conditions within building, nail and overlap 3 plies 15 lb felt, mop laps and surface one coat and embed		
2' x 8' x 1/2" T&G asphalt sheathing	.041	2 roofers (pitch), 1 laborer
4' x 8' x 1/2" asphalt sheathing or building block	.039	2 roofers (pitch), 1 laborer
Over noncombustible decks, normal moisture conditions within building, mop 1 coat and embed		
2' x 8' x 1/2" T&G asphalt sheathing	.029	2 roofers (pitch), 1 laborer
4' x 8' x 1/2" asphalt sheathing or building block	.028	2 roofers (pitch), 1 laborer
Over noncombustible decks, humid moisture conditions within building, mop 1 coat, embed 2 plies 15 lb felt, mop and embed		
2' x 8' x 1/2" T&G asphalt sheathing	.051	2 roofers (pitch), 1 laborer
4' x 8' x 1/2" asphalt sheathing or building block	.049	2 roofers (pitch), 1 laborer
Walls, nailed, 4' x 8' x 1/2" asphalt sheathing or building board		
Straight wall	.015	2 carpenters
Cut-up wall	.018	2 carpenters

For more information on related topics, see:

Acoustics, page 21

Floor Framing, page 299

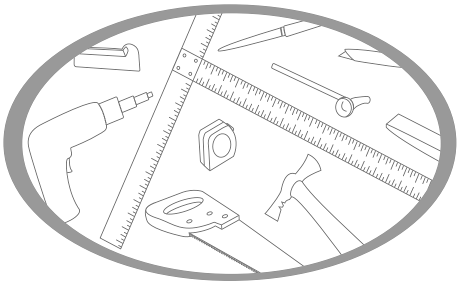
Heating and Air Conditioning, page 379

Radon and Other Pollutants, page 499

Roof Framing, page 513

Ventilation, page 701

Wall Framing, page 709



Insurance

Way back when business was done with a handshake and a person's word, few contractors carried any kind of insurance beyond what they needed to protect themselves from theft, storms, or fire. But times have changed. Now you need a confusing array of insurances not only to protect yourself, but in many areas, just to be able to pull a building permit. This section provides you with a brief overview of the different kinds of coverage you may need for various aspects of your business.

Workers' Compensation Insurance

Workers' compensation is disability insurance. Every state requires a company to carry compensation insurance for its employees, regardless of whether the company has one employee or a thousand. You may need to provide proof of workers' compensation insurance before you can get a building permit.

Workers' comp is sold through the state, private insurance companies, or both, depending on the state. When the state acts as the carrier, the rates are often lower than you might get through a private company. The insurance premiums are figured as a percentage of the worker's income. For instance, if the rate is 15 percent, then 15 cents out of every dollar the employee earns is paid in workers' comp premiums. In other words, if you pay an employee $10 an hour, for every hour he works, you'll pay $1.50 for insurance premiums.

Rates are also based on the type of work done. Carpenters, carpet layers, office workers and roofers all have varying rates. The greater the hazards of the job, the higher the rate. Both the rates and the benefits vary dramatically from state to state.

General Liability Insurance

Another frequently required insurance is general liability, sometimes referred to as "broad form" insurance. A general liability policy covers problems arising from contractual liability, personal slander, bodily injury, and property damage. The property damage clause covers damage caused by poor workmanship, but not the poor workmanship itself.

General liability policies are written for a minimum amount, usually a minimum of $300,000. Two kinds of policies are written for contractors:

- *Occurrence form* covers problems that occurred while the policy was in force, even if you're no longer insured by that company. In the long run, occurrence form coverage is the cheapest and most complete.
- *Claims made* coverage is in force only during the policy period. Once the policy period ends, the coverage also ends. You can buy a rider for a claims made policy that covers you for previous periods, but the riders become increasingly expensive as the length of time is extended.

Builder's Risk Insurance

A builder's risk policy covers a contractor for theft, vandalism, storm and fire during the construction period.

For small jobs, especially remodeling work, builder's risk isn't necessary because the client's homeowner policy should cover this type of loss. For new construction or large remodeling jobs, it's not only a good idea to carry it, but often the client will require that you have it.

Umbrella Policies

An umbrella policy provides coverage for major lawsuits. This type of insurance is necessary if you have a lot of exposure and a lot to lose. An insurance company will only write an umbrella policy if you're already adequately insured.

Property Insurance

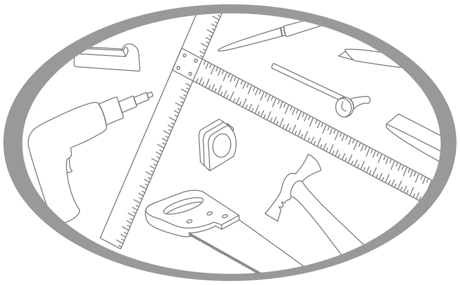
Property insurance for a business is just like homeowner's insurance for a homeowner. It covers your property against fire, storm, theft and vandalism. Coverage for tools and equipment at the job site isn't automatic with every policy. However, since that's where your tools and equipment have the greatest exposure to loss, check to make sure they *are* included in your policy.

Vehicle Insurance

Most states require vehicle liability insurance. Carrying comprehensive and collision insurance on your vehicles is your choice.

Your employees probably carry their own vehicle insurance, but you should have a rider on your policy to cover them further if they're going to be driving their own vehicle for company business. If an employee is in an accident, you could be sued regardless of whether or not the employee is at fault.

Trailers under 2,000 pounds are covered by the liability policy of the towing vehicle. Over 2,000 pounds they need a separate liability policy, which will also cover whatever is being carried on the trailer. If you carry equipment in a trailer, be sure you're adequately covered.



Painting

Painting looks easy: Just open a can of paint, stir it up a bit, and brush it on. But in fact, painting is a complicated process that, if poorly done, can ruin an otherwise quality job. Although using good-quality tools, materials and techniques are important, most painting jobs are botched because of inadequate preparation or careless work.

Coating Systems

In technical terms, paint and stain are coating systems because they do, in fact, coat or cover. Although most people think of the color first, both paint and stain are also designed to protect surfaces from wear and weathering.

All coating systems have three basic elements: the *pigment*, or color; the *vehicle*, which carries the pigment and then evaporates; and the *binder*, which bonds the pigment to the surface.

For thinning or cleaning purposes, coating systems are identified by their vehicle. They may be either water-thinned or solvent-thinned. For example, oil paints are solvent-thinned because the vehicle that carries the color in these paints is oil. Some important characteristics depend on the binder, such as the coating's ability to protect or adhere to a surface and its durability. The binder also determines whether you use the coating on metal, wood, cement, or other surfaces.

Paint

Latex is the most common binder among water-thinned coatings. Other binders in that category include solvent-thinned alkyds, epoxies, polyesters and urethanes. In the solvent-thinned group, alkyds, which are synthetic resins, are used increasingly over oil as the binder. Some painters prefer either latex or alkyd/oil paints, but neither is an all-purpose paint. Each has characteristics that make it the right choice for certain kinds of jobs.

Latex paints are easy to use because they dry fast and are quickly cleaned up in soap and water. They also have the advantage of holding color well and resisting alkali and blistering. Latex is often used for painting stucco, concrete, and wood since it “breathes,” or allows moisture to pass through.

Alkyd/oil paints have the advantage of providing good one-coat coverage that’s smooth and very durable. In addition, they’re more resistant to stains and damage than latex and can withstand frequent scrubbings. Oil-base paints bind well to wood and metal, but they don’t adhere to masonry. Alkyds dry faster and have less odor than oil paints, but still require good ventilation. Both alkyd and oil paints pose an environmental hazard and must be disposed of properly. Call your local health department for the disposal requirements in your area.

Latex and alkyd/oil paints come in four different gloss levels: flat, eggshell, semigloss, and gloss. Generally, the higher the gloss, the denser, or less porous, the finished surface is. The less porous the surface, the easier it is to clean and the more difficult it is for moisture to penetrate. So semigloss and gloss paints are logical choices for bathrooms, kitchens, and interior wood trim — all areas that are subject to moisture and grime and need frequent cleaning.

In addition to latex, oil and alkyd, there are other binders available for special purposes:

- Cement-base paints are commonly used on concrete, stucco, and masonry. The portland cement binds well to rough surfaces and dries to a hard, durable finish.
- Epoxy paints consist of two parts that, when mixed, react with each other to form a hard coating. They’re used on masonry and concrete to give a hard, glaze-like finish.
- Rubber-base paints adhere well to masonry and metal. They’re highly water resistant, so they’re excellent for places exposed to a lot of moisture or high humidity.

Surface Finishes

Painters also commonly use other coatings that dry to a glossy finish. Lacquers, shellacs and urethanes are usually clear; varnishes may be clear or they may add color.

Lacquers dry by evaporation to a hard, glossy finish and are often preferred over varnish because they’re fast drying. However, they’re not nearly as durable or tough as varnishes. They’re used most often on furniture. Don’t use lacquers for exterior surfaces — they don’t tolerate weathering. For the best finish, spray lacquers instead of brushing. They’re highly flammable, so follow the manufacturer’s directions. Work in a well-ventilated area, and rinse your rags to prevent combustion.

Varnishes dry by oxidation. They're the slowest drying of the glossy finishes, but next to urethanes are the most durable. Even if you're using a varnish as the final coat, use a urethane for the first coat to increase sheen and durability. The number on the container indicates the gloss of the final finish. The higher the number, the higher the gloss will be.

Urethane finishes are similar to varnishes except that they dry faster to a harder, more durable finish than varnish. They're often used for hardwood floors and exterior surfaces. The drawback to urethane is that it looks somewhat plastic when it dries.

Shellacs work extremely well as a sealer or barrier coat. In the past, they were used like varnish. Because they're more expensive and lack durability, especially when exposed to moisture, shellacs are rarely used now as a final finish coat.

Stains

Stains are coating systems that protect wood and provide color, or enhance the natural color and grain of the wood they're covering. A paint *coats* a surface, preventing moisture from moving into or out of the surface. Stain, on the other hand, *penetrates* the surface, without trapping moisture that could cause blistering or peeling. This makes it an excellent coating for exterior wood.

Stains may be either penetrating or pigmented. A penetrating stain is quickly absorbed into the wood grain and tends to highlight the grain. A pigmented stain doesn't penetrate as much as it colors, tending to hide the wood grain.

Cut-Sheets

Manufacturers of coating systems provide information sheets, called cut-sheets, for each of their products. These sheets give details about product characteristics (drying time, flash point, weight per gallon), label analysis, uses, specifications, surface preparation, application and cleanup procedures, and cautions. Ask for cut-sheets and read them to understand the coating system you're working with.

Equipment

The right tools make any job easier, and painting is no exception. And choosing the right quality is just as important as choosing the right equipment. As with anything else, you get what you pay for. It's well worth your while to buy high-quality brushes and rollers, and then take exceptionally good care of them. They'll make the job go easier and give a more professional look. In addition to the tools listed below, a sturdy 4- or 6-foot ladder is necessary for almost any painting project.

Preparation Equipment

Because good surface preparation is the foundation for a good paint job, you'll need some combination of the following tools. Except for the sand and water blasters and the strip heater, they only cost a few dollars each. A good strip heater will cost under $100; you can rent sand and water blasters if you don't want to invest the several thousand dollars to buy them.

- Safety goggles and mask: wear for surface preparation and painting
- Wire brush and scraper: for loose or peeling paint; use only stainless steel
- Spackle: use to repair small holes and flaws
- Caulk: seal all cracks before painting
- Drywall or putty knives: for spackling and minor scraping
- Utility knife: for opening windows that are painted shut
- Screwdriver: for removing outlet and switch plate covers, etc.
- Sandpaper: have a range of grit sizes
- Liquid sanders: they'll cut through dirt and grime and even restore small cracks; use carefully, though, as they're flammable and toxic
- Belt sander: an electric sander will speed up the work for large surfaces
- Electric strip heater: heat softens paint, which can then be scraped off with a putty knife
- Water blaster: hooks up to a standard spigot, producing 2,000 to 4,000 psi water stream; cleans off dirt, chalk, grime, and paint; wood must totally dry out again before painting, usually at least two to three days
- Sand blaster: use to remove paint and rust; when used on wood, take care or you'll damage the wood surface

Protection Equipment

Just like the preparation tools, the following items are fairly inexpensive. But they keep splatters and spills from being major problems.

- Cotton gloves and hat: protect your skin and head from paint splatters
- Vaseline: spread it on all exposed skin for easy cleanup
- Drop cloth: use either canvas tarps or disposable paper; 4 to 6 mil plastic is workable, although paint splatters stay wet and tend to get tracked off the plastic
- Painter's tape: mask off trim, lines, and carpet; don't use masking tape, which leaves an adhesive residue and allows paint to seep under
- Liquid masking: use it for glass; spread it on the glass, paint, then wipe liquid masking and paint off together

- Spray shield: a 12- x 36-inch plastic or metal blade with a 36-inch handle; excellent way to prevent overspray and splatters when spraying; the plastic guide is easier to clean up, but its thickness leaves a $^1/_8$-inch line to paint
- Paint guide: a 6- to 24-inch plastic or metal blade; used for preventing splatters and keeping a straight line when brushing

Painting Equipment

Except for pressure-fed rollers and airless spray systems, even the most expensive items on this list still fall in the inexpensive range. Good quality brushes and rollers will easily pay for themselves in quality of painting and ease of cleanup.

- 5-gallon bucket: more practical than a roller tray because it holds far more paint; the paint is less likely to splash out or spill than a roller tray; allows you to mix several buckets of paint together for a totally even color and texture
- Roller rack: place inside a 5-gallon bucket and use to roll off excess paint from a roller
- Roller trays: use with either a disposable plastic liner or a single sheet of heavy-duty aluminum foil for easy clean up
- Cloths: use clean, lint-free cloths for staining
- Paint pads: use pads with at least $^3/_8$ inch nap for cutting in; use foam pads on smooth surfaces; use foam and fiber pads for rough or textured surfaces such as stucco, masonry, or rough-sawed lumber; use lambs wool for staining. Don't use pads for shellacs or lacquers.
- Paint glove: has rubber lining with mohair on the outside; excellent for painting railings, pipes, gutters, etc.
- Brushes: use nylon or polyester or a blend for water-thinned paint; a natural or china brush for solvent-thinned paint. Buy full, thick brushes that fan out evenly when pressed against a hard surface. The bristle tips should be flagged, or split slightly, at the ends to hold more paint. Brushes come in a variety of sizes to fit every painting job:

  6 inch — large surface areas such as siding

  $3^1/_2$ to 4 inch — walls, ceilings, floors

  $2^1/_2$ to 3 inch — baseboards, doors, cabinets, fences, handrails

  $1^1/_2$ to 2 inch — window sash, shutters, molding

  1 inch — small trim, touchups

  chiseled, round sash or artist's brushes — fine touchups and difficult to paint places
- Rollers: use at least a $^3/_4$-inch nap for smooth surfaces, and 1- to $1^1/_2$-inch nap for rough ones. Lamb's wool holds more paint, has less splatter, and is easier to clean than polyester, but it's harder to spread paint evenly with it. Lamb's wool is twice as

expensive as polyester but will last twice as long with proper care. Some synthetic lamb's wool works as well as genuine lamb's wool. Check the package to make sure the roller will work for a particular paint. Different sizes are available for variety of jobs:

18 inch — fast wall coverage, although its size makes it more difficult to use

9 inch — common general-purpose size

7 inch — lap siding

3 to 4 inch — trim work

serrated — foam roller for acoustic ceiling

hot dog, long john or pencil — 1-inch diameter for narrow places

- Pressure-fed roller: feeds paint from inside of core to outside of nap; reduces labor by one-third to one-half because you don't have to reload the roller
- Airless spray systems: can be rented or bought; experienced painters can cover about 1,000 square feet per hour, so a system can easily pay for itself in a single, sizable job

Cleanup Equipment

Whether you're using a $5 brush or a $3,000 paint sprayer, a thorough and complete cleaning is essential for protecting your investment.

- Soft-bristled brush and baking soda: clean hard to remove spots on skin
- Buckets: use for dipping brushes and rollers
- Rags: keep a wet rag handy for immediately wiping up latex paint splatters; keep a rag and solvent on hand for oil-base paint
- Metal brush comb: for thoroughly cleaning bristles
- Spinner: helps remove excess moisture from brushes and rollers
- Detergent and water: for cleaning up water-thinned paints
- Mineral spirits: for cleaning up solvent-thinned products and, if necessary, as an extra cleaning agent for water-thinned paints; mineral spirits may be reused

Surface Preparation

A quality paint job should last 7 to 12 years. If problems arise or the paint starts to deteriorate before then, it might be because the paint itself was of poor quality. More often, though, paint deteriorates because the surface wasn't correctly or adequately prepared. Before you open the first can of paint on a job, you should make sure the surface to be painted is clean, dry and smooth. If it's not, the paint won't stick, and you'll be back to fix it. Refer to Figure 1, Troubleshooting paint problems, to get an idea of what kinds of problems are common with paint. Preventing problems in the first place is a lot simpler than going back and correcting them.

Preparing the Interior

Begin by moving everything out of the room. If some pieces are too large to remove, push them to the center and cover them completely with tarps. Make your working space as open and large as possible.

Turn off electricity to the room while removing outlet and switch plate covers. To keep from losing the screws, put each set in a plastic sandwich bag and tape it shut. Disconnect the light fixtures and wrap them in plastic. Tape plastic bags over all doorknobs. Mask windowpanes and anything that can't be removed and shouldn't be painted.

Using a broom or a clean rag, wipe off baseboards, window casings and sills, and anywhere else that might harbor dust. Sweep cobwebs out of corners. Remove nails or screws from the walls, checking for loose plaster or drywall as you go. If you find any spots that need repairing, take the time to fix them now so they can dry. (See *Drywall*, *Repair*.) Caulk any cracks between woodwork and walls.

If it's been a while since the room has been painted, you'll probably need to wash down the walls and ceiling. This is especially true for kitchens, where there's probably a grease film, and for the homes of smokers. Use trisodium phosphate (TSP), which is sold at paint supply stores, and water followed by a clean-water rinse. That will take care of most minor problems. For tougher stains, check the stain treatments chart later in this section.

Check the trim for loose or peeling paint. Remove any loose layers and sand the spot smooth. You may need to use a power sander if there are many old layers or deep chips. If the chip is too deep to sand smooth, fill in with a thin layer of spackle and sand it when dry. The surface should be smooth to the touch when you're done. If you can feel any paint edges, you'll be able to see them when the paint is dry. And that's the first place the paint will start to chip or peel.

When all the surfaces that you'll be painting are smooth, clean, and dry, vacuum the carpets. Tape the carpet away from the baseboard and cover the floors with tarps.

Preparing the Exterior

Follow the same process with the exterior as you did for the interior: Protect what you can, clean the surfaces to be painted, and prepare a smooth surface by removing loose paint and sanding smooth.

Problem	Characteristics	Cause	Repair
Alligatoring, checking; paint not adhering to previous coat	Irregular, interconnected cracks	Incompatible paints; poorly prepared surface; second coat added before first is dry; top coat too thin	Strip to bare wood; apply 2 coats primer and top coat
Bleeding	Stain or wood resins ooze through top coat	Poorly prepared surface	Test stain to see whether it dissolves in oil or water; sand surface and seal with killer primer, aluminum paint, pigmented shellac, or all-purpose primer; repaint top coat
Blistering	Bubbles form under paint	1. If there's paint under blister, temperature was too high when top coat was applied 2. If there's raw wood under blister, it was caused by moisture	1. Sand and repaint. 2. Find moisture problem and repair; then scrape blisters and allow surface to dry; sand and spot prime before applying top coat.
Cat's eyes, fish eyes	Spots with circles around them on freshly-painted surface	Oil under surface; surface not cleaned well enough; oil or grease on equipment	Touch up spots while paint is still wet
Chalking (some chalking is desirable to keep paint looking clean)	Chalky residue comes off when surface is rubbed; new paint binds to surface powder and not surface	Weathering; not enough binder to wet paint pigment; too much thinner added to paint	Light: Scrub with detergent and rinse Moderate: Wire brush or sand to remove excess surface powder Heavy: Sand or water blast to remove loose powder
Cracking, scaling	Cracks in the paint	Too many layers of paint; old paint that's lost its elasticity; moisture seepage or pollution	Fix moisture problem; strip surface and sand; prime and paint
Discoloration	Brownish stains in redwood or cedar siding	Moisture dissolves natural staining in wood and brings it to the surface	Apply 1 or 2 coats of primer; dry for several days; reprime remaining spots; let dry and apply 1 or 2 top coats
Flaking, peeling	Paint not sticking to surface	Surface not cleaned adequately; too many layers of paint; wrong type paint used; moisture problems	Fix moisture problem; strip to bare wood, sand, prime and paint
Intercoat peeling	Paint peeling from previous coat	Too long between primer and top coat; first layer too hard, smooth, or oily; surface should have been roughed up or cleaned better	Remove peeling paint; prepare surface and repaint
Mildew	Mottled discoloration; looks like dirt but doesn't easily wash off like dirt would	Poor ventilation	Sterilize by washing with mixture of $^2/_3$ cup TSP, $^1/_3$ cup powdered detergent, 1 quart household bleach, 1 gallon warm water. Leave on for 10 minutes, rinse with clean water. [Caution: Wear rubber gloves and goggles when applying.] Let dry 48 hours. Add fungicide or mildewcide to primer and paint
Rust stains	Rust spots and streaks around nails	Didn't use galvanized nails	Remove rust and stains; seal nail heads with shellac or stain killer; paint
Tackiness	Paint stays slightly sticky long after it should have dried	Poor quality paint; applying second coat before first is dry; using alkyds in damp weather	Strip and repaint
Wrinkling	Paint wrinkles, drips, or puckers	Too thick a coat; applying second coat before first is dry; painting in hot sun	Strip and repaint

Figure 1
Troubleshooting paint problems

Often, preparing an exterior will be far more involved than an interior because weathering causes so much damage to painted surfaces. Fortunately, a sand or water blaster is a quick way to remove peeling paint.

Sealer

It may be necessary for you to use a sealer to seal a stain or an odor that you can't remove and might bleed through. Sealers harden the surface fibers, which may mean you can sand off the stain. It's especially necessary to seal wood that has knots or a lot of sap. The coating dries to a very hard surface, so apply it in a thin coat. If the layer is too thick, it may chip or crack, which will cause your top coat to also have problems.

Kilz is probably the most common commercial sealer and is particularly effective for sealing in smoke odors after a fire. Shellac is also a good sealer, but it's more expensive. You may also use a sealer before staining wood, particularly soft woods such as pine, birch, and fir, which may not absorb stain evenly.

Primer

When you have adequately prepared the surface, apply one or two coats of primer. The primer, or undercoat, serves several important purposes. It acts as a moisture barrier and a bonding agent between the surface and the finish coat. It also smoothes over and hides minor flaws in the surface, making it easier to apply the top coat. Primer hardens as it cures. If you don't apply the top coat within two weeks of the undercoat, the primer may have hardened to the extent that the finish coat won't adhere to it anymore. If this is a problem, apply a second coat of primer or lightly sand it before painting the top coat.

To get better coverage with the top coat, tint the primer coat as close as possible to the finish coat color. This works especially well with dark finish coats.

Paint Preparation Problems

Some paint problems are more complicated than just loose or chipped paint. With any problem, try to find the cause first. Fix that and then repair the damage. One way or another you'll have to fix the problem. It's easier to do it before you've started to paint rather than six months after the job is completed.

Moisture

A common cause of many paint problems is moisture, which can come from any number of sources. If you find areas of wood, drywall, or plaster that are soft, spongy, or discolored, there's probably some kind of water problem. When a room isn't properly vented, excess moisture can cause mildewing or flaking paint. The moisture can also creep from the interior to the exterior, causing problems to the exterior surface as well. More often though, exterior moisture problems are the result of leaky gutters, missing caulk, or winter ice dams.

Surface Dirt

If the surface has any dirt, grease, or smoke, paint won't adhere to it. For exteriors, a good power wash will clean off most ordinary grime. Wash down interior walls and ceilings with mild detergent and water or a solution of TSP and water.

Stains

Figure 2 tells you how to remove most stains. For help in locating the chemicals or solvents you need, refer to Sources of Cleaning and Masking Agents, under *Brick* on page 81.

When dealing with stains, avoid using abrasives. If there are still traces of the stain after following the recommended treatment, treat with a mixture of one part bleach to one part water. Let it stand on the stain for several hours, and then follow with a bleach neutralizer. Once the stain is removed, apply a sealer coat and spot prime it. There are commercial stain removers on the market, formulated for really tough stains. Follow the instructions on the label.

Temperature

Painting at extremes in temperature, either too hot or too cold, will result in a poor-quality job. Avoid painting in temperatures lower than 50 degrees or higher than 90 degrees, especially if the surface is in the sun. If the temperatures are too low, the paint will thicken too much, making it difficult to apply smoothly. High temperatures will cause the paint to dry too quickly.

Paint Quality

You can generally get a good-quality paint without spending top dollar. However, if you buy cheap paint, it will probably end up costing you far more in the long run. Low-quality paint doesn't spread evenly or adequately; it chalks heavily, and weathers poorly. Considering that the cost of the paint is only around 20 percent of the total job (labor is the other 80 percent), it's smart to spend a little bit extra for a good-quality paint and find ways to economize on labor. Likewise, don't try to cut corners by buying a cheap primer.

Stain	Treatment	Stain	Treatment
Adhesive tape	Soak with xylene or toluene	Grease silcone non-silicone	 Use method 5 below Use mineral spirits or toluene
Animal urine	Use method 1 below		
Asphalt, tar	Mineral spirits		
Beer	Use method 3 below	Ice cream	Use method 2 below
Bleach	Use type A or type B bleach neutralizer	Ink	Use method 4 below
Blood	Use method 2 below	Lipstick	Use method 5 below
Butter	Use method 4 below	Milk	Use method 2 below
Candle wax	Use method 5 below	Mustard	Use method 3 below
Candy	Remove excess, then use method 4	Nail polish	Remove excess; wipe with acetone or mineral spirits
Chewing gum	Use method 5 below	Perfume	Use method 5 below, then method 1
Chocolate	Use method 3 below	Rust stain	Brush on solution of 4 oz. oxalic acid crystals; let set 3-4 days; rinse
Coffee	Use method 3 below	Shoe polish	Use method 6; if spot remains, try method 2; if spot remains, try method 5
Cosmetics	Use soap and water; if spot remains, try method 5; if spot remains, try method 2	Soft drinks	Wash with soap and water; if spot remains, try method 1 or 2
Dirt	Wash with soap and water	Sour milk	Mix 1 cup lye crystals in 1 gallon of water; use steel wool to scrub in solution; rinse well [wear eye protectors and gloves]
Dye, water-base	Use method 2 below	Tar	Use trichloroethylene, xylene, or mineral spirits
Egg	Use method 2 below	Tea	Use method 1 below
Fruit	Use method 2 below	Vomit	Use method 2 below
Furniture polish silicone wax: non-silicone:	 Apply coat of same wax, wipe off when it has cut through old wax; then try method 6 Use method 6; if spot remains, try method 2; if spot remains, follow method 5		
Glue water base household	 Use method 2 below Use recommended solvent; wipe off excess; wipe with mineral spirits or xylene		

Treatment Methods:

1. Mix 1 tablespoon white vinegar 1 cup of warm water; follow with soap and water wash; rinse with clear water.
2. Scrape off excess; wash with soap and water; follow with 1 tablespoon clear, nonsudsing ammonia in 1 cup water; then step 1.
3. Wash with soap and water; then step 1.
4. Wash with tricholorethylene, or use a solution of 1 part household bleach and 1 part water; follow with type A bleach neutralizer.
5. Try trichloroethylene, or xylene, or solution of 1 part alcohol and 1 part water.
6. Wash with solution of 1 part alcohol and 1 part water; rinse with mineral spirits.

Figure 2
Stain treatments

	Aluminum	Cement base paint	Exterior clear finish	House paint	Metal roof paint	Porch and deck paint	Primer or undercoater	Rubber base paint	Spar varnish	Transparent sealer	Trim and trellis paint	Wood stain	Metal primer
Wood													
Natural finish	--	--	P	--	--	--	--	--	P	--	--	P	--
Porch floor	--	--	--	--	--	P	--	--	--	--	--	--	--
Shutters & trim	--	--	--	P+	--	--	P	--	--	--	P+	--	--
Siding	P	--	--	P+	--	--	P	--	--	--	--	--	--
Windows	P	--	--	P+	--	--	P	--	--	--	P+	--	--
Masonry													
Asbestos cement	--	--	--	P+	--	--	P	P	--	--	--	--	--
Brick	P	P	--	P+	--	--	P	P	--	P	--	--	--
Cement & block	P	P	--	P+	--	--	P	P	--	P	--	--	--
Cement porch floor	--	--	--	--	--	P	--	P	--	--	--	--	--
Stucco	P	P	--	P+	--	--	P	P	--	P	--	--	--
Metal													
Copper	--	--	--	--	--	--	--	--	P	--	--	--	--
Galvanized	P+	--	--	P+	--	--	P	--	P	--	P+	--	P
Iron	P+	--	--	P+	--	--	P	--	--	--	P+	--	P
Roofing	--	--	--	--	P+	--	--	--	--	--	--	--	P
Siding	P+	--	--	P+	--	--	--	--	--	--	P+	--	P
Windows, aluminum	P	--	--	P+	--	--	--	--	--	--	P+	--	P
Windows, steel	P+	--	--	P+	--	--	--	--	--	--	P+	--	P

"P" indicates preferred coating for this surface.
"P+" indicates that a primer or sealer may be necessary before the finishing coat or coats (unless the surface has been prviously finished).

Figure 3
Exterior paint selection chart

Of course, even the best quality paint won't work if you're using it incorrectly or on the wrong surface. The charts in Figure 3 and Figure 4 show the preferred coatings for exterior and interior surfaces.

Stripping Paint

Sometimes a surface has too many layers of paint or the surface is too cracked or chipped to simply paint over. As tedious as it is, the only solution is to remove the paint down to bare wood, sand, and repaint. If the surface is removable, one option is to take it to a commercial stripper and have it professionally stripped. Often, though, this is impractical because it's too expensive or it's impossible to transport the surface that you need to strip. For instance, you can hardly take the

	Aluminum paint	Casein	Cement base paint	Emulsion paint (including latex)	Enamel	Flat paint	Floor paint or enamel	Floor varnish	Interior varnish	Metal primer	Rubber base paint (not latex)	Sealer or undercoater	Semigloss paint	Shellac	Stain	Wax (emulsion)	Wax (liquid or paste)	Wood sealer
Floors																		
Asphalt tile	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	P+	--
Concrete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	P+	P+	--
Linoleum	--	--	--	--	--	--	P	--	--	--	--	--	--	P	--	P	P	--
Vinyl & rubber	P	--	--	--	--	--	P	P	--	--	--	--	--	--	--	P	P	--
Wood	P	--	--	--	--	--	P+	P+	--	--	--	--	--	--	--	--	P	--
Masonry																		
Old	P	P	P	P	P+	P+	--	--	--	--	P	P	P+	--	--	--	--	--
New	--	--	P	P	P+	P+	--	--	--	--	P	P	P+	--	--	--	--	--
Metal																		
Heating ducts	P	--	--	--	P+	P+	--	--	--	P	P	--	P+	--	--	--	--	--
Radiators	P	--	--	--	P+	P+	--	--	--	P	P	--	P+	--	--	--	--	--
Stairs																		
Treads	--	--	--	--	--	--	P	P	--	--	--	--	--	P	P	--	--	--
Risers	--	--	--	--	P+	P+	--	--	P	--	P	--	P+	P	P	--	--	--
Walls & ceilings																		
Kitchen & bathroom	--	--	--	P	P+	--	--	--	--	--	P	P	P+	--	--	--	--	--
Plaster	--	P	--	P	--	P+	--	--	--	--	P	P	P+	--	--	--	--	--
Wallboard	--	P	--	P	--	P+	--	--	--	--	P	P	P+	--	--	--	--	--
Wood paneling	--	--	--	P+	--	P+	--	--	P	--	--	--	--	--	--	--	--	--
Wood trim	--	--	--	P+	P+	P+	--	--	P	--	P	P	P+	P	P	--	P	P
Windows																		
Aluminum	P	--	--	--	P+	P+	--	--	--	P	P	--	P+	--	--	--	--	--
Steel	P	--	--	--	P+	P+	--	--	--	P	P	--	P+	--	--	--	--	--
Wood sill	--	--	--	--	P+	--	--	--	P	--	--	P	--	--	P	--	--	--

"P" indicates preferred coating for this surface.
"P+" indicates that a primer or sealer may be necessary before the finishing coat or coats (unless the surface has been prviously finished).

Figure 4
Interior paint selection chart

exterior of a house to a dip-and-strip shop. And commercial stripping is hard on wood and dissolves the glue used for veneers and joints.

That usually leaves you with the unpleasant job of stripping the paint yourself. You have a choice of two methods. The first is to use a heat gun, which softens and blisters the paint so you can scrape it off. The second is to use a chemical stripper, which also softens the paint for scraping. Neither is particularly difficult or expensive, but they're both time-consuming and messy.

After you remove the old paint, sand the surface smooth, wipe it clean of dust, and then prepare it for staining or painting just as you would new wood. If you'll be painting the surface, you don't have to be quite as meticulous about removing every speck of paint. For staining, though, any flecks of paint left in the wood will show through.

Tools and Materials

- *Heat gun*
- *Putty knife (round the corners to prevent gouging)*
- *Industrial-grade rubber gloves*
- *Steel wool*
- *Fine sandpaper (150 grit)*
- *Tack cloth*

Using a Heat Gun

Caution: Some heat guns reach temperatures of up to 1,200 degrees F. Keep the gun moving at all times so you don't scorch the wood. Follow the manufacturer's guidelines. Don't use a heat gun on veneers because it may cause the veneer to loosen.

Use the following guidelines when you work with a heat gun:

1. Work in sections of about 6 square inches. Hold the gun an inch from the surface, moving it back and forth constantly.
2. The paint will soften and begin to blister almost immediately. Use a putty knife to scrape the paint off of the wood. If you plan to stain, use a chemical stripper to remove any paint residue.
3. Sand the surface smooth. Wipe clean with a tack cloth, or soak a cotton rag in paint thinner and wipe the surface clean.

Tools and Materials

- *Chemical stripper*
- *Clean, old paint brush*
- *Industrial-grade rubber gloves and other protective clothing*
- *Putty knife (round the corners to prevent gouging)*
- *Plenty of rags*
- *Newspapers and cans or old paint buckets to hold sludge*
- *Steel wool*
- *TSP*
- *Sandpaper*

Using a Chemical Stripper

Two kinds of chemical strippers are available. The formulas with methylene chloride work faster than the water-base strippers, but they are also more caustic. Both require good ventilation. The water-base strippers raise the grain more than the other formula so they require more sanding before you can repaint. Follow the manufacturer's guidelines for other safety precautions.

Don't skimp on the quality or quantity of stripper. You'll just end up having to do two or three coats instead of one. For wood that has several layers to be stripped, expect to repeat the process several times, even with a good quality stripper.

Use the following guidelines when working with a chemical stripper:

1. Pour the stripper onto the surface and using a paint brush, dab (don't brush) it over the entire area. As much as possible, try to keep the surface horizontal.
2. Let the stripper stand on the wood for the manufacturer's recommended amount of time. Nontoxic stripper will soften the paint but won't make it blister. Occasionally test with your putty knife to see if it's ready to remove. When the paint is soft, use the putty knife to scrape off the sludge, always working with the grain.

3. Repeat the process as necessary to remove as much paint or stain as possible.
4. When the surface is clean, go over the area with steel wool and TSP. As a final step, sand for a smooth surface.

Mixing and Thinning the Paint

Some paints are designed to be thinned while others aren't. Follow the manufacturer's recommendation on the can, using water to thin latex paints and turpentine or Penetrol for oil-base paints. Some paint manufacturers recommend thinning when you're painting with an airless sprayer. Again, follow the instructions on the can. Be especially careful not to thin the paint too much. Overthinning the paint will cause streaks or skips as you paint. If you do thin the paint, pour off a little of the undiluted paint first in case you thin it too much and have to add some back later to thicken it again.

Always mix the paint thoroughly just before using it. Ideally, you'd have this done mechanically at the paint store just before you paint. Most of the time, however, you'll probably have to mix the paint at the job site long after the store has mixed it. Don't depend on a paint paddle to do the job. An electric drill with a special attachment works well for water-thinned paints. However, because solvent-thinned paints are flammable, a spark from the drill could cause a fire. So it's better to pour, or chase, the paint from one bucket to another eight or ten times. Each time, use a paddle to scrape the bottom clean. Turning the can upside down 24 hours before using the paint will also help to make the mixing easier.

Even commercially-mixed paints can have slight variations in color. To avoid tint or shade differences, mix together, or box, as many gallons as you can in a 5-gallon bucket. This will give you a consistent color and texture throughout. If you're using more than 5 gallons of one color, mix the additional gallons in as much of the remaining paint as possible.

Applying the Paint

There are a couple of basic principles that apply, whether you're painting with a brush, roller or airless sprayer:

1. Begin each stroke in an unpainted area and end in a painted one. The first stroke, if you're using a brush or a roller, should be away from you.

2. Begin with the ceiling. When that is finished, do the walls, starting at the top and working down. Paint the room in 3-feet square sections, coving top to bottom of each section rather than side to side.

Brush

When using a brush, dip it into the paint no more than half way up the bristles. Gently tap the brush against the inside of the can to remove the excess. The first brush stroke should go up, followed by an even up and down stroking. Keep your pressure even and light; don't force paint out of the bristles. As much as possible, paint with the broad end of the brush rather than the side. Otherwise, the bristles will tend to separate, or finger, which will leave streaks in the paint.

Flat wall paint is fairly forgiving, assuming you're working with a good quality paint that's the right one for the surface. As long as you don't leave any skips or ridges of paint, it will dry to a smooth surface.

High-gloss enamel is more difficult. To achieve a smooth, even finish, dip the brush into the paint and complete the first three steps listed below before reloading with more paint. Don't try to cover more than 2 to 3 square feet at a time.

1. Begin by painting three vertical stripes less than a brush-width apart.
2. Brush in horizontal strokes across the stripes. As you work, smooth out the paint.
3. When all the areas have been filled in, lightly brush over the whole section in vertical strokes.
4. Reload the brush and begin the next section, brushing back into the already-painted area.

Cutting In

One of the more difficult and critical steps in painting is cutting in. Sometimes when you use a brush to cut in and follow with a roller for the rest of the wall, you'll end up with a shade or texture difference where you've brushed. This happens because a brush will leave a different texture and amount of paint than a roller. Plus, the roller often leaves a tiny ridge of paint. To avoid this "picture frame" look, have one person roll paint while another follows immediately with a brush. If you're working alone, roll smaller areas, cutting in as described below while the paint is still wet.

1. Trim with a wet trim roller to within $^1/_2$ inch of the corner.
2. Brush the remaining area, using a semicircular stroke to brush the paint into the corner.

3. Dab, or *stipple*, the brushed area with the tips to match the texture of the rolled area.

Often, you'll need to paint one color right next to another color or next to an unpainted area. In most situations, masking off with painter's tape will be the fastest and easiest way to make a clean, straight line. Avoid masking tape because it absorbs paint and allows it to bleed under. Also, if you don't remove the masking tape soon enough, it'll leave a sticky residue that's a hassle to clean up.

Painting Straight Lines

A 2 1/2-inch chiseled brush will work best in most situations.

Inconspicuous or Small Areas —

Press the flat side of the brush next to the line until small beads of paint appear at the top. In a smooth, steady motion, draw the brush down the line.

Larger or More Visible Areas —

1. Paint the first color. Let it dry.
2. For the second color, mask off the line.
3. Or, using a straightedge, scribe a very shallow groove along the line with a thin flathead screwdriver. Carefully paint so that the bead of paint flows in the groove.

Horizontal Lines —

Measure up from the floor for the initial measurement. Since floors aren't always level, use a carpenter's level to get the straightest line.

Vertical Lines —

Use a carpenter's level or plumb line along with a straightedge to mark and then mask or scribe a straight line.

Wall and Ceiling Joints —

1. Paint the ceiling. Let it dry.
2. Scribe a shallow groove where the wall and ceiling meet. Then carefully paint so that the bead of paint flows in the groove.

Baseboards

In new construction, paint before the trim is installed. Sometimes in extensive remodel work, the trim is removed. If so, do the painting before the trim is reinstalled. If the trim wasn't removed, follow these steps:

1. Mask off the carpet with painter's tape.
2. Use a plastic or metal guard to further protect the floor or carpet.

Windows

Work from the top down, using a $1^1/_2$- to 2-inch brush. Wipe up splatters as you go and scrape off the excess paint with a single-edge razor blade before it's completely dried.

1. Use painter's tape or liquid masking, which wipes off along with the excess paint. Brush on the paint.
2. For multipane windows, cut 20-pound bond paper the size of the window panes. Either glue the paper to the glass with a glue stick or use painter's tape to tape it on. Brush or spray on the paint.

Roller

When using a roller, paint about 3 square feet at a time.

Walls

1. Load roller with paint. Your first stroke should be up and away from you. Without lifting the roller, move it in an M pattern until it takes more effort to roll, which means the roller is running out of paint.
2. Without lifting the roller, roll back and forth over the area. Spread out all of the paint, filling in the M.
3. Move to the next section, repeating steps 1 and 2. Begin in an unpainted area and finish in a painted one.

Ceilings

Follow steps 1, 2, and 3 above. Again, your first stroke should be away from you, which means you'll paint in a W pattern rather than an M.

Spray Painting

Using a spray system can be tricky at first. But an experienced sprayer can cover two to three times as much square footage in a single hour as someone with a roller. It's worth learning to do well. Since labor costs run about 80 percent of most paint jobs, spray equipment can sometimes pay for itself in a single job.

The information in this section will help you get started. Spray equipment varies from manufacturer to manufacturer. If you're buying or renting spray equipment, the dealer should give you detailed instructions. There are two different kinds of spray systems: airless spray systems and conventional systems. Professional painters use both, depending on the job.

Airless Sprayers

An airless sprayer forces paint through its system at high pressure, up to 3,000 psi. The most important advantage of an airless sprayer is that you can paint large areas without any interruption because the feeder hose feeds directly from the paint bucket. A conventional sprayer has about a quart-size pot to hold the paint. Another advantage of an airless sprayer is that it doesn't require the paint to be thinned as much as a conventional system. That's particularly important when you're using latex. If you thin latex too much, it won't cover adequately.

A minor disadvantage of an airless system is that there's a slight delay in starting or stopping the paint after you pull or release the trigger. It takes some practice to compensate for this.

A term commonly used with airless systems is gpm, or gallons per minute of liquid flow. This measures how much paint is sprayed per minute. Depending on the machine, the tip size, and the material being sprayed, the gpm may be as little as .05 or more than 7.0.

Conventional Sprayers

A conventional system uses an air compressor to provide pressure. The paint is either pressure-fed through a tube and into the nozzle, or siphon-fed through a vacuum process. A siphon feed system requires thinner paint because the vacuum process may not be able to pull paint that's too thick. Because a conventional system can spray only about a quart at a time, it's rarely used for large areas such as walls or ceilings. More often you'd use it for applying paint or stains to trim and cabinets, where a smooth finish is highly desirable but a long stretch of uninterrupted painting isn't necessary.

Two common measurements used with a conventional system are psi and cfm. The first, psi, refers to pounds per square inch, which measures the amount of air pressure or force with which the paint is sprayed. The second, cfm, or cubic feet per minute, gives the volume of paint sprayed.

Conventional systems use either a bleeder gun or nonbleeder gun. The bleeder gun has a continuous stream of air even when paint isn't flowing. This allows the paint to start or stop almost instantaneously when the trigger is pulled or released. A nonbleeder gun has air flowing only when you pull the trigger, which means there's a slight delay action with the trigger.

Both types of guns use either an internal-mix nozzle or an external-mix nozzle, depending on the type of paint you're spraying. The internal-mix nozzle works well with enamels, urethanes and latex paints, which are heavy or slow-drying. The external-mix nozzle is designed for lacquers and stains, which are thin, lightweight, and fast-drying.

Spray Patterns

When you're finished spraying, check the surface from all different angles to make sure the paint is even in texture and color. If it's uneven, you'll need to adjust your technique or one of the other variables that may affect the spray pattern.

You can easily adjust the amount of pressure by using the pressure control knob. Too much pressure will produce a high amount of mist. Too little pressure creates a stream, rather than a fan of paint.

With any painting, the air temperature should be neither too hot nor too cold. When spraying, this is even more critical. You'll get your best results spraying when temperatures are below 75 degrees and above 50.

The paint viscosity (thickness of the material) is more important for spraying than for rolling or brushing. Paint that's too thick won't cover evenly or may not fan out as it's sprayed. Overthinned paint will mist excessively. Use a viscosity test stick or a Zaun Cup to determine how much to thin the paint. The Zaun Cup comes in a variety of sizes, with specific size holes or sieve screen ratios, with the time for draining specific to the type of paint being tested. The results of the timed drain will indicate how much to thin the paint. Typically, paint needs to be thinned about 10 percent for even spraying. If you find that you've thinned it too much, add back in some of the unthinned paint, or use a tip with a slightly larger orifice.

The right tip size and fan pattern also affect the quality of the paint job. The tips come in various orifice (opening) sizes as well as different spray patterns. The larger the orifice, the heavier the material you can spray and the thicker the coverage. Generally, thin viscosity materials like lacquers, stains, sealers and wash primers take an orifice size of 0.007 to 0.013 inch. Most medium viscosity materials (house paints, sprayable adhesives and industrial enamels) use an orifice size of 0.013 to 0.023 inch. Heavy viscosity materials like epoxies and block fillers require an orifice of 0.021 inch or larger.

Because the tip orifice is extremely small, in some cases less than a hundredth of an inch, even very small particles can clog up the system. When using any kind of paint sprayer, strain the paint before you use it. The simplest way to do this is to buy a straining cloth that covers a 5-gallon bucket, or use several layers of cheesecloth or nylon stockings. Pour the paint through the cloth. Paint sprayers also come with filters, which you should clean daily.

Keeping the spray tip itself clean is equally important. A clogged tip will cause the gun to spray unevenly. To keep it clean, occasionally dip it in solvent. Most manufacturers make a reversible tip. When the tip starts to clog, simply reverse the tip, spray to clean, and return it to the spraying position.

If the tip gets clogged from hardened paint, carefully push a plastic toothpick through the orifice, and then reverse the tip on the gun and blow. If it's still clogged, soak the tip in paint thinner or clean it with liquid sandpaper. The tip can be easily damaged, so be careful as you clean. Some painters recommend using a thin wire or a soft wire brush to clean the tip. Although this might be an easier way of removing hardened paint, it's also an easy way to ruin the tip.

Here's a safety tip. An airless system sprays paint at up to 3,000 psi. If your skin comes into contact with paint at this pressure, the paint can penetrate the skin, which can be nasty business. Paint can cause blood poisoning or other serious complications. So treat it respectfully. Never spray it towards yourself or other people or animals. When cleaning the tip, always unplug the machine first. Use safety goggles and a mask or respirator and work in a well-ventilated area. Remember, too, that many paints and finishes are flammable, so turn off pilot lights and don't smoke.

Spraying the Paint

If you're unsure about how to use spray equipment, practice first with water until you get a feel for the trigger action and how much delay there is in stopping and starting.

Most tip manufacturers assume a spray distance of 12 inches. You can vary this distance a little, but keep in mind that if you get too close, you'll put on more material and it may run or cover unevenly. If you hold the nozzle too far away, you'll be putting on less material and it may not cover adequately.

Walls —

1. Holding the spray gun perpendicular to the surface about 12 inches away, begin moving the gun before pulling the trigger. Likewise, release the trigger just before ending the stroke. Move with the gun, keeping parallel to the work surface at all times. Don't stand in one spot and just move the gun.

2. Work in 3-foot wide strips in a back and forth pattern. Overlap $^1/_2$ to $^1/_3$ of the previous stroke. Keep moving and overlapping while the first pass is still wet. Overlapping on dry paint causes shadowing.

3. As you spray, smooth any drips or sags with a brush.

4. Some surfaces may need a second or even a third coat, depending on the viscosity of the paint. If you have to do another coat, spray the second coat perpendicular to the first.

Acoustic Ceilings —

1. Use a flexible extension tip, which bends up or down without affecting the spray pattern.
2. Using either very thin paint or acoustic paint, apply two coats. Spray the first coat the width of the room, and then spray the second coat the length of the room.

Care and Cleanup of Equipment

Prevention is the real key to cleaning up. By avoiding spills and splatters to begin with, you'll save time at the end of the day.

When you first open the paint, make a few punctures on the inside rim lip of the paint can so the paint will drain back into the can instead of overflowing down the outside. For gallon cans, glue a paper plate to the bottom to catch drips.

If you take a break, put your brushes and rollers in a plastic bag and close it securely. (First, make sure the paint won't melt the plastic.) Leave it in a cool spot. Cover the paint with plastic wrap for short breaks. Overnight, put the lid over plastic wrap to make it easy to open the next day.

When you're finished with the paint for that job, sweep around the lip of the can with your brush; then hammer the lid on. The brush will catch the last few drips in the lip to keep them from splattering, and the coating of paint will seal the can as it dries. Be sure to label the paint with the job and room you used it for. Don't trust your memory.

Wearing a hat, gloves, long-sleeved shirt, and long pants is a good way to avoid paint splatters on you, but sometimes it's too hot to wear them. If that's the case, spread petroleum jelly or cold cream on your exposed skin, and spray hair spray on your hair before you start painting. They'll keep the paint from penetrating. For any paint that does stick, use mineral spirits followed by a commercial hand cleaner. Or try scrubbing with baking soda and a soft-bristle brush.

Buy good quality equipment — brushes, rollers, and sprayers — then take good care of it. Clean your equipment immediately after you've finished painting. Don't depend on mineral spirits to salvage what you're too lazy to clean carefully.

Brushes

Give your entire brush a thorough cleaning, not just the visible part.

Nylon and polyester brushes (when using latex and water-based stains): Use mild soap and water as the cleaning solvent.

Bristle brushes (when using stains, polyurethanes, varnishes, plastics, oils/alkyd paints): Use mineral spirits or paint thinner as the cleaning solvent.

To routinely clean a brush after each use, follow these steps:

1. Use three clean 1-gallon buckets, and pour 1 pint of cleaning solvent into each.
2. Dip the brush into the first bucket several times to saturate the brush. Use a comb or wire brush to work the solvent into the filaments. Spin the paint brush inside an empty bucket to remove excess solvent and paint particles.
3. Dip the brush into the second bucket several times, and spin again.
4. Dip the brush into the third bucket and spin. Test to see if the brush is clean by dipping the brush in clean solvent and squeezing the bristles. If the solvent doesn't run clear, then repeat dipping and spinning until it does.
5. When clean, straighten the filaments with a comb. Avoid combing the tips. Hang the brush up until it's almost dry, and put it back in its cover. Or wrap it in wax paper or aluminum foil to retain the brush's shape.

Some painters finish the cleaning process by dipping the brush into kerosene or thinner that has a little motor oil in it. This keeps the filaments a little softer. If you do this, rinse the brush in clear thinner before you use it again.

Nylon and polyester brushes tend to be harder to keep clean than bristle brushes, partly because water-thinned paints dry so much faster than solvent-thinned. To prevent problems, clean the brush thoroughly at least once during the day as well as at the end of the day, more if it's a hot day or you're working in the sun. Working water into the heel of the brush at the beginning of the day will also keep the paint from drying too quickly where it's the hardest to clean. For the stubborn jobs, you can use paint thinner and follow with soap and water as described above.

If you leave paint in the filaments, the brush will heel harden. That's when dried paint builds up and hardens in the heel of the brush. This eventually causes fingering and reduces the flexibility of the filaments, making the brush unusable. You can sometimes save a heel-hardened brush with a thorough cleaning. Never try to salvage a brush by soaking it in solvent. It might make the paint easier to remove, but it's hard on the filaments. The following process might work to clean a heel hardened brush, although it may shorten its life.

1. Rinse the brush in mineral spirits. Use a comb to work the solvent into the filaments.
2. When the brush is clean, dip it in boiling water, and comb the filaments straight. Avoid combing the tips, which causes excess wear.
3. Hang the brush up until it's almost dry, and put it back in its cover. Or wrap it in wax paper or aluminum foil to retain the brush's shape.

Rollers

Some painters believe rollers aren't worth cleaning up, that it's cheaper in the long run to throw them away after a job and buy new ones. Granted, cleaning rollers isn't fun or easy, but many painters would still say it's worthwhile.

To clean water-base paint from a roller:

1. Roll out the excess paint on newspaper. Rinse the roller in water.
2. Follow with a mild detergent and water solution until the water runs clean. Spin the roller in a bucket several times to remove paint particles and excess water.
3. Stand the roller on end to dry, and wrap it in a plastic bag or foil. Store it on end.

For oil-base paint, follow the steps above but use mineral spirits. End with a soap-and-water rinse. Wearing rubber gloves will help protect your hands from the harshness of the chemicals.

Spray Equipment

It's essential to thoroughly clean your spray system at the end of each day's work. Paint left in the system will result in a ruined machine or costly repair bills. If you can afford the sprayer to begin with, you can afford the solvent to clean it. Individual manufacturers give specific instructions for their machines. In general, though, follow these steps:

1. Pump excess paint out of the system.
2. Flush the system with the appropriate solvent (soap and water for water-thinned; mineral spirits for oil-base). This will take about a gallon of mineral spirits, which you can reuse many times.
3. Take apart individual components. Carefully clean them in the appropriate solvent.
4. When the machine appears clean, run another $^1/_2$ gallon of clean mineral spirits (even for water-thinned paints) through as a final flush.

Manhours

Manhours for Interior Paint Preparation, per SF		
Job	**Manhours**	**Suggested Crew**
Cleaning, wet, smooth finishes		
Plaster, drywall or paneling	.007	1 painter
Millwork and trim	.008	1 painter
Floors	.005	1 painter
Cleaning, wet, sand finishes	.011	1 painter
Light sanding	.008	1 painter
Paint or varnish removal, liquid (170 SF/gal)		
Paneling	.038	1 painter
Millwork and trim	.044	1 painter
Floors	.026	1 painter
Paint or varnish removal, burn off	.062	1 painter
Sizing on sheetrock or plaster, smooth finish		
Brush (650 SF/gal)	.005	1 painter
Roller (625 SF/gal)	.004	1 painter
Sizing on sheetrock or plaster, sand finish		
Brush (550 SF/gal)	.007	1 painter
Roller (525 SF/gal)	.005	1 painter
Sealer on sheetrock or plaster, smooth finish		
Brush (300 SF/gal)	.009	1 painter
Roller (285 SF/gal)	.007	1 painter
Spray (250 SF/gal)	.005	1 painter
Sealer on sheetrock or plaster, sand finish		
Brush (250 SF/gal)	.012	1 painter
Roller (235 SF/gal)	.009	1 painter
Spray (210 SF/gal)	.005	1 painter
Sealer on acoustical tile or panels		
Brush (225 SF/gal)	.010	1 painter
Roller (200 SF/gal)	.008	1 painter
Spray (160 SF/gal)	.006	1 painter

Manhours for Interior Painting, per SF		
Type	**Manhours**	**Suggested Crew**
Latex flat – one coat application		
Drywall or plaster, smooth finish		
Brush (300 SF/gal)	.009	1 painter
Roller (285 SF/gal)	.007	1 painter
Spray (260 SF/gal)	.005	1 painter
Drywall or plaster, sand finish		
Brush (250 SF/gal)	.013	1 painter
Roller (235 SF/gal)	.010	1 painter
Spray (210 SF/gal)	.005	1 painter
Acoustical tile or panels		
Brush (225 SF/gal)	.011	1 painter
Roller (210 SF/gal)	.009	1 painter
Spray (185 SF/gal)	.006	1 painter
Latex flat – two coat application		
Drywall or plaster, smooth finish		
Brush (170 SF/gal)	.014	1 painter
Roller (160 SF/gal)	.012	1 painter
Drywall or plaster, sand finish		
Brush (170 SF/gal)	.021	1 painter
Roller (160 SF/gal)	.016	1 painter
Acoustical tile or panels		
Brush (130 SF/gal)	.018	1 painter
Roller (120 SF/gal)	.014	1 painter
Latex enamel – one coat application		
Paneling		
Brush (300 SF/gal)	.009	1 painter
Roller (285 SF/gal)	.007	1 painter
Spray (260 SF/gal)	.005	1 painter
Doors and windows		
Brush and/or roller (360 SF/gal)	.019	1 painter
Spray, doors only (260 SF/gal)	.009	1 painter
Cabinets		
Brush and/or roller (360 SF/gal)	.021	1 painter
Spray, doors only (260 SF/gal)	.009	1 painter

Manhours for Interior Painting, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Latex enamel – one coat application (continued)		
Louvers		
Spray (300 SF/gal)	.028	1 painter
Molding and trim, less than 6″ high (SF equals LF on trim less than 6″ high)		
Brush (900 SF/gal)	.013	1 painter
Latex enamel – two coat application		
Paneling		
Brush (170 SF/gal)	.014	1 painter
Roller (160 SF/gal)	.012	1 painter
Doors and windows		
Brush and/or roller (200 SF/gal)	.037	1 painter
Cabinets		
Brush and/or roller (200 SF/gal)	.039	1 painter
Molding and trim, less than 6″ high (SF equals LF on trim less than 6″ high)		
Brush (510 SF/gal)	.025	1 painter
Floors, wood		
Brush (230 SF/gal)	.011	1 painter
Roller (220 SF/gal)	.010	1 painter
Natural finishes – one coat application		
Paneling (brush work, unless noted)		
Stain – brush on, wipe off (360 SF/gal)	.022	1 painter
Varnish (380 SF/gal)	.009	1 painter
Shellac (630 SF/gal)	.008	1 painter
Lacquer (450 SF/gal)	.006	1 painter
Lacquer – spray application (300 SF/gal)	.005	1 painter

Manhours for Interior Painting, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Doors and windows (brush work, unless noted)		
Stain – brush on, wipe off (450 SF/gal)	.049	1 painter
Varnish (550 SF/gal)	.036	1 painter
Shellac (550 SF/gal)	.034	1 painter
Lacquer (550 SF/gal)	.032	1 painter
Lacquer – spray application (300 SF/gal)	.015	1 painter
Cabinets (brush work, unless noted)		
Stain – brush on, wipe off (450 SF/gal)	.052	1 painter
Varnish (550 SF/gal)	.038	1 painter
Shellac (550 SF/gal)	.036	1 painter
Lacquer (550 SF/gal)	.032	1 painter
Lacquer – spray application (300 SF/gal)	.016	1 painter
Louvers		
Lacquer – spray application (300 SF/gal)	.026	1 painter
Molding and trim, less than 6" high (SF equals LF on trim less than 6" high) (brush work, unless noted)		
Varnish (900 SF/gal)	.012	1 painter
Shellac (900 SF/gal)	.012	1 painter
Lacquer – spray application (700 SF/gal)	.010	1 painter
Floors (brush work, unless noted)		
Varnish (500 SF/gal)	.006	1 painter
Shellac (450 SF/gal)	.006	1 painter
Penetrating stainwax (hardwood floors) (450 SF/gal)	.006	1 painter
Penetrating stainwax (hardwood floors) – roller application (450 SF/gal)	.005	1 painter
Buffing by machine	.004	1 painter
Waxing and polishing by hand	.008	1 painter

Manhours for Exterior Paint Preparation, per SF		
Job	**Manhours**	**Suggested Crew**
Cleaning, wet		
Plain siding	.008	1 painter
Doors and trim	.009	1 painter
Window (including glass)	.010	1 painter
Porch floors and steps	.005	1 painter
Acid wash gutters and downspouts	.012	1 painter
Sanding and puttying		
Plain siding	.009	1 painter
Doors and trim	.017	1 painter
Windows (including sash and reglazing)	.051	1 painter

Manhours for Exterior Painting, per SF		
Type	**Manhours**	**Suggested Crew**
Latex, flat – one coat application		
Plain siding		
Brush (300 SF/gal)	.015	1 painter
Roller (275 SF/gal)	.012	1 painter
Spray (325 SF/gal)	.007	1 painter
Shingle siding		
Brush (270 SF/gal)	.014	1 painter
Roller (260 SF/gal)	.010	1 painter
Spray (300 SF/gal)	.008	1 painter
Stucco		
Brush (135 SF/gal)	.015	1 painter
Roller (125 SF/gal)	.010	1 painter
Spray (150 SF/gal)	.008	1 painter
Doors (exterior side only)		
Brush (375 SF/gal)	.019	1 painter
Roller (375 SF/gal)	.014	1 painter
Windows (exterior side only)		
Brush (1500 SF/gal)	.019	1 painter
Storm windows and doors, 2 lites		
Brush (340 SF/gal)	.036	1 painter

Manhours for Exterior Painting, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Latex, flat – one coat application *(continued)*		
Blinds or shutters		
Brush (120 SF/gal)	.094	1 painter
Spray (300 SF/gal)	.031	1 painter
Gutters and downspouts, galvanized		
Brush (225 LF/gal)	.021	1 painter
Porch floors and stairs, wood		
Brush (340 SF/gal)	.008	1 painter
Roller (325 SF/gal)	.006	1 painter
Shingle roofs		
Brush (135 SF/gal)	.012	1 painter
Roller (125 SF/gal)	.009	1 painter
Spray (150 SF/gal)	.006	1 painter
Latex flat – two coat application		
Plain siding		
Brush (170 SF/gal)	.028	1 painter
Roller (155 SF/gal)	.022	1 painter
Spray (185 SF/gal)	.013	1 painter
Shingle siding		
Brush (150 SF/gal)	.026	1 painter
Roller (150 SF/gal)	.019	1 painter
Spray (170 SF/gal)	.014	1 painter
Stucco		
Brush (90 SF/gal)	.026	1 painter
Roller (85 SF/gal)	.018	1 painter
Spray (100 SF/gal)	.014	1 painter
Doors (exterior side only)		
Brush (215 SF/gal)	.037	1 painter
Roller (215 SF/gal)	.027	1 painter
Windows (exterior side only)		
Brush (850 SF/gal)	.037	1 painter
Blinds or shutters		
Brush (65 SF/gal)	.174	1 painter
Spray (170 SF/gal)	.058	1 painter

Manhours for Exterior Painting, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Latex, flat – two coat application *(continued)*		
Gutters and downspouts, galvanized		
Brush (130 LF/gal)	.039	1 painter
Porch floors and stairs, wood		
Brush (195 SF/gal)	.015	1 painter
Roller (185 SF/gal)	.012	1 painter
Shingle roofs		
Brush (75 SF/gal)	.019	1 painter
Roller (70 SF/gal)	.015	1 painter
Spray (85 SF/gal)	.012	1 painter
Latex, high gloss – one coat application		
Trim, less than 6" high (SF equals LF on trim less than 6" high)		
Brush (300 SF/gal)	.014	1 painter
Screens, full		
Brush, wood only (700 SF/gal)	.023	1 painter
Brush wood, spray wire (475 SF/gal)	.027	1 painter
Latex, high gloss – two coat application		
Trim, less than 6" high (SF equals LF on trim less than 6" high)		
Brush (230 SF/gal)	.026	1 painter
Screens, full		
Brush, wood only (400 SF/gal)	.043	1 painter
Brush wood, spray wire (270 SF/gal)	.051	1 painter
Masonry latex – one coat application		
Masonry block, brick or tile		
Brush (180 SF/gal)	.014	1 painter
Roller (125 SF/gal)	.009	1 painter
Spray (160 SF/gal)	.007	1 painter
Masonry latex – two coat application		
Masonry block, brick or tile		
Brush (120 SF/gal)	.024	1 painter
Roller (85 SF/gal)	.016	1 painter
Spray (105 SF/gal)	.012	1 painter

Manhours for Exterior Painting, per SF (continued)		
Type	**Manhours**	**Suggested Crew**
Epoxy cement enamel – one coat application		
Cement walls, smooth finish		
Brush (120 SF/gal)	.009	1 painter
Roller (110 SF/gal)	.006	1 painter
Concrete porch floors and steps		
Brush (400 SF/gal)	.006	1 painter
Roller (375 SF/gal)	.005	1 painter
Epoxy cement enamel – two coat application		
Cement walls, smooth finish		
Brush (80 SF/gal)	.017	1 painter
Roller (75 SF/gal)	.012	1 painter
Concrete porch floors and steps		
Brush (225 SF/gal)	.012	1 painter
Roller (210 SF/gal)	.012	1 painter
Stain – one coat application		
Shingle siding		
Brush (180 SF/gal)	.015	1 painter
Roller (170 SF/gal)	.011	1 painter
Spray (200 SF/gal)	.008	1 painter
Shingle roofs		
Brush (180 SF/gal)	.013	1 painter
Roller (170 SF/gal)	.010	1 painter
Spray (200 SF/gal)	.006	1 painter
Stain – two coat application		
Shingle siding		
Brush (105 SF/gal)	.026	1 painter
Roller (100 SF/gal)	.021	1 painter
Spray (115 SF/gal)	.014	1 painter
Shingle roofs		
Brush (105 SF/gal)	.022	1 painter
Roller (100 SF/gal)	.016	1 painter
Spray (115 SF/gal)	.011	1 painter

For information on related topics, see:

Drywall, page 241

Radon and Other Pollutants, page 499

Siding, page 611

Trim, page 673

Wallpaper, page 737

Wood Flooring, page 759

Paneling

You may want to use wood paneling as a finish wall surface for a variety of reasons. In some cases, you might use inexpensive paneling to cover up a flawed wall surface, such as broken plaster. Or, you might choose beautiful solid wood paneling as a luxurious wall finish in a high-end remodeling job. In between these two examples are many excellent options for wall paneling finishes. You can divide paneling into two general groups: plywood paneling and solid wood paneling.

Paneling Types

Plywood paneling is available in 4 × 8 sheets. It comes prefinished or unfinished, and textured, grooved, or smooth. It's available in a wide variety of finishes, with a wide variety of costs to match. The more expensive varieties include exotic hardwood finishes.

Hardboard paneling also comes in 4 × 8 sheets. Hardboard imprinted with a wood grain pattern is generally less expensive than plywood. The better hardboard paneling uses a photograph of wood to provide a wood grain effect, producing a very realistic pattern. It also comes in vinyl coatings in many different patterns and colors. Plywood and hardboard panels are installed in the same way.

Solid wood paneling is generally sold in tongue-and-groove boards, usually limited to 8 inches in nominal width, and up to 12 foot lengths. It's available in a variety of types and patterns to satisfy a wide range of decorative treatments. For informal treatments you can use knotty pine, white-pocket Douglas fir, sound wormy chestnut, or pecky cypress in unfinished natural or stained and varnished finishes. Solid wood paneling can be installed horizontally or vertically.

Backing for Paneling

You can attach plywood or hardboard paneling directly to the studs, but that's seldom a good idea because plywood paneling is only $^{3}/_{16}$-inch thick. Without backing, sooner or later someone or something will punch a hole in it. Drywall is an inexpensive backer that you can easily install, especially since there's no need to finish it. No one will see the drywall once the paneling is in place.

In a finished basement, polystyrene (beadboard) placed between $^{3}/_{4}$-inch furring strips provides both insulation and an adequate backing for plywood paneling.

Wood paneling should be applied over a vapor barrier and insulation when the application is on the exterior wall framing or blocking. When applying the paneling vertically, you'll need to install 1 × 4 nailing strips or 2 × 4 cross blocking at 24 inch intervals for nailing (see Figure 1). You'll also need to install 1 × 4 nailing strips when applying the paneling over concrete, plaster or masonry. The maximum spacing of supports for nailing should be 24 inches on center. Horizontal applications can be nailed to the studs.

Wood panel thickness should be at least $^{3}/_{8}$ inch for 16 inch spacing of frame members, $^{1}/_{2}$ inch for 20 inch spacing, and $^{5}/_{8}$ inch for 24 inch spacing. Unfinished wood paneling should be cut, sanded and stained before installation.

Fasteners for Paneling

You attach plywood and hardboard paneling using a combination of nails and adhesives. Ring-shanked paneling nails are available in colors to match most prefinished paneling. If you use them, you can set them flush with the surface. Set bright nails so that you can fill over them with colored putty that matches the wood surface. You can also use bright finish nails on jobs where panels will be finished on site, again using colored putty that will blend when the surface is finished. Before nailing, you should glue panels to the backing. Panel adhesives are available that have been formulated specifically for this purpose. When using polystyrene backing, be sure you're not using an adhesive that will react negatively to the backing.

Wood paneling should be attached with $1^{1}/_{2}$- to 2-inch finishing nails or 5d or 6d casing nails. Blind nail through the tongue, and for 8-inch boards, face nail near the opposite edge. Use two nails for boards 6 inches or less, and three nails for 8-inch boards.

Estimating the Number of Panels

Plywood and hardboard panels are available in 4-foot widths that are 8 feet high. Estimating the number of panels involves more than simply totaling up the lineal footage of the walls and dividing by 4. To estimate correctly, you should first determine the number of full panel sheets that you'll need.

If the studs have been laid out at 16 inches on center, three consecutive full spaces equal one sheet. Less than three full consecutive spaces or spaces at either end of the layout that aren't full spaces will require cutting. Measure and count these partial spaces, and determine how you can cut the sheets to make the best use of a full sheet. Add these partial pieces to the full sheet count for your total.

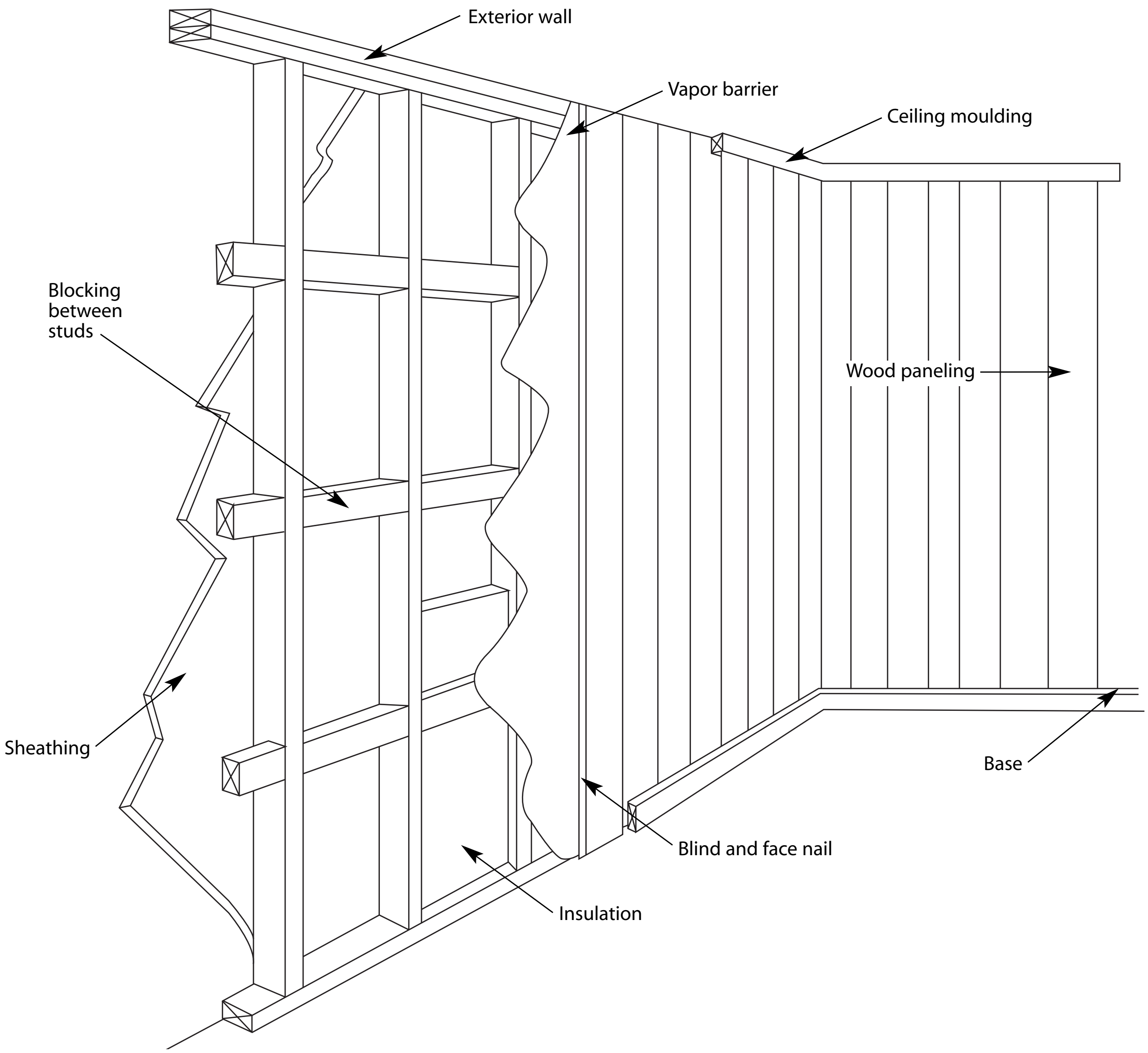


Figure 1
Blocking between studs for vertical wood paneling

When counting the partial spaces, remember that when you cut prefinished panels, factory edges will then meet factory edges. Place the cut edge in a corner where it will be covered by molding. Try not to end with a layout where you'll have to take 12 inches off of one side of the panel and 8 inches off the other side. The result will be 28 inches of perfectly good paneling without a factory edge. It's possible to join plywood paneling at a cut edge, rather than a factory edge, but it seldom results in a good finish.

Estimate solid wood paneling by the foot of wall space. Measure the width of each wall and ceiling and multiply the total feet by 12 to determine the total inches. Divide that by the width of the boards, say 8 inches, to determine the number of boards it will take to cover the area. For example, to cover a wall that measures 8 feet high by 16 feet wide, you'll need 24 8-inch wide boards.

16' × 12" = 192"
192" ÷ 8" = 24

Add on an additional 5 to 10 percent for waste, depending on the size of the project. For heights over 12 feet, you'll also have to add in the extra footage for your pattern. Figure your pattern first, then estimate the number of widths required based on the lengths of the boards needed.

Installing Paneling

Paneling is a relatively stable product. However, you should still bring any paneling material to the job site and allow it to adjust to the temperature and humidity prior to installation. As you lay out the panels for this job site adjustment, note the color variations in the paneling. Take the time to match the panels in a pleasing arrangement, avoiding any stark contrasts between two adjoining panels. This step will not only ensure a nice flow to the wood pattern, but will speed up your work later. You can plan to use less attractive panels as partial pieces in corners or in out-of-the-way places.

Begin your installation with a full panel. Use a level to plumb the side of the first sheet. To prevent having to "step" the panels, use extra care to make certain the first panel is plumb. After the first panel is plumbed and fastened in place, follow with the remaining full panels, butting each tight against the preceding panel.

After you've installed all of the full panels on all walls, fill in the partial panel pieces. If you've kept the panels plumb and the intersecting wall is plumb, the cuts should be straight rips. Check by measuring the top and bottom distances between the last panel and the intersecting wall.

Locating Openings

Locate door and window openings by measuring off of the last panel to the opening. If you have trouble visualizing the location of the opening on the back of the panel, it may help to lay the panel face down (with the face protected, of course) in front of its location. Mark a mirror image of the openings on the back of the panel to prepare for cutting.

Cutting Paneling

To prevent tearing plywood or hardboard panels during cutting, make your cut so that the teeth of the saw enter the face of the panel first. If you use a circular saw, this means cutting from the back. When running a sheet through a table saw, the face should be up.

Cut solid wood paneling in the same manner that you would cut any other solid wood finish board. It's always a good practice to make a few trial cuts on a scrap piece of any expensive material being used. If normal cutting techniques produce chipping, use a blade with more teeth.

To cut small openings for outlets or switches, first draw the opening on the panel. Drill holes safely inside the diagonal corners of your drawing. Using a keyhole saw or a saber saw with a very fine blade, start your cut from one hole and cut to the next along the inside of the outline on the face of the panel. If you don't have a fine blade available, cut plywood panels from the back side. When cutting prefinished panels from the front using a tool such as a saber saw, check the base of the tool for any burrs or screws and make certain that your work surface is clean. This will lessen the chance of scratching the finish while you're cutting. As the last step of the cut, clean up the holes.

Finishing the Paneling with Trim

After you've installed the paneling, finish the base and corners using matching prefinished moldings. There are inside and outside corners, as well as baseboard and wainscot caps, available in most paneling finishes. See *Trim, Installation* for cutting and fitting. Fasten the moldings with matching colored nails, or in the same way you fastened the panels.

Manhours

Manhours to Install Paneling		
Type	**Manhours**	**Suggested Crew**
Hardboard, economy	.024	1 carpenter
Plywood or hardboard paneling, prefinished	.030	1 carpenter
Vinyl-clad hardboard paneling	.032	1 carpenter
Hardwood plywood paneling, unfinished		
$^{1}/_{4}$"	.032	1 carpenter
$^{1}/_{2}$"	.040	1 carpenter
$^{3}/_{4}$"	.042	1 carpenter
Solid plank paneling, V-joint or T&G, prefinished	.050	1 carpenter
Board wainscot, T&G, $3^{1}/_{2}$" to $5^{1}/_{2}$" wide	.080	1 carpenter
Frame and panel wainscot	.090	1 carpenter

For information on related topics, see:

Adhesives, page 25

Trim, page 673

Wall Framing, page 709

Plaster

In most parts of the country, it's rare to see lath and plaster walls in new construction. Plastering is an expensive, time consuming, and difficult process that most contractors have readily replaced with drywall. However, you may still want to use plaster for some commercial work or in expensive houses because its a highly durable and valued wall finish.

Also, from time to time, you may need to do plaster repair. Structures built before the 1940s were plastered rather than drywalled. If you're doing extensive remodeling, and find plaster walls that are cracked or buckled, it may be easier just to knock them out and replace them with drywall rather than trying to repair the plaster. But it's handy to have the skills for minor plaster repairs when a wall is solid except for a few chips or a hole or two. If a job requires extensive plastering, you probably won't do it yourself. More likely you'll sub it out to an experienced plastering contractor. We'll just provide an overview that will give you an idea of what to look for in a quality job.

New Plaster Application

You can buy plaster ready to mix with water, or you can mix it together in a specific proportion of water, sand, and a binder, such as cement or gypsum with lime. You can include additives to increase fire resistance or water resistance, cure to a greater hardness, add color or to increase workability.

Lath

You apply plaster over lath, which used to be made of wood but is now more commonly made out of gypsum or metal. Typically, you would use gypsum lath in residential construction, with metal lath being used most often in commercial work.

Gypsum lath comes perforated or unperforated, with the perforated variety offering a stronger bond. There are a few types of metal lath: expanded metal lath sells by the weight per yard and comes in various textures; woven wire fabric comes in different gauges and mesh sizes; and welded wire fabric lath usually comes with a paper backing.

Plaster Coats

You can apply plaster in either a two- or three-coat process. A two-coat or double-up process combines the first two steps into one and is used over gypsum or insulating lath. Apply three-coat plastering over metal or gypsum lath. All the coats should combine to be a minimum of $^1/_2$ inch thick for gypsum lath and a minimum of $^5/_8$ inch thick for metal lath on interior coats. Check your local building code for the requirements for the depth on a specific base.

To gauge for an even surface, check to see how square and level the walls are. Then, using either a plumb bob or a level, place plaster dots or pieces of wood on the wall. Later, when you rod or darby the wall, you can use the dots as checkpoints to make sure the coats are even and there aren't any dips or bumps.

Scratch Coat

The scratch coat is the first layer that you apply to the lath to make a solid base for the other coats. When the coat has set slightly, cross-scratch the surface with a rake or scarifier to a depth of $^1/_8$ inch, then allow it to dry completely. The scratching creates a rough surface and makes a stronger bond with the second coat. Before you apply the brown coat, dampen the scratch coat again.

Brown Coat

The second coat is the brown or leveling coat. It's slightly thinner than the scratch coat, and is intended to level the surface for the final coat. You need to rod, or level, the brown coat with a darby, which is a long flat tool with handles shown in Figure 1. Do the rodding both horizontally and vertically, and then allow the coat to dry completely for at least 48 hours.

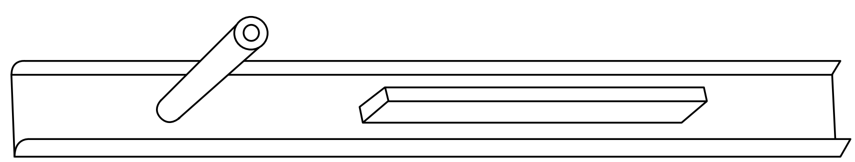


Figure 1
Darby

Finish Coat

The finish or final coat is the last coat and it's usually applied in two steps: a very thin layer over the brown coat with a second coat smoothed over the first. Use either a sand or putty finish. The sand has texture; the putty is smooth. You can also use Keene's cement, which is waterproof and highly durable, for a smooth finish. The minimum thickness for the finish coat is $^{1}/_{16}$ inch.

As in any process using a cementitious mixture, plastering and curing shouldn't be done when it's too cold or too hot. The temperature should remain between 55 and 70 degrees Fahrenheit. Ideally, the permanent heating system should be in place before you plaster. It's best not to use space heaters for heat during plastering. They add excess moisture and create wider swings in temperature, causing problems in the curing.

Plaster Repairs

Before making any repairs, try to find the cause of the problem and fix it. Otherwise, you'll be back to fix the problem again. Typically, plaster problems are caused by water, shifting soil under foundations or careless construction, which may be difficult if not impossible to remedy. (That's all the more reason for you to build right the first time, following soils, engineering, and architectural recommendations.) If the damage was caused by water, give the plaster several weeks to completely dry out before you fix the damage. As you repair plaster cracks or holes, avoid damaging or loosening the lath underneath. Having to repair the lath as well makes the job more complicated.

For patching and repair jobs, don't bother to mix your own plaster. Lumberyards and hardware stores sell gypsum plaster-perlite mixtures that require only water. For the finish coat, use a topping compound. (See *Drywall* for more information on using drywall tools to apply topping compounds.)

Repairing Holes

1. Clean away loose or damaged plaster with a chisel and ball peen hammer, chipping away until the plaster and lath are firm. If the lath is loose, nail it to the stud with ringed nails. Use a utility knife and undercut the plaster edge.

2. Spray the open area with water to dampen the lath and plaster edge. With a drywall knife, spread the scratch coat of plaster in the opening, making it slightly less than half the depth of the existing plaster. When the plaster has set slightly, about 30 minutes, use a scarifier to scratch the surface in two directions.

Tools and Materials

- *Drywall knives in various sizes*
- *Utility knife*
- *Spray bottle with water*
- *Trowel*
- *Hawk*
- *Scarifier*
- *Tub*
- *Saw (for repairing lath)*
- *Ball peen hammer*
- *Chisel*
- *Safety goggles*
- *Sanding respirator*
- *Gloves*
- *Plaster mix and water*
- *Sandpaper*
- *Topping compound*
- *Tarp*

3. Allow the plaster to dry for 24 hours. Spray it with water to dampen the surface and then apply the brown coat. It should come to within about 1/16 inch of the old surface. Allow it to dry for 24 to 48 hours.
4. Apply the topping compound just as you would for a drywall joint, feathering it out as smoothly as possible. Let it dry 24 hours.
5. Sand. Repeat Step 4 if necessary, sanding the final coat as needed. Seal the area with a primer before you paint or wallpaper.

Repairing Cracks

You can repair plaster cracks in the same way as drywall cracks. (See *Drywall*.) Or, use the following guidelines.

1. Clean away the loose and damaged plaster along the crack. Undercut the edges with a utility knife. Mist with water. Spread joint compound or plaster in the crack.
2. Let it dry for 24 hours. Sand lightly. Repeat the process with a topping compound, feathering out the edges as much as possible. Allow it to dry, and then sand again. Seal it with a primer before you paint or wallpaper.

Repairing Lath

1. Remove the plaster from the lath in an area wide enough to expose the studs. Clean and undercut the plaster as described above. Saw out the damaged lath so you can attach the new lath across both studs.
2. Cut gypsum lath or 3/8-inch drywall to fit into the area. Screw the pieces to the studs.
3. Patch as you would for a plaster hole.

Covering Plaster with Drywall

Sometimes plaster is too damaged for you to bother trying to repair. Removing it is a dirty job that most contractors and homeowners would prefer to avoid. If you decide to remove it, seal the area with polyethylene to keep the dust down. Most important, wear a good respirator, safety goggles and protective clothing.

An alternative to removing old plaster is to drywall right over it. This is more complicated than it sounds because it means removing all of the trim and then reinstalling it once you have the drywall up. Another option would be to use 1/4- or 3/8-inch drywall, and leave the trim in place. Sometimes, however, 1/4-inch drywall isn't thick enough or sturdy enough to hide the problems in the plaster.

To cover plaster walls, hang the drywall as you would for new construction. Use long enough drywall screws — at least $2\frac{1}{4}$ inches — to grab the studs through the drywall and plaster. Don't depend on drywall nails to hold the drywall in place. Finish the joints as you would for new drywall. (See *Drywall*.)

Manhours

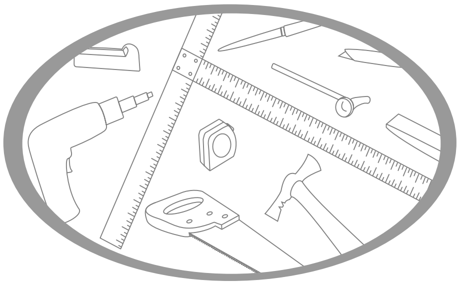
Manhours to Install Plaster, per SY

Item	Manhours	Suggested Crew
Lath, nailed to walls or ceilings		
Gypsum or wood	.154	1 lather
Plaster, applied to walls and ceilings		
Two coats gypsum plaster		
On gypsum lath	.320	2 plasterers, 1 laborer
On unit masonry, no lath	.329	2 plasterers, 1 laborer
Three coats gypsum plaster		
On gypsum lath	.444	2 plasterers, 1 laborer
On unit masonry, no lath	.444	2 plasterers, 1 laborer
On wood lath	.462	2 plasterers, 1 laborer
Above second floor, add	.096	2 plasterers, 1 laborer

For information on related topics, see:

Drywall, page 241

Stucco, page 665



Plumbing

You can divide plumbing into two areas: Bringing fresh water into a structure, and taking the waste waters away. The system bringing water in is simply referred to as the water supply. The system that removes waste liquids from a building is called the DWV (drain, waste and vent) system. Both of these systems must be installed in accordance with local plumbing codes along with the *International Plumbing Code*. Safe and sanitary water distribution and waste disposal are the ultimate goals of these plumbing systems.

Water Supply Lines

Water supply lines, either hot or cold, distribute water to the various fixtures throughout the house. Water is brought into a structure through a water main running from the water meter into the house. The first break inside the house is usually a shutoff valve allowing the entire system to be shut down in case of a failure. The main then branches with a run to the hot water heater. Hot water is distributed in branch lines from the hot water heater while cold water is distributed as the main line branches out.

In the past, galvanized steel, copper and plastic water supply lines have all been used. However, because corrosion eventually occurs in galvanized steel, its use as water supply line has been limited in recent years to replacement of broken fittings. Today, we usually tie copper or plastic piping into existing galvanized pipe for extensions in remodeling work.

Copper Pipe

Copper piping is available in diameters from $^{1}/_{4}$ inch to 8 inches. The largest size that you'll normally use for an inside water supply in single-family residential construction is $^{3}/_{4}$ inch. Larger diameters are used for commercial or multi-family residential uses or as DWV lines.

Copper pipe is also available in three different sizes of wall thickness with use recommendations corresponding to the thickness of each.

- Type K: Heavy wall, code stripe green
- Type L: Medium wall, code stripe blue
- Type M: Light wall, code stripe red
- Type DWV: Drain pipe, code stripe yellow

You can use Type K and L for all copper piping needs including underground service, interior plumbing, heating and cooling systems as well as for gas, oxygen, steam, oil, and snow melting lines.

Limit Type M pipe to interior plumbing, hot water heating systems, chilled water lines, and interior DWV lines. In areas with hard water problems, the minerals in the water are sometimes corrosive to copper. In these areas, avoid using Type M pipe except on runs served by a water softener. Lines up to the softener should be at least Type L.

Soft and Hard Copper

In addition to wall thickness, copper pipe is further categorized by temper, either soft or hard. Soft copper, which you can bend by hand, is sold in coils. Take care when unrolling a coil or working with soft copper that you don't kink the line. If it's kinked, you'll have to cut out the damaged section and repair it with a coupler. Soft copper connections are usually made with compression fittings. In most areas, the primary use for soft copper is the outside main water supply line.

Use hard or rigid copper for interior piping. It comes in 20-foot lengths, although many do-it-yourself supply houses sell shorter lengths. With the proper tools, you can bend hard copper. However, you would rarely do this for water supply lines. Instead, you make your bends and adjustments with fittings, such as angles, reducers, caps, and connectors.

You can cut both hard and soft copper using a pipe and tubing cutter, which has a sharp wheel and a hand screw. The wheel rotates around the pipe while you continually tighten the screw. The pressure from the screw forces the wheel through the pipe for a clean, burr-free cut.

Working with Copper Pipe

Fittings are available in solder or compression types. Usually, you would use solder fittings for rigid copper, although you can use compression fittings as the final connection. Always solder connections in the line.

***Compression Fittings* —** A compression fitting is made up of a threaded fitting piece, a tightening nut, and a compression ring that you assemble in the following manner:

1. Check the pipe receiving the fitting for any damage, such as scratches or burrs, that would prevent the compression ring from sealing.
2. Place the nut, compression ring, and fitting on the pipe, making sure that the fitting is on as far as it will go.
3. Slide the compression ring and tightening nut up to the fitting and hand tighten the nut as tight as it will go.
4. Tighten the nut snugly using a wrench; 1 to $1^1/_2$ turns past hand tight should do it. Overtightening will cause the fitting to leak.

***Solder Fittings* —** Solder fittings are simpler and cheaper devices than compression fittings, and soldering is really not all that difficult. While many people may have had bad experiences with soldering, their problems usually center around poor preparation and improper heat. For proper soldering, in addition to the pipe and fittings, you need a torch, solder, flux and sandpaper. Use the following guidelines for soldering:

1. Clean the end of the pipe using fine grit sandpaper. Plumbing supply stores sell rolls of sandpaper in 2-inch widths just for this. Clean the inside of the fitting using a wire brush made for this purpose. You'll need a brush for each size pipe you're working with. Clean until the pipe is bright and shiny. This removes the residues from the manufacturing process.
2. Brush flux along the pipe the length of the fitting. The flux further cleans as well as helping to pull the solder into the fitting.
3. Place the fitting on the pipe. Use a slight twist if necessary to ensure the fitting is on as far as it will go.
4. Heat the fitting and pipe, occasionally testing with the solder. When it's hot enough, the solder will liquefy and be sucked up into the fitting. When this happens, run the solder fully around the base of the fitting allowing it to be pulled up into the joint. Beware of a cold solder joint. If the pipe and fitting aren't hot enough, the solder may melt enough to stick to the pipe, but it won't be pulled up into the joint. This is a mistake many beginners make. Most likely it won't hold, and even if it does, it will certainly be a weak joint.

Plastic Pipe

Plastic water supply pipe has many notable values, including insulation quality, ease of installation, and freeze protection and resistance. There are also problems that have been associated with its use, although these are primarily with polybutylene pipe, which is no longer used. Before you use plastic water supply pipe, be certain that it's accepted by the building code in your area. Plastic pipe is usually CPVC type plastic.

Working with CPVC Pipe

CPVC water supply pipe is a rigid plastic pipe, available in 20-foot lengths. You can cut it using a fine-toothed saw. Either sand or file away any burrs created by cutting to ensure that pipe and fittings meet properly. Make connections by cementing the pipe to the fitting. You must first prime the pipe and the fitting. Priming dulls the finish of the pipe and provides a better contact for the cement.

Connecting CPVC Water Supply Line —

1. Cut the pipe and file off burrs for a smooth finish.
2. Prime the pipe and fittings.
3. Brush cement onto the outside of the pipe and the inside of the fitting.
4. Slide the fitting onto the pipe using a slight twisting motion to ensure good cement spread.

Installing Water Supply Lines

The first stage of installing water supply lines is called the *rough plumbing*. This stage takes place after the rough framing, but before you begin installing the insulation or putting up any wall finishes. On single-story structures, much of the rough plumbing takes place in the crawl space or basement. You run the lines in the crawl space and bring them up either through the floor or into a wall cavity where you then stub them out through the wall. Bringing the supply through the wall makes for neater installations, as well as facilitating cleaning and improving storage.

Although you run water supply lines in joist and stud spaces as much as possible, their installation inevitably requires cutting and drilling the framed floor and walls. You should know the local building codes governing the notching and drilling of framing materials. Consult the job supervisor and/or the framers if there's any question. Refer to the section on floor framing, under Drilling and Notching, for a general overview of *International Building Code* regulations in this area.

Water Supply Rough-In

Many plumbers begin their water supply rough-in by stubbing down below the floor from the fixture locations. You can then tie these drops together using a standard branch system, manifold system or circulating system.

Using a Standard Branch Supply System

Using a standard system requires the least amount of materials and labor. You run hot and cold water supply lines with a branch coming off at each fixture. Terminate these lines at the final fixture requiring cold and/or hot water.

Using a Manifold System

You only use a manifold system on the hot water line; the cold water line is a standard branch system. A manifold is a larger diameter pipe, approximately 2 feet long, coming off the hot water heater. Assemble the manifold with as many tees on it as there are fixtures requiring hot water. Then run a hot water line directly from the manifold to each fixture. The advantage of a manifold system is that there's little or no change in water temperature at one fixture, such as a shower, when another fixture is turned on or off.

Using a Circulating System

Like the manifold system, you only use the circulating system on the hot water supply. The cold water supply is again a standard branch system. The advantage of a circulating system is that it provides hot water almost immediately. You accomplish this by routing the hot water supply in a loop from, and returning to, the hot water source. With hot water continually circulating through the system, you never have a warmup time at the tap waiting for the hot water.

See *Bathroom Fixtures* for information on connecting fixtures to the interior plumbing lines.

Sillcocks

Sillcocks are the water valves providing fresh water for outside use. Use freeze-proof sillcocks, such as the one shown in Figure 1, for these installations. You can make a sillcock freeze-proof by using a long valve stem that controls the water well inside the structure where warmth is provided. Sillcocks are available for threaded or solder connections. You should also install a stop valve on the water supply line at the fixture so that you can repair or replace the sillcock without shutting down the entire system.

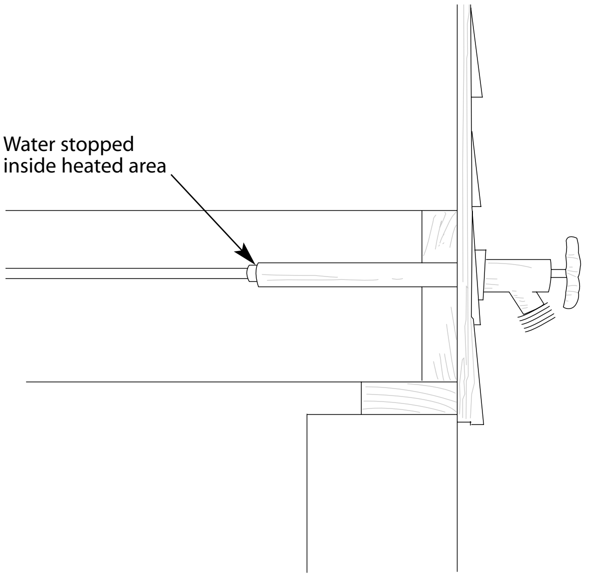


Figure 1
Freeze-proof sillcock

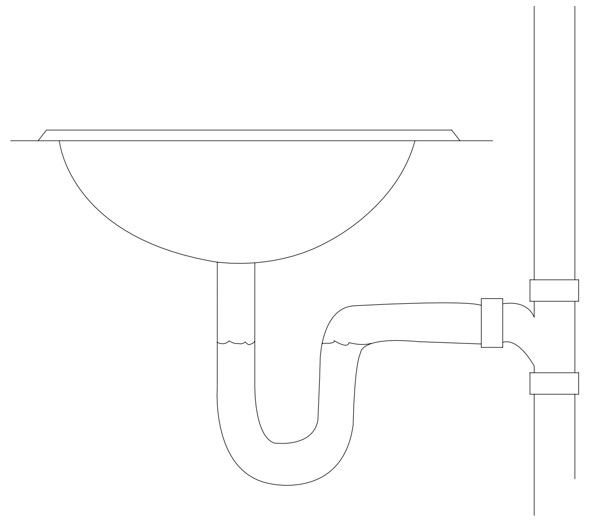


Figure 2
Sink trap

Drain, Waste and Vent Systems

The purpose of the DWV system is to remove liquids and gases from the structure. The drainage portion of the system transports the liquids to feed into a municipal sewage disposal system or a site disposal such as a septic system. The venting portion of the system prevents siphoning from the trap as well as preventing sewer gases from building up in the drainage lines.

The trap is the U-shaped fitting found at the drain of every fixture. Figure 2 shows a typical trap under a sink. The trap retains water from the last use and blocks sewer gases from coming in through an empty pipeline. If a fixture isn't used for some time, the water will evaporate and allow gases to come in. Running water in the fixture to fill the trap will solve the problem.

One of the most basic concepts for proper drainage and venting is knowing the difference between a legal P-trap and an illegal S-trap. A P-trap is a vented trap and prevents water from siphoning out and allowing gases in. An S-trap isn't vented and can cause the water to siphon. Figure 3 shows the difference between these two traps.

DWV Materials

Construct your inside DWV systems of PVC or ABS plastic, copper, or cast iron piping. In most areas, plastic has replaced both copper and cast iron for residential use. Plastic costs less and is easy to work,

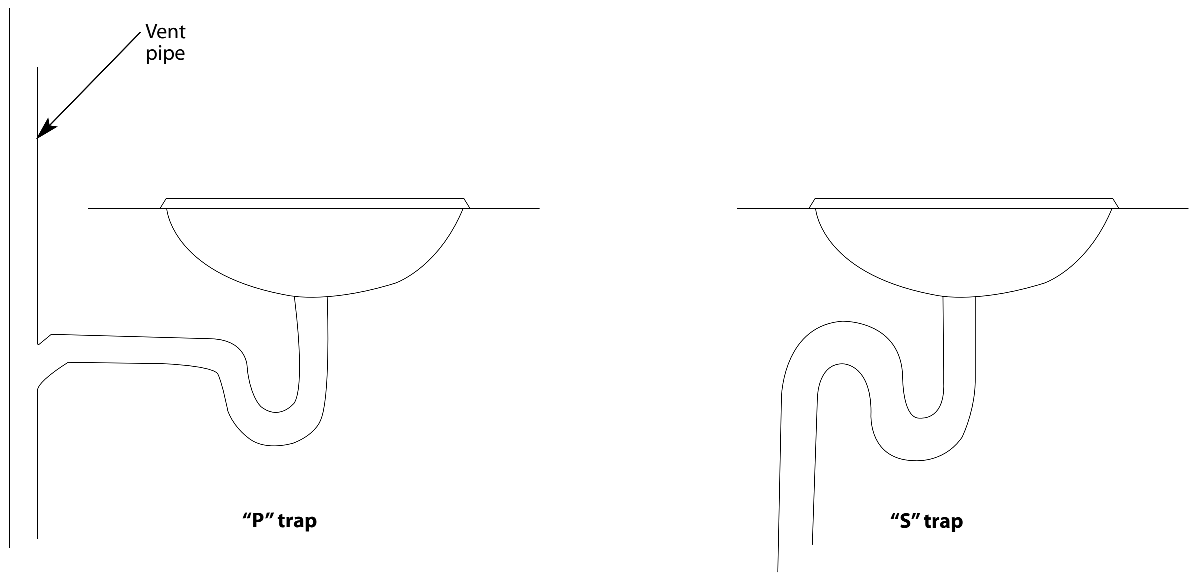


Figure 3
Legal traps must be vented

without sacrificing durability. Each of these products has distinct working characteristics.

Copper

Copper is a durable product, but it's more susceptible to eventual corrosion when used as DWV than when you use it for fresh water supply. Refer back to copper water supply for sizes, types, and assembly. Note, however, that only hard copper, rated DWV or heavier, and solder fittings are used for DWV.

Make your connections using the same methods that you use for copper water supply lines. Follow the same steps, but when soldering, expect more difficulty as the diameter increases. The larger diameter required of DWV lines makes even heating of the entire fitting, and a good solder joint, more difficult than when you're joining the smaller supply lines. As with water supply lines, when the solder pulls into the joint, you're on the way to a good connection.

Plastic

You can use both PVC and ABS plastic pipe for DWV systems. PVC is a white plastic with a relatively glossy finish. ABS is a black plastic with a dull finish. ABS is much more flexible than PVC, though it's still considered rigid. Because of the difference in their chemical makeup, these two types of plastic pipes can't be mixed. Most plumbing shops usually stock either all ABS or all PVC.

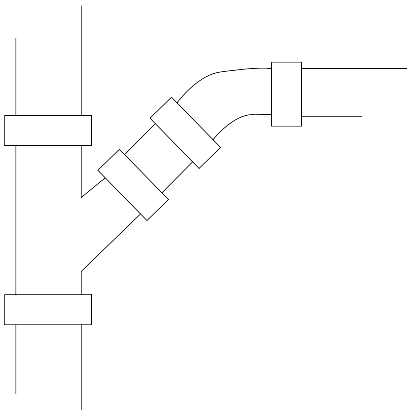


Figure 4
Plastic DWV pipe assembly

Use the same techniques to assemble PVC pipe as you would for CPVC water supply lines. You must sand and/or use a primer before cementing pipes (or pipes and fittings) together in the pipe assembly. Figure 4 shows a plastic DWV pipe assembly.

Assembling ABS pipe is the same as PVC except there's a single-step cement you can use with ABS pipe instead of the primer and cement you need for PVC. Because ABS pipe has a dull surface, you can cement it together without using a primer.

One of the few disadvantages of plastic pipe is the possibility of noise when water passes through it. You can overcome this by insulating around vertical plastic stacks.

Cast Iron

Cast iron pipe was used extensively for DWV before plastic piping was available. Bell and spigot connections are the traditional method of joining two cast iron pipes. The cast iron pipes and fittings are manufactured so that one end is belled and the other smooth (the spigot). To connect two pipes, you insert the spigot of a pipe or fitting into the bell, or hub, of the adjoining pipe. (See Figure 5.) You used to have to fill the gap between the spigot and bell with a combination of oakum, an oil saturated rope-like product, and lead. Today, for the most part, neoprene gaskets have replaced oakum and lead.

You can also use no-hub couplings with cast iron pipe. You make these connections by butting two equal-sized ends together and joining them with a neoprene sleeve and a stainless steel clamp.

Outside Plumbing

Outside plumbing involves connecting the water service lines and the drain lines to the municipal lines using the house sewer line and a house water main.

You must follow trenching guidelines for the safety and protection of both the job personnel and general public that may be exposed to the project. OSHA is the federal enforcement arm for job site safety.

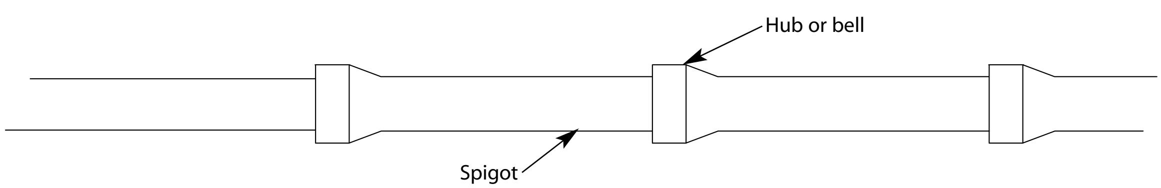


Figure 5
Cast iron hub and spigot DWV pipe assembly

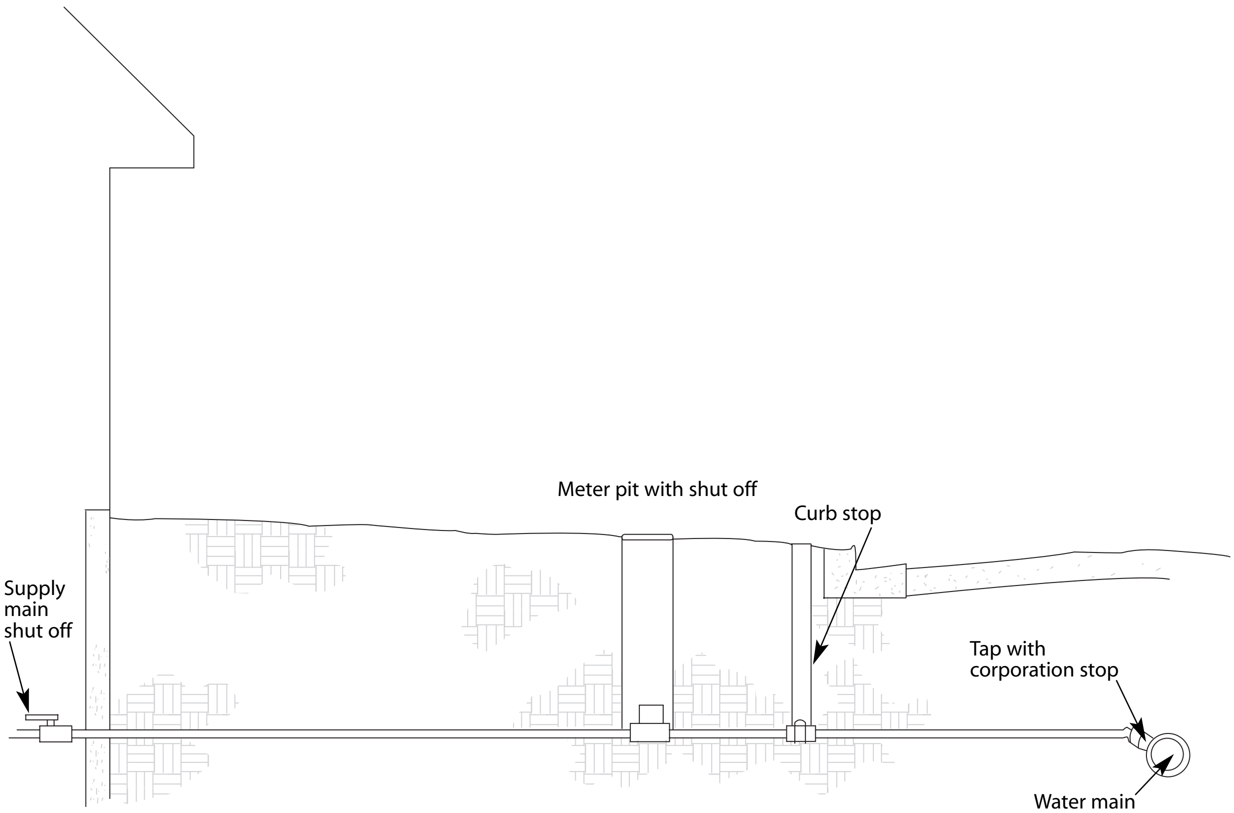


Figure 6
Outside water piping

Many states have their own safety division that assumes this responsibility instead of OSHA. You must have protective barriers and provide cave-in protection when trenching. Contact your state safety program or OSHA office for specific guidelines.

Outside Water Piping

The outside water service line begins at the water main and terminates at a shutoff valve just inside the structure. It usually includes a meter pit in between these points as shown in Figure 6. In some areas, meters are set inside the structure. If this is the case, the meter is considered the break point between the service line and house water piping.

Use soft copper and compression fittings for water service lines. For single-family dwellings, $^3/_4$-inch lines are standard. Use larger lines as needs increase. Again, you must take care when working with soft copper. If you kink it or damage it, repair the pipe with a compression coupling fitting.

Connecting the water service line to the municipal main is called a *tap*. In most areas the city or organization controlling the main line makes the tap. This is usually included as part of the tap fee that you pay to gain access to the main supply line. The tap contains a shutoff called a *corporation stop*. The stop is used only during the construction process. If you needed to gain access to the stop after the installation, you'd have to dig up the line.

There's another shutoff valve, called a *curb stop*, usually located just inside the property line. This stop consists of a square nut on top of a valve; you can turn it to control the water. A pipe approximately 6 inches in diameter allows access to the stop. Depending on the depth of the water line, you may need a special wrench, sometimes 8 to 10 feet long, to reach the valve through the access pipe.

You should place outside water meters in a meter pit. You can place up to 1-inch lines in pits with access only from above. Loop deep lines up inside the pit so that you can reach the meter from ground level. You would usually place meters for 1 1/2-inch lines and larger in vaults large enough so that a person working on the meter or line can climb down into the vault. Both types of pit have cast iron lids.

Water lines must be protected from freezing. In all but severe situations, this involves placing the water line below the anticipated frost line. The frost line for each area is an established depth included in the local code of most building departments. Severe situations include some mountain areas and other regions that experience extreme frost depths. Use alternative methods for insulating the lines in these situations.

If the lines aren't too deep and the soil is stable, you can use a trenching machine for water lines. You can then unroll the soft copper line into the trench from above. For deeper lines you'll generally need a backhoe to excavate a trench large enough to work in. If you encounter rocks, lay the water line in a bed of sand and cover it over with sand as well to prevent damage to the line. Remember, you must provide cave-in protection when working in excavated areas.

Building Sewer Service

The sewer service connects the house sanitary drain system to the public sewer main or a private system. The house sewer service is typically 4-inch pipe for single-family residential use. Check the *International Plumbing Code* for specific sizing guidelines. The calculations you use to determine the proper sewer size include the number of fixtures along with trap sizes.

The house sewer service is usually a straight run from the structure to the tie-in at the public sewer main. The only necessary opening is a cleanout, which you should place close to the structure. The cleanout provides access to the sewer line in the event that an obstruction occurs.

Private Sewage Disposal Systems

You'll find private sewage disposal systems in areas not served by a public sewage disposal system. Because these are most often rural locations, their approval and inspection often comes under the jurisdiction of county health departments. Contact your local building department if there's a question of jurisdiction.

Most building and health departments require certified engineering for private sewage disposal systems. You'll also need a soils report to determine the absorption rate of the soil. The soils report, space limitations, and the estimated amount of sewage that will be entering the system are used to determine the size and type of system that you'll need to install.

***Septic Tanks* —** All private sewage disposal systems begin with a septic tank. The septic tank receives all of the waste and separates the solids from the liquids. Septic tanks are most often made of precast concrete. Other types of tanks, such as fiberglass, are also available. Check with your building or health department on acceptable tank materials for your area.

The size of the septic tank you'll need to install is based on anticipated usage. Local codes have information available on sizing requirements for your area. Most areas usually require a 1000-gallon tank for a typical three-bedroom residence.

Septic tanks generally have at least two chambers separated by baffles. The baffles allow liquids to pass into the next chamber while the solids sink to the bottom. State and local plumbing codes vary on specific guidelines regarding chamber sizing, depths, baffles, and inlets and outlets for septic tanks used in their jurisdictions. Again, check the local codes before making a selection.

Septic systems are designed so that the effluent (liquid) from the septic tank flows out and is gradually absorbed into the ground. There are several systems you can use that will leach the effluent into the surrounding soil. Figure 7 shows various components of a private sewage system. The system you choose will usually be dictated by the soils report or space requirements. Leach fields are often preferred where there's enough available space.

A leach field uses branches to distribute the effluent over a large area. You determine the number and length of the branches by the size of the septic tank. There are a number of variations in leach field types that you can use. When space is limited, you can use leach rings, or pits, instead. A leach pit is made up of concrete rings that allow the effluent to seep out of the sides and bottom. Refer to the engineering or health department for specific installation requirements for your area and system.

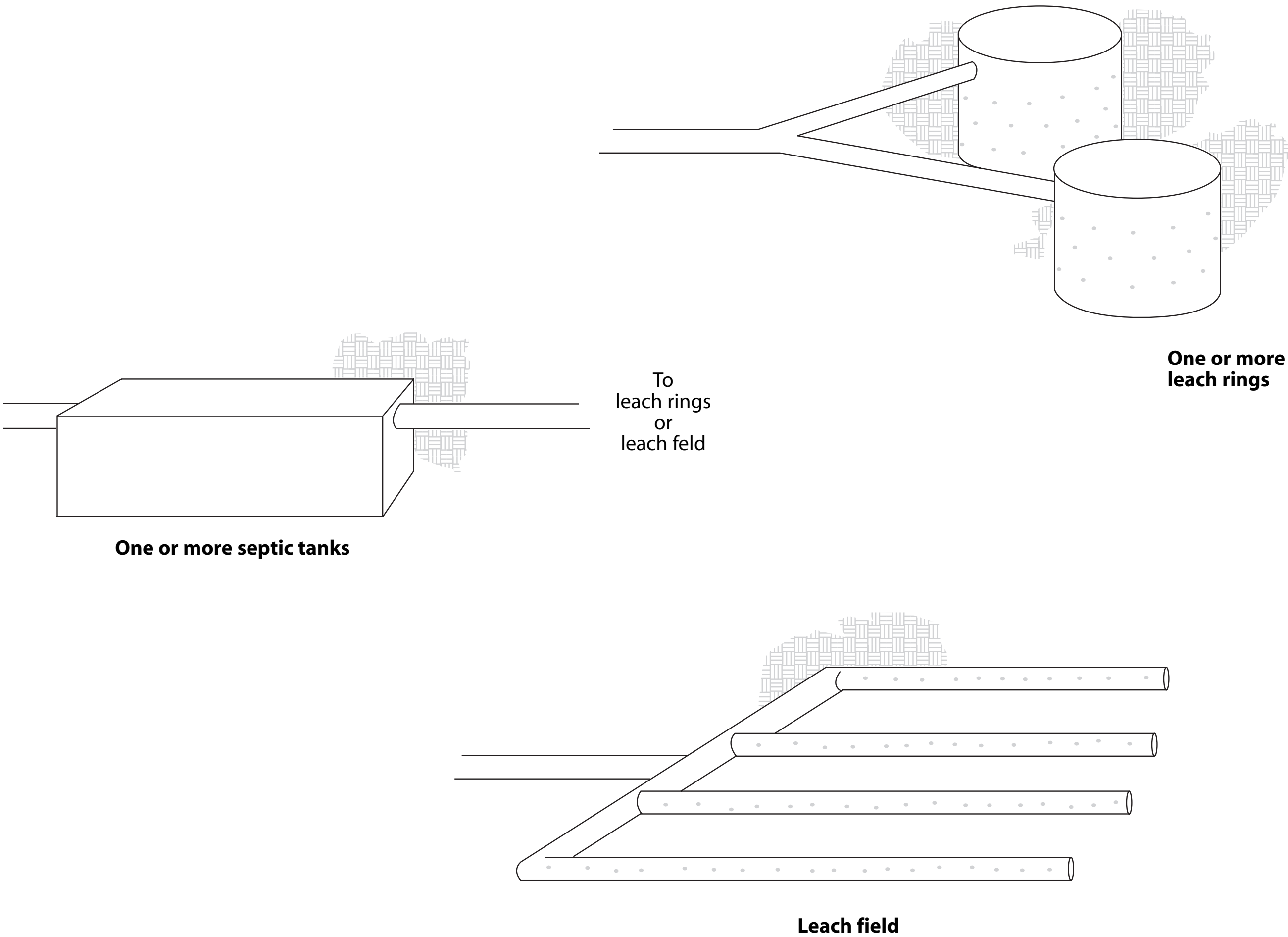


Figure 7
Private sewage system

Manhours

Manhours to Install Residential Plumbing Rough-In (whole house)		
Type	**Manhours**	**Suggested Crew**
Single story home, total plumbing rough-in	35	1 plumber, 1 laborer
Hot and cold water supply rough-in only	15	1 plumber, 1 laborer
Drain, waste, vent system rough-in only	20	1 plumber, 1 laborer
Two-story home, total plumbing rough-in	45	1 plumber, 1 laborer
Hot and cold water supply rough-in only	20	1 plumber, 1 laborer
Drain, waste, vent system rough-in only	25	1 plumber, 1 laborer
Septic tank installation, including excavation and piping		
500 gallons, polyethylene	15.2	1 plumber, 2 laborers
1,000 gallons, fiberglass	16.1	1 plumber, 2 laborers
2,000 gallons, concrete	17	1 plumber, 2 laborers
5,000 gallons, concrete	22.3	1 plumber, 2 laborers
Drain field for septic system, per LF		
With 12″ gravel base	6.30	1 plumber, 2 laborers
With 24″ gravel base	7.40	1 plumber, 2 laborers
With 36″ gravel base	8.40	1 plumber, 2 laborers
Add for pipe laid 6′ deep	2.10	1 plumber, 2 laborers
Add for pipe from house to tank and from tank to drain fields, per LF	4.40	1 plumber, 2 laborers

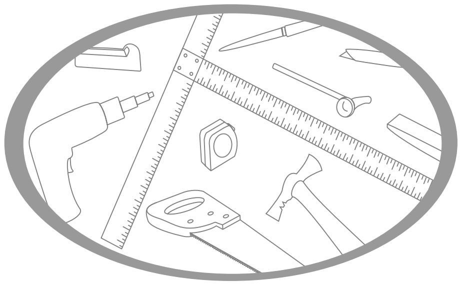
For information on related topics, see:

Bathroom Fixtures, page 43

Floor Framing, page 299

Framing Materials and Planning, page 363

Wall Framing, page 709



Porches and Decks

Building a porch or deck is a lot like building a house. It involves excavating for a foundation system that's adequate for the type of soil and frost condition at the site. Then, building the foundation, followed by rough framing for the structure; possibly adding a roof system for a covered porch; putting up siding; and finally, finishing with the exterior trim.

While there are many similarities between a porch and a deck, there can also be many variations. Because a deck is basically a neat job of framing, a good place to start discussing porches and decks is with basic deck building techniques. You can then use these same procedures to construct a more elaborate porch.

Building a Deck

The first step in building a deck is to find a design. If the deck is part of a new structure, you'll be lucky enough to have the design, complete with material sizing, provided for you. In many cases, however, plans for a deck consist of a picture torn out of a home improvement magazine. Although a deck may seem like a minor project, you must design and build it to carry the loads its space permits. In other words, building codes also apply to decks. Have your completed design approved by the building department before you start construction.

Layout

The first step in constructing the deck is laying it out. Most decks are attached to the structure using a ledger. Start your layout by locating the placement of the ledger. With the ledger positions marked, or with the ledger placed, lay out the deck using the ledger position as your reference point. Set batterboards in the approximate position of the layout. Measure from the ledger to establish a line parallel to the structure. Then, using the 3-4-5 method, square the sides of the layout.

Squaring the Layout

1. Stretch a string from the ledger mark, or the end of the ledger if it's placed, to the batterboard. Set a framing square on the structure to get a close approximation of where to set the string on the batterboard for square.
2. Set the string on square using the 3-4-5 method. Measure 3 feet on one leg, 4 feet on the second and then check the diagonal. If it's exactly 5 feet, the string is square. If it's off, adjust the string at the batterboard in the direction indicated by the measurement. Then, mark both legs again and check the diagonal. You can also use multiples of 3, 4 and 5 as long as you use the same multiplier on all three numbers. For example, you can multiply each number by 3 and work with 9, 12, and 15 feet, or multiples of 2 (6, 8 and 10) as shown in Figure 1.
3. When you have the first side set square, measure off of it to set the second side. With both sides set, you can take diagonal measurements to confirm that they're both square. If the diagonal measurements aren't the same, your layout isn't square. Make the necessary adjustments and remeasure.

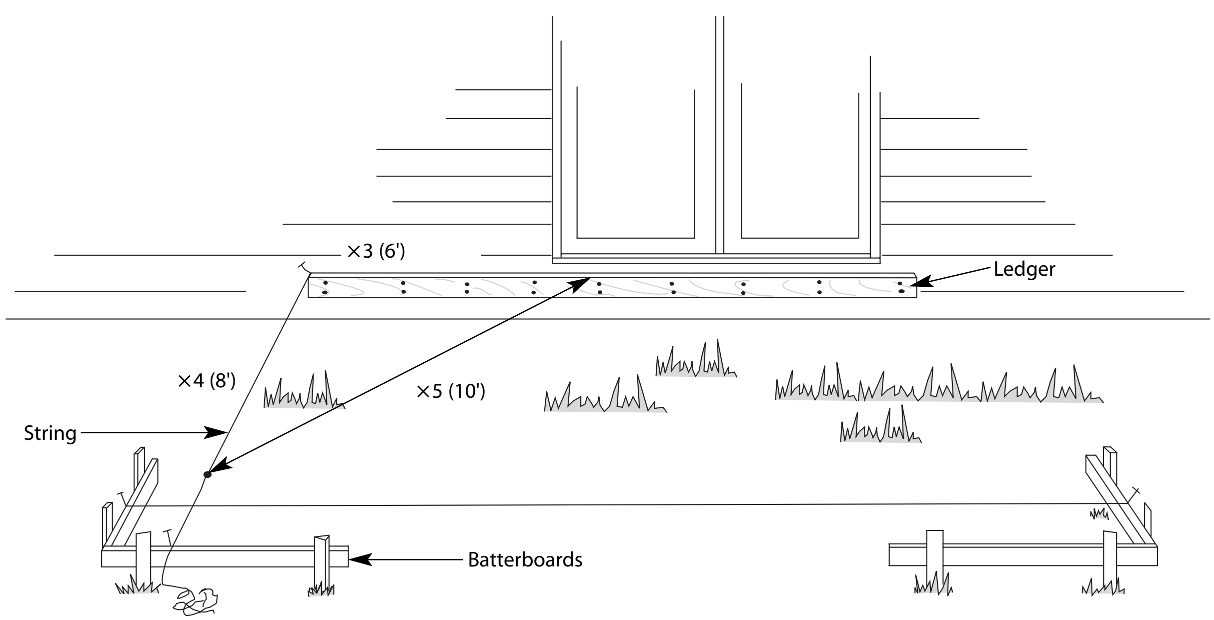


Figure 1
Square the layout using the 3-4-5 method

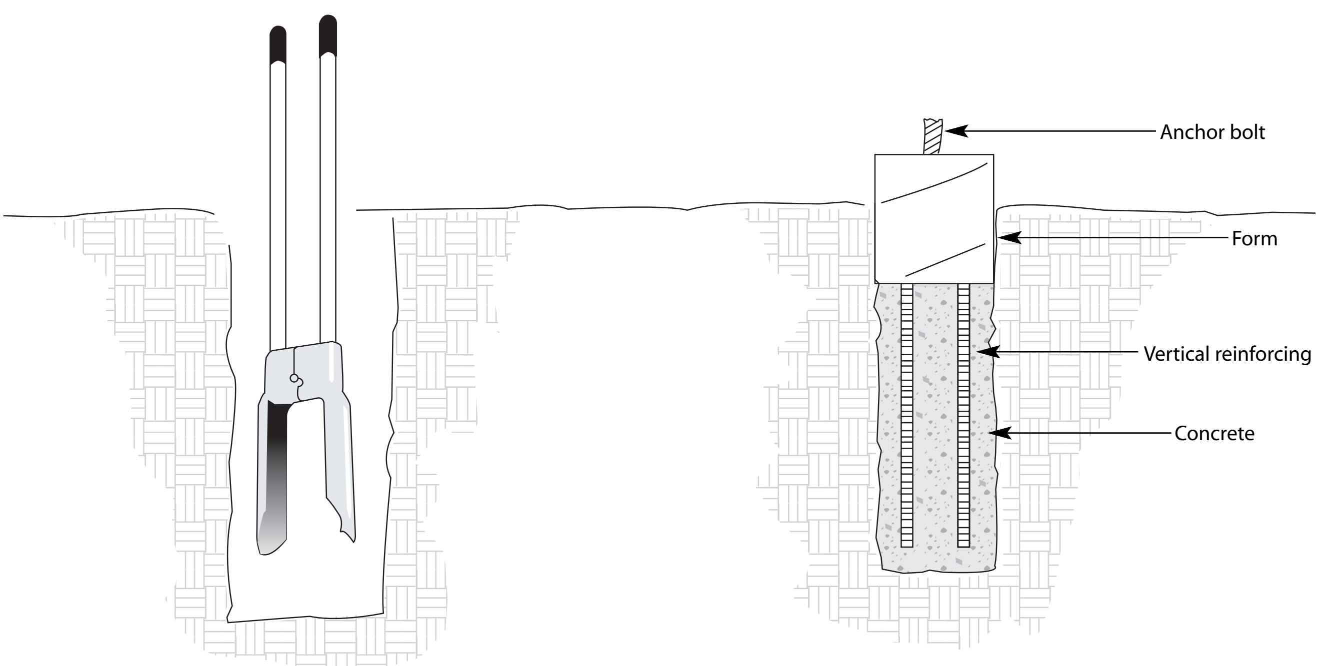
The Foundation

For most decks, you'll either use a pier or a pad foundation system. See *Concrete* for information on piers, concrete foundations and reinforcement.

In brief, you create a pier by digging a post hole below the known frost line for your area and then filling it full of concrete. You determine the diameter of the pier by the bearing conditions of the soil and the load the pier will carry. The greater the distance between piers, the heavier the load will be.

When digging the hole, make the sides smooth and straight. Finish the base off as square and clean as possible (see Figure 2 a). Any loose soil left in the bottom will eventually compact, causing the pier to settle. If the soil is unstable enough that it might cave in while you're placing the concrete, use a cardboard tube, such as a sonotube, as a form. You can also use this type of form for extending the pier above ground level.

Fill the pier with concrete, with two reinforcing bars placed vertically as shown in Figure 2 b, unless otherwise engineered. If you'll be using wooden posts between the piers and other framing, the elevation of the piers isn't critical. If, however, you're going to place a girder with a connector directly on the pier, you must level the top of the pier precisely.



a. Dig hole smooth and straight *b. Place vertical reinforcing*

Figure 2
Creating a pier

After you place the concrete, set an anchor bolt to attach to a post base or other connector. Or, in place of anchor bolts, there's another style of post base that you can place directly in the concrete. This type of base must be set more accurately, as no movement can take place once the concrete has set. The post base types that attach to an anchor bolt have some latitude of movement before they're tightened down. Set the anchor bolts or the post bases using a string placed on the batter-boards for measuring.

Precast piers are available for use in many areas. However, some building departments won't accept them. Check with your building department to see if they're accepted in your area before using them. If you can use them, select the length you need, dig a hole to the required depth, place the pier solidly in the hole and backfill the soil around it. Tamp the soil to compact it tightly around the pier.

Ledgers

The first framing to be done on a deck is installing the ledger. The ledger is a header joist attached to the house or structure that you're building the deck out from. Most builders prefer to locate and install the ledger as one of the first steps of their layout. As mentioned above, it provides a solid point to measure, square, and shoot elevations from.

Install the ledger at an elevation that allows for the thickness of the decking as well as at least $^1/_2$ inch below the level of the floor level of the house.

Attach the ledger to the structure with the appropriate fasteners. Use lag bolts to attach to wooden structures and expansion anchors for masonry structures. The sizing and spacing of the bolts depends on the size and load of the deck. Typically, you place two $^1/_2$-inch bolts every 16 inches. Install flashing over the ledger as illustrated in Figure 3 to protect the structure from water.

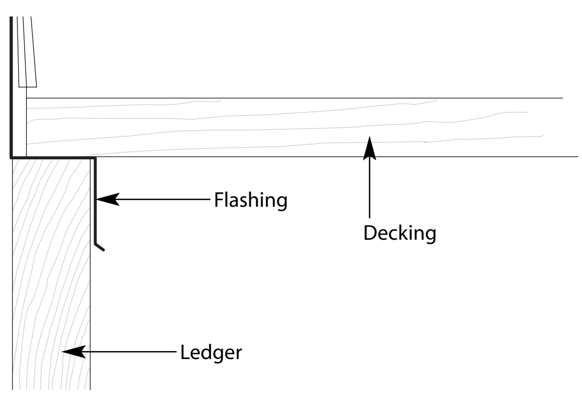


Figure 3
Install flashing over the ledger

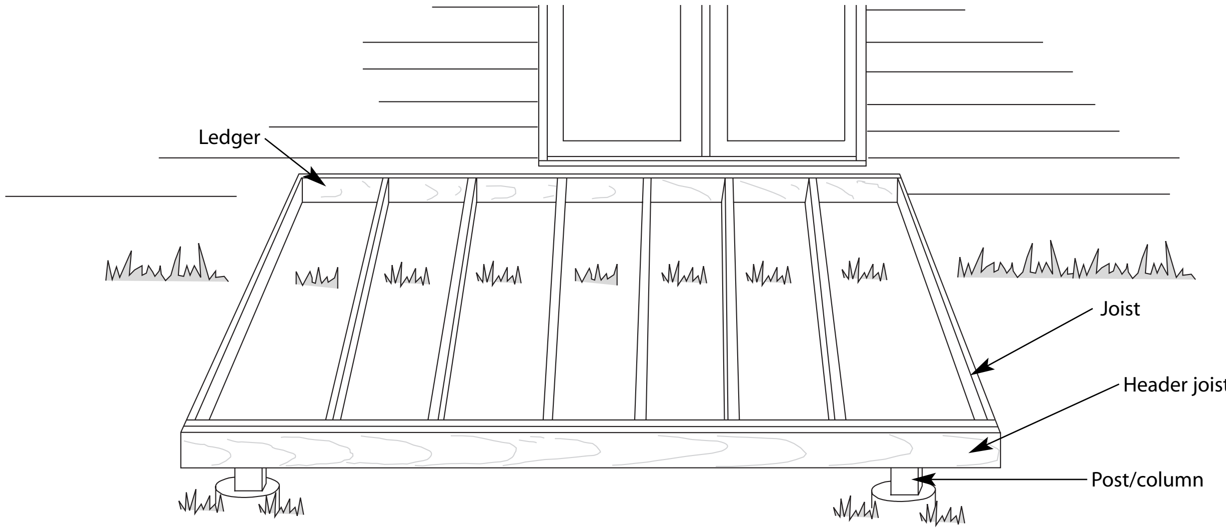


Figure 4
Framing deck built on posts

Posts

Most decks are built on posts connected to the piers as shown in Figure 4. The size of the posts you'll need is determined using the dead and live loads for the deck along with the accepted building code regulations for your area. For an example of how to determine post size, refer to *Floor Framing*, *Columns* on page 299. For most decks, 4 × 4 posts are adequate, depending on how you place them and the number you use.

You can connect the post to the pier using a post base. Fasten the post to the post base using the fasteners recommended in the manufacturer's instructions. Level the tops of the posts and cut them to the height required for the girder. If you have a builder's sight level available, you can determine the length of the posts by shooting the elevation of the post base as shown in Figure 5. Follow the guidelines described below.

1. Shoot the top of the ledger attached to the structure.
2. Shoot the top of the post base.
3. The difference between these two elevations is the overall post length.
4. Subtract the joist thickness and the girder thickness (if you're using one) from the overall length. This will give the unadjusted post length.
5. To find the final post length, adjust for any desired slope. A standard slope for a deck is $^1/_8$ inch per foot.

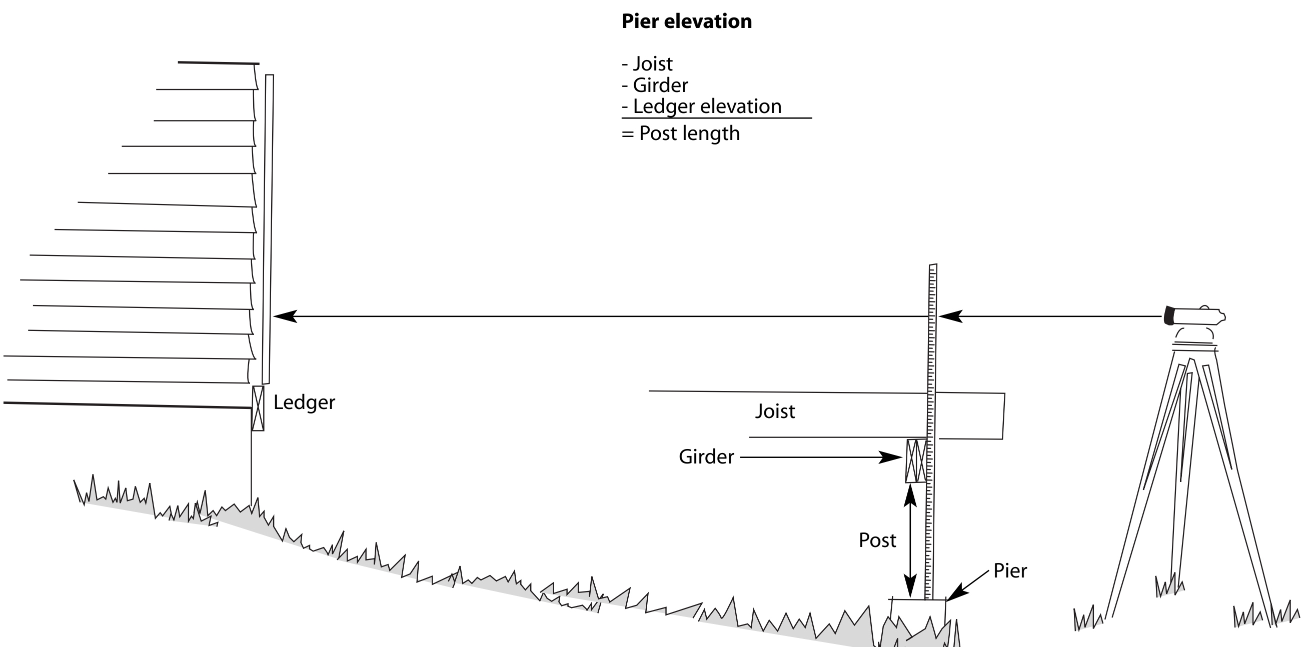


Figure 5
Shooting the elevation of the post base

Girders

The ledger on the structure carries a portion of the load of the joists. A girder carries the remaining portion. You can build the girder into the header joist, or you can place it underneath the joists. If you place it underneath, cantilever the joists to keep the girder and short posts out of sight.

You can find more information on sizing, building, and erecting girders under *Floor Framing*. There are several factors that enter into the sizing of girders, including the pounds-per-square-foot dead and live loads of the deck, how the loads transfer to the joists, the joist span, as well as the span of the girder between posts.

Joists

Deck joists should be made of a rot-resistant wood. Redwood and cedar were once considered good choices although they're not species with strong structural properties. Now that pressure-treated woods and even plastic woods have become more available, they're being used more and more for decks.

Size and space the joists based on the loads they'll be carrying and the species of wood you're using. See the Joists section under *Floor Framing* for more information on sizing.

Installing Deck Joists

The first step in installing deck joists is laying out their locations. Using the spacing in the deck design, lay out the spacing on the ledger, the girder, and the header joist. Mark the layout as accurately as possible. However, since you'll be using random length decking rather than 8-foot sheet goods, you can pull the layout off of the first joist. It isn't necessary to make the decking splice on center as you would with joists receiving plywood decking.

Joist Installation —

1. Cut the joists to length. If the ledger is straight, the same length should be good for all of the joists. Make a simple square cut with a circular saw.
2. Place the joists on the layout.
3. Toenail the joists to the ledger with two galvanized 16d nails.
4. Toenail the joists to the girder using three galvanized 16d nails.
5. Place the joist hangers tightly on the joists at the ledger and nail to the joist and ledger as shown in Figure 6. Some people like to decide on their own how many of the nail holes in the hangers really need to have nails in them. The hangers were engineered, however, to have a nail in each hole. So, *put a nail in every hole!*

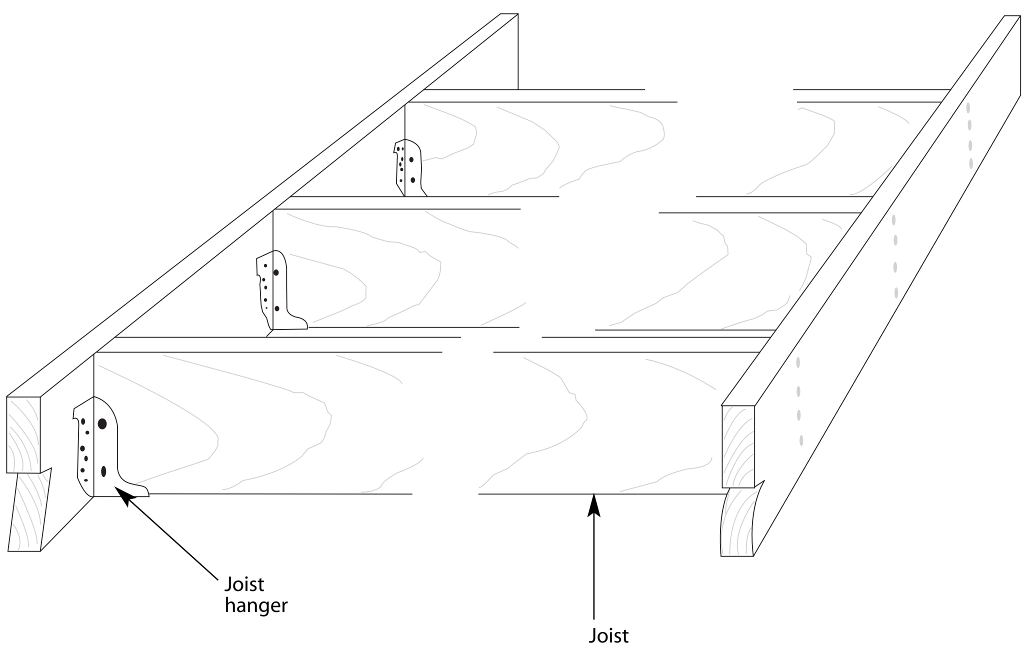


Figure 6
Install joists using joist hangers

6. Place the header joist across the end. Face nail into the ends of the joists using at least three 16d galvanized nails at each joist. Use four nails for 2 × 10 and 2 × 12 joists.

The Decking

As with joists, many people today are choosing pressure-treated woods for their decking material instead of the traditional redwood. A good combination is a pressure-treated structural system, with redwood decking. This combination gives a traditional redwood look with the structural strength of the pressure-treated materials. The most common sizes for decking material are 2 × 4 or 2 × 6.

Installing Decking

Install the decking as shown in Figure 7 a. When used for decking, wood has a "right side up." You should place boards "bark" side up. To determine which side is the bark side, look to the end grain for the answer. The end grain will almost always curve in one direction. By imagining how a tree grows, it's fairly obvious that the outside of the ring pattern is the "bark" side (see Figure 7 b).

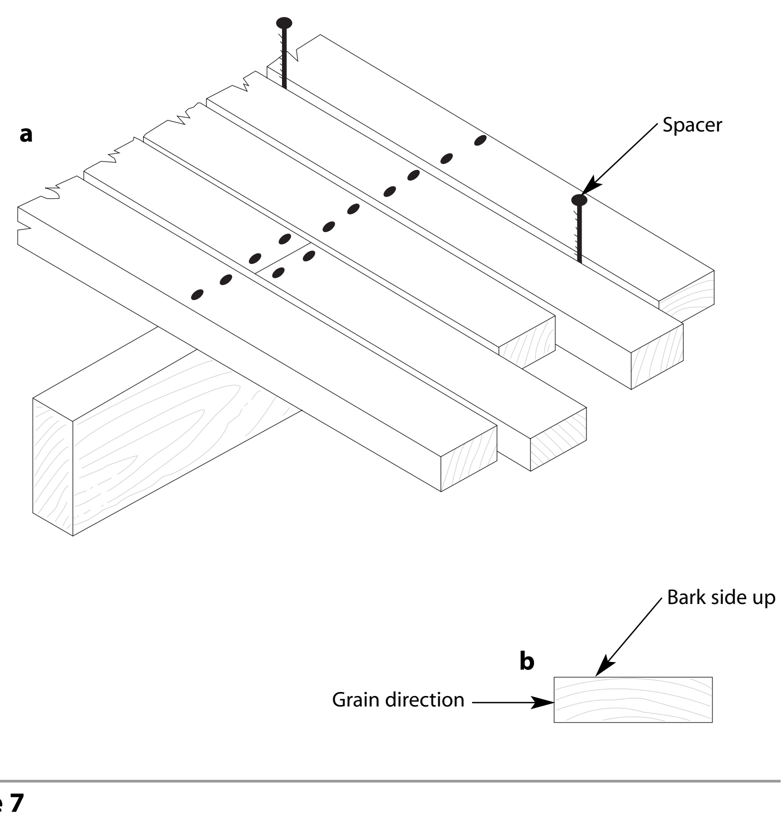


Figure 7
Installing deck boards

Fasten the decking with protected fasteners. Galvanized 16d nails are commonly used, but a better choice are the deck screws available from most suppliers. Deck screws are narrow, non-tapered, and usually brass-coated, though you may find them with other coatings as well. The 3-inch length makes an excellent fastener. Because screws are threaded, they're less prone to work out of the wood and so are more permanent fasteners than nails. It's also easier to replace a warped or split board fastened with screws than with nails. Figure 8 shows the proper method of fastening decking with screws.

***Decking Installation Steps* —** Decking is often "run wild" when it's installed, then trimmed with a circular saw and a guide to make a straight and even edge cut. Use a sharp, fine-toothed blade to prevent the decking from tearing. A straight piece of 1-by material tacked to the deck makes a simple guide for the edge of the saw. Use the following as a guide to installing decking:

1. Place flashing over the ledger, tucked up under the siding. For stucco or masonry, cut a reglet for the flashing.
2. Lay out the decking. Measure the width of the deck including any desired overhang. Taking your spacing into consideration, determine whether you'll need to rip a board. If you do, it's often desirable to start with the ripped board against the structure. An alternative to a narrow ripped piece is using a wider board. You can either place the wide board next to the structure or as the final piece, where it will overhang or be under a railing or bench.
3. Once you have the layout, snap a straight line as a guide for placing the first piece.

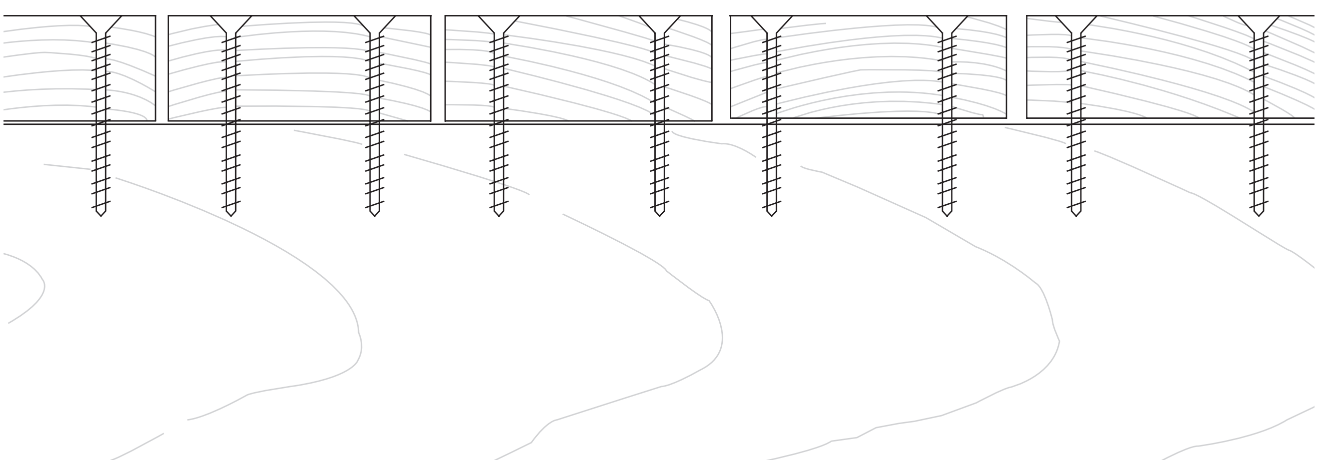


Figure 8
Fasten decking with screws

4. Place and secure the first piece of decking in position using two fasteners per joist.
5. Use spacers off the first decking piece to keep the subsequent decking pieces straight as you install them. Determine the size of the spacer you use by the size of the final gap desired. You should also consider the moisture content of the decking and its expected shrinkage. If you want a narrow gap and the moisture content of the decking is high, you can place each decking piece touching the adjoining piece and the shrinkage will create your desired gap.
6. Fasten the decking with either 16d galvanized nails or deck screws, placing two fasteners per joist. Take care to locate the fasteners as systematically as possible. Randomly placed fasteners will be an eyesore when the deck is complete.
7. When all the decking is installed, you'll need to trim the ends. Use a straight 1-by or plywood strip as a straightedge for your circular saw. Check the distance from the edge of the saw to the blade to determine where to place the straightedge. Tack the straightedge in place to prevent it from moving while you make your cut, then trim the ends using the straightedge as your saw guide.

Deck Railings

Railings can be decorative as well as functional and protective. You can incorporate seating into the railing installation to combine function and usability. However, before you build the railing, there are a number of code-related issues that you have to consider.

To begin, your building code will dictate when a railing is required. You can, of course, build one regardless of the deck height, but at certain heights, you *must* build one. You'll find this height in the codes governing your area. The *International Building Code* (IBC) says you must have a railing around any deck that's 30 inches or more above the ground. Your building department may have other regulations.

The height of the railing itself also comes under the code. On all structures except single-family residences, the IBC says a railing must be at least 42 inches high. Single-family home railings may be 36 inches high. Again, check with your building department for current local regulations.

Once you have the requirements and height of the railing established, you need to check into further design considerations. A railing must be built so that no spheres larger than 4 inches can pass through it. In other words, a 4-inch ball (or a small child's head) can't pass through, or get stuck in, the railing. This dimension has continued to be reduced over the years. Check your code for the current size.

With all these design parameters, it's easy to see why so many deck railings are built like the one in Figure 9. But there are many creative alternatives — you can find idea books at your lumber suppliers that offer many different options.

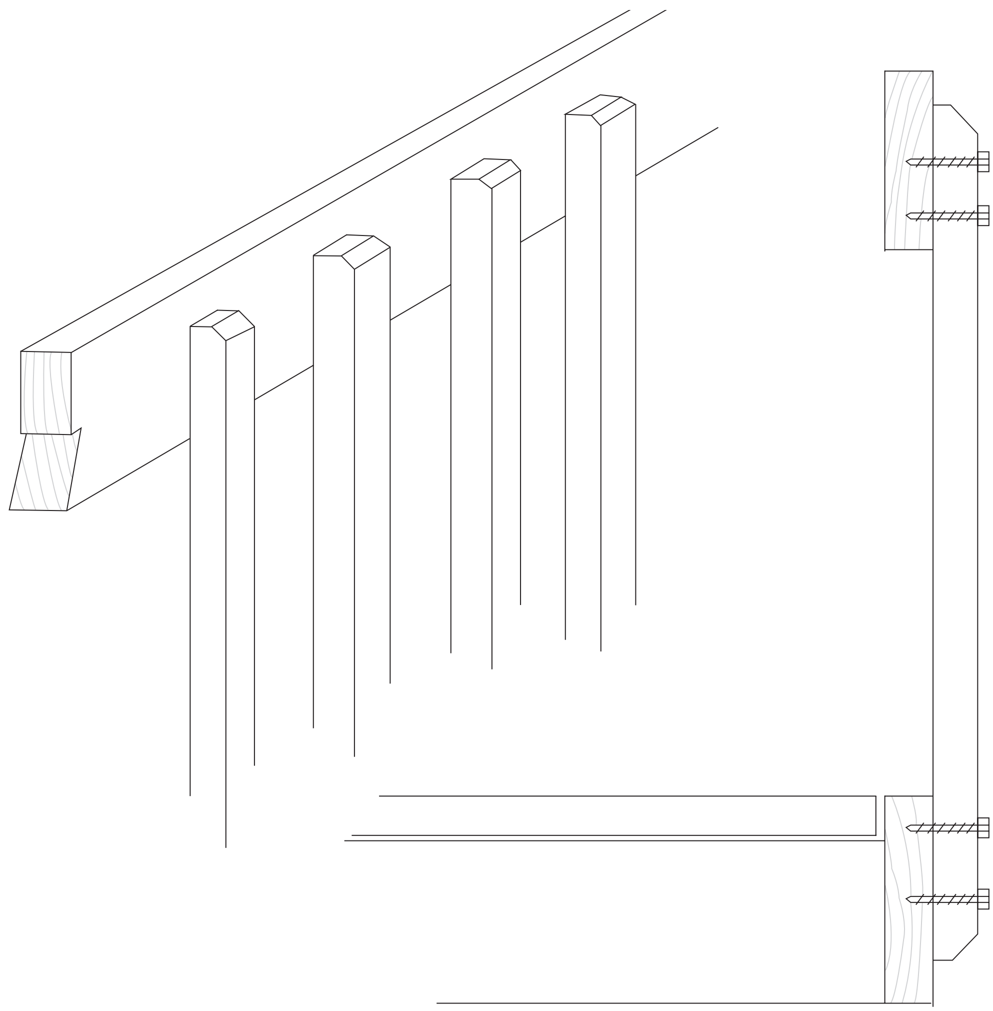


Figure 9
Simple deck railing

Building a Porch

You can build a porch like the one in Figure 10 using most of the same guidelines that we just covered for building decks. Besides the fact that a porch is covered by a roof, the distinction between a deck and a porch is usually made by the way the porch is finished.

Porch Foundations

You size a porch foundation in the same way that you do for a deck, but you must take the additional load of the roof, and siding if the porch is enclosed, into consideration. Because of the additional weight, you should always place a framed porch on reinforced, poured

Figure 10
Covered porch

piers rather than the precast piers available for decks. In many areas, a porch with a concrete or masonry deck and an overhanging roof has replaced the traditional “country-style” porch with its tongue-and-groove fir flooring supported by piers and posts. Be sure and build these more modern porches on a foundation that reaches below frost level to prevent movement. In frost-free areas, extend the concrete down far enough to prevent any washout from rains.

To finish the decking, roofing and paneling for a porch, refer to the sections of this book that cover these specific topics.

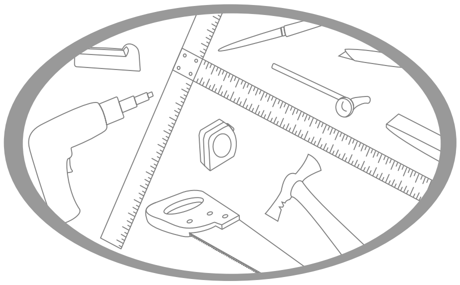
Manhours

Manhours to Build a Deck, per SF		
Item	**Manhours**	**Suggested Crew**
Deck, rectangular, redwood or pine, 10' × 45' to 20' × 55', 3' above ground; 2" × 8" decking supported by 2" × 8" joists spaced 24" oc over 4" × 8" beams. Beams are supported by 4" × 4" posts set 6' oc in concrete.	.170	1 carpenter, 1 laborer
Deck cover, conventionally-framed wood cover joists		
2" × 4"		
16" centers (.59 BF per SF)	.020	1 carpenter, 1 laborer
24" centers (.42 BF per SF)	.014	1 carpenter, 1 laborer
2" × 6"		
16" centers (.88 BF per SF)	.020	1 carpenter, 1 laborer
24" centers (.63 BF per SF)	.015	1 carpenter, 1 laborer
Support posts, each corner	.333	1 carpenter, 1 laborer
Deck finish roof, over conventional framed wood ceiling joists; flat roof with built-up roofing: 1/2" CDX roof sheathing with 3-ply asphalt. Add in framing cost from deck cover listed above.	.333	1 carpenter, 1 laborer

Manhours to Build a Sun Porch, per each		
Item	**Manhours**	**Suggested Crew**
Lean-to type sun porch enclosure attached on long dimension to an existing structure, one door and three walls; not including foundation and floor or deck		
7' high, 3' wide	8.40	1 carpenter, 1 laborer
7' high, 6' wide	16.8	1 carpenter, 1 laborer
7 1/2' high, 9' wide	27.0	1 carpenter, 1 laborer
8' high, 12' wide	38.4	1 carpenter, 1 laborer
8' high, 15' wide	48.0	1 carpenter, 1 laborer

Manhours to Install Railings and Stairs			
Item	**Unit**	**Manhours**	**Suggested Crew**
Deck railing, 42" high handrail, wood; 2" × 2" vertical boards, 5" oc; 2" × 4" top rail	LF	.333	1 carpenter, 1 laborer
Porch or step rail, prefabricated steel; 2' 10" high, 6" oc solid twisted pickets, 4' or 6' sections			
1" × 1/2" rails	LF	.171	1 reinforcing iron worker
1" × 1" rails	LF	.180	1 reinforcing iron worker
Deck stairs, 12" tread composed of two 2" × 6" lumber and riser, per LF of step. (A 4' wide stair with 2 steps has 8 LF of step)			
One or two steps high, box construction			
Treads with open risers	LF	.270	1 carpenter, 1 laborer
Treads with closed risers	LF	.350	1 carpenter, 1 laborer
Three or more steps, 36" wide with 3 stringers cut from 2" × 12" pressure-treated lumber, cost per riser			
Treads with open risers	Each	.530	1 carpenter, 1 laborer
Treads with closed risers	Each	.620	1 carpenter, 1 laborer

For information on related topics, see:
Concrete, page 141
Concrete Block, page 189
Concrete Reinforcement, page 201
Electrical Installations, page 269
Floor Framing, page 299
Framing Materials and Planning, page 363
Roof Framing, page 513
Roofing, page 561
Siding, page 611
Trim, page 673
Wall Framing, page 709



Radon and Other Pollutants

Pollutants emitted by various building and household materials (or radon which comes out of the earth itself) are a growing concern in the construction industry. Ironically, one of the most significant industry improvements in the last twenty years — making houses more airtight to lower energy costs — traps the pollutants inside and aggravates the problem. Common practices like smoking or using household cleansers also contribute to the pollution of our indoor living and working areas. These pollutants cause a range of health problems, from headaches and rashes to asthma and even cancer.

Eliminating Common Pollutants

There's a two-step approach you can use to help alleviate the problem of interior air pollution. First, contain the pollutants at their source by sealing soil or exposed surfaces. Second, plan a ventilation system that continually exchanges fresh air for stale air to ensure a healthy environment. The ventilation system may be either an exhaust-only system, which is a single fan system, or an exhaust-and-supply system, which requires two fans.

By itself, a good ventilation system won't solve all indoor pollution problems. However, it's an essential part of the solution. In addition to providing adequate ventilation, follow the suggestions in Figure 1 for preventing and/or controlling specific problems.

Radon

Radon is a colorless and odorless radioactive gas that occurs naturally in certain parts of the country. It results from the radioactive decay of radium, which, in turn, is produced by the decay of uranium in the soil. Radon seeps up naturally through porous soil.

Pollutant	Characteristics	Source/Cause	Hazard	Detection	Preventing/Controlling
Aldehydes, such as formaldehyde	Colorless organic compounds that vaporize at room temperature; pungent odor.	Urea-formaldehyde foam insulation; urea-formaldehyde adhesives and resins found in plywood and particleboard, furniture, carpets, carpet glues, wallpaper, and protective coatings for wooden floors; burning of natural gas, tobacco, and other combustibles.	Headaches, nausea, dizziness, vomiting, skin rash, and coughing; may cause cancer.	Dosimeter.	Emission rate decreases over years. Seal product with polyurethane varnish, plastic laminate, or nonporous paint. If possible, avoid buying products with aldehydes.
Asbestos	Airborne particles.	Pipes, insulation, paint, shingles, etc.	May cause various lung diseases, including cancer.	Visually inspect for flaking or peeling; hire a consultant to monitor airborne particles, or contact the local health department.	Avoid disturbing particles; if removal is necessary, hire a certified asbestos abatement contractor. (See *Asbestos* and *Asbestos Abatement).*
Carbon Monoxide	Colorless, odorless.	Incomplete combus-tion of natural gas, oil, wood, coal, tobacco, etc.; cracks in chimneys or inadequate supply of air for combustion may result in excess carbon monoxide.	Absorbtion of oxygen into the bloodstream is affected; mild oxygen deficiencies can affect vision and brain function; more serious deficiencies can cause headaches, nausea, mental confusion, and even death.	Hire consultant who uses either an active or passive monitoring system; OSHA may monitor commercial or industrial sites if it appears there may be violations.	Inspect chimneys and heating systems for cracks; vent to the exterior the space over gas stoves and all combustible-type heating systems.
Chlordane	Odorless, nearly colorless in original form; remains active for 15 to 20 years.	Was used for termites between 1948 and 1988. Banned by EPA due to evidence of neurotoxicity in human subjects.	May cause headaches, flu-like symptoms, irritability, short term memory loss, and hyperactivity in children; may also cause liver cancer.	Hire consultant who will use a sample pump; the Department of Agriculture may monitor for commercial or industrial sites.	Little research has been done, but treat as you would for radon.
Lead	Small particles that may be inhaled or ingested.	Found mostly in older homes with lead-based paint, lead pipes, and lead solder.	May cause fatigue, headaches, stomach cramps, and damage to brain, liver, and kidneys; in rare situations may be fatal.	Test kit consisting of test strips; purchased from an industrial hygienist supply house.	Don't remove paint if in good condition; if cracked or peeling, cover with paneling or wallpaper, or send surface out for chemical removal; don't paint over it; avoid making dust or burning surface. Dispose of at a recycling center or hazardous waste collection site.

Figure 1
Controlling pollutants

Pollutant	Characteristics	Source/Cause	Hazard	Detection	Preventing/Controlling
Nitrogen Oxides	Colorless, odorless.	Unvented nonelectric space heaters, gas-burning appliances; outdoor pollution.	May cause respiratory problems.	Hire a consultant, who uses either an active or passive monitoring system; OSHA may monitor commercial or industrial sites if it appears there may be violations.	Vent to the exterior space over gas stoves and all combustion-type heating systems.
Radon	Radioactive gas that's colorless and odorless.	Found in soil, rocks, mineral deposits, and water; varies considerably by geographic area.	May damage lungs; may cause cancer.	Radon detection kits; purchased at lumberyards or hardware stores.	Seal cracks in basement walls and floors; cover exposed soil with concrete slab; don't allow soil to be exposed to living-space air.

Figure 1 (continued)
Controlling pollutants

Because radon is a product of uranium in the soil, the geographic areas with high radon levels are those with uranium deposits. Consequently, the highest levels of radon are found throughout the Rocky Mountain region of the United States and Canada. Many areas of the country have no indication of radon at all.

Dangerous Radon Levels

For the most part, radon is only a problem if it gets trapped in buildings or drawn into them with a vacuum effect. As the gas accumulates, it can reach dangerously high levels. Prolonged exposure may lead to lung damage or cancer. Radon is measured in pico Curies per Liter (pCi/L). The Environmental Protection Agency (EPA) considers the average of a lifetime indoor exposure of 4.0 pCi/L equal in health risk to smoking half-a-pack of cigarettes daily. In areas where radon is at highest risk, the outdoor pCi/L levels usually fall under 0.5.

Indoor radon levels, if the gas is trapped, can rise as high as 200 pCi/L. High radon levels are made worse in buildings constructed since the mid 1970s due to the construction industry's efforts to make structures airtight and lower energy costs. This energy-saving benefit has its downside in trapping pollutants inside the structures. It's no coincidence that the EPA only began to realize the seriousness of the radon problem in the early 1980s.

Controlling Radon Levels

Initially, the industry attempted to solve the problem by stopping radon at entry points. Caulking and other passive barriers were used extensively, and were good up to a point. However, in anything but new construction, it was almost impossible to seal all the cracks and openings in a building and keep the radon out.

Currently, the preferred method of dealing with radon is to capture the gas at the substructure level, before it enters the building, and vent it away from the structure. This is called *sub-slab depressurization*. The second choice in dealing with radon is to improve the interior ventilation through the use of a single-fan exhaust-only ventilating system or a double-fan exhaust-and-supply ventilating system. Although these are not quite as effective as sub-slab depressurization, they do double duty by removing other air pollutants as well as much of the radon.

For information on related topics, see:

Adhesives, page 25

Asbestos, page 31

Heating and Air Conditioning, page 379

Insulation, page 395

Painting, page 427

Ventilation, page 701

Resilient Flooring

In purely technical terms, resilient flooring refers to any kind of flooring that “gives.” By this definition, carpet and wood fall into this category, while nonresilient flooring would include ceramic tile, pavers, and stone. Within the construction industry, however, resilient flooring has come to mean flooring materials made of vinyl, rubber, asphalt, and cork. Up until the early 1970s, linoleum, which was made of linseed oil, was also a popular choice for flooring. But because vinyl is more durable and easier to maintain, it quickly replaced linoleum in both commercial and residential use. In fact, vinyl is now often used interchangeably with the term resilient flooring.

Figure 1 shows the various types of resilient flooring, where to use them and their particular advantages.

In the past, asbestos was used as a backing for vinyl to add durability and reduce shrinkage. But because of the health concerns related to asbestos, it’s been replaced with fiberglass. (See *Asbestos*.) However, if you’re involved with a remodeling job where the vinyl flooring was installed before the 1980s, you need to be aware that the original flooring material may contain asbestos. Before removing it, have it tested, either by the local health department or a flooring supplier. If it contains asbestos, have it removed professionally.

Another option, if the flooring hasn’t deteriorated and is securely bonded to the subfloor, you can either place underlayment over the old flooring or install new flooring right on top of it. Just make sure you strip off all the old wax or finish so the adhesive will adhere.

Material	Where to Install	Ease of Installation	Ease of Maintenance	Resistance to Stains	Resistance to Grease	Resistance to Heel Damage	Durability	Quietness	Resilience
Inlaid vinyl	Felt-backed, above grade; Foam-backed, below, on, or above grade	Fair to difficult	Easy	Fair	Very good	Good to poor	Good to very good	Fair to good	Fair
Printed vinyl	Felt-backed, above grade; Foam-backed, below, on, or above grade	Easy to fair	Easy to fair	Fair	Very good	Good to poor	Fair to good	Good to poor	Fair
Vinyl composition tile	Below, on, or above grade	Easy	Good	Good	Good	Poor	Good to very good	Poor	Poor
Cork tile	Suspended floor	Fair	Poor	Poor	Poor	Poor	Poor	Very good	Very good
Vinyl cork tile	Suspended floor	Fair	Good	Very poor	Very good	Fair	Poor	Good	Good
Rubber tile	Below, on, or above grade	Easy to fair	Poor	Very good	Fair	Poor	Good	Good	Good
Linoleum	Suspended	Easy to fair	Good	Good	Very good	Good	Good	Fair	Fair

Figure 1
Resilient flooring chart

Types of Vinyl

Vinyls fall into two categories: inlaid and printed. Inlaid vinyl, which was developed initially by Armstrong, is made by a process of fusing the color to the backing and then covering it with a clear coat. Another method is to inlay the pattern by printing it onto the backing and then covering it with clear vinyl.

Printed vinyl has the pattern printed on the surface. Vinyl in either category is still a relatively soft product and not nearly as durable as a nonresilient product, such as ceramic tile. For obvious reasons, though, between inlaid and printed vinyl, the inlaid will be less likely to show scratches or other surface damage.

The Subfloor

As with any kind of flooring, resilient flooring depends on a suitable subfloor; it must be perfectly level and smooth. As we already mentioned, concrete subflooring must be completely cured or the adhesive bond may not adhere. (See *Floor Framing*, *Subfloor*.) Wood subfloors should be $^1/_2$-inch thick or heavier plywood. If you use double-layer tongue-and-groove strip wood that's 3 inches wide or less, cover with $^1/_4$ inch or heavier plywood.

You can also lay resilient flooring over existing flooring under the following conditions:

- The existing floor is smooth, firmly bonded to the substrate, and properly installed.
- There's no evidence of moisture, alkaline salt, or hydrostatic pressure.
- The existing floor isn't a rotovinyl or cushioned-backed floor.
- The flooring has been stripped of wax and other finishes where adhesive is to be spread.

Underlayment

Resilient floorings tend to mold themselves somewhat to irregularities in the surface over which they're laid. This is particularly true of floorings with a high gloss finish. By using an underlayment, however thin, you can achieve a smooth surface. And, the smoother the surface, the more even the flooring will wear.

There are two underlayments commonly used with resilient flooring: mastic and board. The best mastic consists of portland cement and a binder of latex or polyvinyl acetate resins. You can use it over concrete as a leveling material. Apply mastic in layers no more than $^1/_8$-inch thick, with all layers being no more than a total of $^3/_8$-inch.

Board underlayment should be no more than $^1/_4$-inch thick. Don't use either particleboard or regular plywood. Most people in the industry currently recommend $^1/_4$-inch mahogany plywood as underlayment for resilient floor covering. Because of this specialized use, you'll probably be more likely to find mahogany plywood at flooring suppliers rather than at a lumberyard. Staple the underlayment to the subfloor in a 4-inch grid pattern, no closer than $^1/_2$ to $^3/_4$ of an inch from the edges. Or better yet, first glue the underlayment and then nail it down. (See *Floor Framing*, *Underlayment*.)

Installing Sheet Flooring

You can install sheet flooring in one of three ways: loose lay, full-bed adhesion, or perimeter adhesion.

Loose lay is simply as it sounds. The sheet vinyl is trimmed to size and placed on the floor without adhesives or anything else to secure it. This method isn't very durable.

Perimeter adhesion installation requires the floor covering to be secured only at the edges. This is a specialized process that you use with products designed for this type of installation. This method is best left to professional floor installers.

Most of the time sheet vinyl is installed with full-bed adhesion, and the seams are chemically sealed. Bring the sheet vinyl to the room where you'll be installing it at least 24 hours before your installation. This allows the vinyl to adjust to the temperature in the room. The room should be between 65 and 100 degrees during the 48 hours prior to installing the vinyl. After the installation, keep the temperature at least 55 degrees or warmer. Install sheet vinyl after everything else in the room is completed, including the drywall and the painting. The only thing that you should have to do after the sheet vinyl is install the shoe molding.

Tools and Materials

You'll need the following tools and materials for your installation:

- *Utility knife or sharp shears*
- *Metal straightedge*
- *Notched trowel*
- *Linoleum roller or push broom*
- *Buckets of water or heavy objects for weight*
- *Multipurpose floor tile adhesive*

Use these guidelines for installing vinyl sheet flooring:

1. Make a sketch of the room. Take precise measurements of each wall length. Unroll the vinyl in a larger room or area, such as a living room or basement, and carefully cut it with the knife or shears, allowing an extra 3 inches on all sides. If at all possible, plan for the factory edge to be along the longest wall, as long as the shoe molding will hide any factory markings along that edge. This will save cutting and provide a guide for aligning the floor covering. If you have to have a seam, overlap the pieces a couple of inches, matching the patterns exactly.

2. Roll up the flooring and lay it out in the area where it is to be installed. Place buckets of water or heavy objects on the vinyl to keep it in position as you trim down the edges and corners to fit. Begin with the longest straight edge and trim the excess until the flooring lies flat, with no more than a $^1/_8$-inch gap between the vinyl and the baseboard. The shoe molding will hide a small gap. Trim the excess either by cutting away a little at a time, or by creasing the flooring by tightly pressing a 2 × 4 into the corner where the floor and wall meet and using a metal straightedge along the crease as a guide for cutting off the excess.

3. To trim around doorways or other obstacles, make a template with a compass. Lay a piece of paper around the obstacle. Place the compass point against the uneven edge and the pencil on the paper. Move the compass along the edge to trace the shape for a cutting line. Tape your template to the vinyl and cut out the pattern. An alternative to making a template is to cut vertical slits, from the floor up, at all the inside and outside corners of the obstacle. Then, using a screwdriver, force the flooring material into the corners and angles where the floor and wall

meet. Angle your utility knife at about 45 degrees and trim away the excess material.

4. When you have trimmed the flooring to the exact size, pull back about half of it. Again, use buckets of water or heavy objects to keep the vinyl from sliding out of position. Use a notched trowel to spread the adhesive on the floor. Use the manufacturer's specification for drying time to determine how large an area you can work with at one time. If the adhesive loses its tackiness before you lay the vinyl, you may have to scrape it up and spread a new layer. If you have to match seams, do not apply adhesive within 8 or 9 inches of the seam.

5. Gently roll the vinyl out onto the adhesive. From time to time, pull the vinyl up in spots to make sure enough adhesive is sticking to the vinyl. Working from the center to the edges, push a heavy linoleum roller over the entire glued portion, the length and width of the room, in order to force out trapped air bubbles. If you can't rent a roller, use a push broom initially, and then slide over every inch of surface in your stocking feet, again working outward from the center to the edges.

6. Repeat steps 4 and 5 for the other half of the flooring.

Matching the Seams

Sheet vinyl comes in sizes from 6 to 15 feet wide. Although the ideal would be to not have any seams in a room, with the advent of chemical and heat sealers, at least now the seams are tight and have become nearly invisible. About 90 to 95 percent of all residential sheet vinyls are now sealed chemically and it's easy enough for a novice to do.

The process of applying a chemical to the edges of the vinyl and then heating the seams to seal them is called welding the seams. This is far more difficult than the plain chemical sealers. This process requires special tools and should be left to the professionals. Most commercial grade sheet flooring has welded seams because they're more durable. Consult your flooring supplier to figure out how much extra material you'll need for welded seams. Keep in mind that some patterns require reversing the direction of the second sheet in order to match the design.

Use the following instructions as a guide for chemically sealing seams:

1. Match the pattern on the two pieces exactly. Overlap the two by at least an inch. Using a straightedge and utility knife, cut through both layers of sheeting.

2. Pull back the unglued edges and apply the adhesive. Press the flooring in place. Clean off the excess adhesive with a damp sponge.
3. Spread a bead of the chemical adhesive along the seam line according to the manufacturer's directions. As it dries, the seam should meld together.

Installing Resilient Floor Tiles

To determine the number of tiles you'll need to cover an area, multiply 144 (square inches) times the number of square feet to be covered. Then divide by the square inch area of the tile size you're using.

For example, a room is 10 wide by 12 feet long, and you're using 9-inch square tiles.

10 feet × 12 feet = 122 square feet

122 square feet × 144 square inches = 17,568 square inches

9 inches × 9 inches = 81 square inches

17,568 square inches ÷ 81 square inches = 216.89 square inches

Round up to get a total of 217 tiles

Add 10 percent to allow for breakage and waste. For larger jobs — and greater experience — drop the extra tiles to 5 percent or less.

Tile Layout

Laying out tile is more complicated than laying out sheet flooring for obvious reasons. If you find yourself off just a little, the error will grow as you lay the floor. By the time the room is finished, the misalignment will be a glaring embarrassment.

Begin by finding the center of the room, or the center of the focal point in the room. To do this, find the center of each wall, and snap a chalk line lengthwise and widthwise across the centers. These will be the base line and the test line for laying the tile (see Figure 2). If you're using the center of a fireplace, a doorway, or a window as the focal point, shift your chalk line accordingly. The intersecting lines should be a perfect 90-degree angle. Use a carpenter's square to double-check it.

The placement of the first tile will determine the width of the border tiles. If the intersecting lines fall right at the room's center, this is easy enough. If not, use the guide in Figure 3 for positioning the center tile.

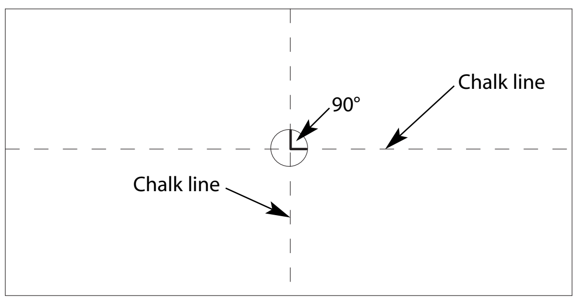


Figure 2
Locating center of room

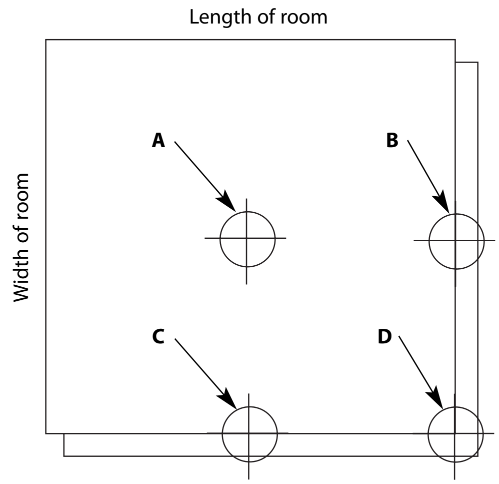


Figure 3
Positioning center tile

If the room has a:

- length and width that are both even — place point A over room center
- length and width that are both odd — place point B over room center
- length only that is odd — place point C over room center
- width only that is odd — place point D over room center

If you're using a visual point as the center, rather than the center of the room, dry lay the tiles to determine how wide the borders will be. Ideally, the borders should be no less than half a tile wide. If necessary, shift the chalk lines accordingly. Remember that you need to allow for a $^1/_8$-inch expansion joint between the tile and the walls.

Laying the Tiles

You can make straight cuts using a sharp utility knife or shears for most tiles. For irregular cuts and for some tiles, such as rubber and a few vinyl composite tiles, you'll need to heat the tile first before cutting. Warm the tile on a food warmer or hold it in front of a portable electric heater or over a lamp until the tile is warm. Then cut with a knife or shears.

Many tiles come with an adhesive back and don't require an additional layer of glue. However, many professionals still use an adhesive to give the tile a more permanent bond. Be sure to read the adhesive manufacturer's instructions before you apply it. The application, thickness, and drying time vary considerably from one adhesive to another.

Tools and Materials

- *Chalk line*
- *Utility knife or shears*
- *Notched trowel, paintbrush, or short-nap roller (refer to directions on the adhesive)*
- *Rolling pin*
- *Linoleum roller*
- *Adhesive*

Lay the tiles in either a jack-on-jack pattern or a running bond using the following guidelines:

1. Snap a chalk line to find your starting point. Work one quadrant at a time, starting where the base and test lines intersect. Avoid covering the base and test lines. Spread the adhesive in a triangular area, following the manufacturer's guidelines for thickness and waiting time. Aim for the right thickness: If you use too much adhesive, the excess may seep up between tiles, or soft pockets will form under the tile resulting in more give to the tile. Too little adhesive may prevent the tile from sticking adequately, or it may cause cracking.
2. Place the first tile at the point where the base and test lines intersect. Do not slide the block in place; rather, drop it lightly onto its spot, twisting slightly. Using a rolling pin, roll the surface of the tile to push out air bubbles and force the tile more firmly into the adhesive.
3. Set the second block next to the first; it should go directly above the first one. From there, build the pattern in a stair step, or pyramid, pattern, checking periodically to make sure the tiles are straight and even. Never kneel on the tiles you're laying. Either kneel on the subfloor, or place a piece of wood on the laid tiles and kneel on that.
4. Occasionally lift up a tile to make sure the adhesive completely covers the back side. About every 10 square feet, use a linoleum roller and roll the surface again in two directions.
5. Cut the border tiles by putting a full block directly on top of the last row of glued tiles. Leave a $^1/_8$-inch space between the loose tile and the wall for expansion. Using a straightedge, draw a line where the secured tile ends. Cut and glue.
6. When all the tiles are glued in place, replace the shoe molding. Follow the manufacturer's suggested time before putting furniture on the new flooring or allowing regular traffic on it. It's usually about 24 hours. Wait five to ten days after installation to wax or wash the floor.

Repairing Resilient Flooring

A little paste wax will often hide light scratches. Some scratches will even disappear if you rub them with the edge of a coin. Other flaws require removing a single tile or all of the damaged area. Heat will generally loosen the adhesive under flooring. Either use a low flame from a propane torch or an electric iron set on moderate heat and wrapped in a towel. Be careful not to scorch the tile. Keep a fire extinguisher handy, particularly if you use a propane torch.

Tile Repairs

Many of these repair methods will work for both sheet flooring and tiles.

Curled Tiles

1. Set an iron on moderate heat and cover it with a towel. Place the covered iron on the tile. When the tile is loosened, pull back the curled corner and spread fresh adhesive on the tile.
2. Press the tile back in place, taking care to wipe up any adhesive that squeezes out. Place a flat board over the tile and weigh it down with a heavy object, such as a bucket of water.

Replacing a Tile

1. Heat the damaged tile (see Step 1 above). As it becomes pliable, use a chisel or putty knife to pry up the bad tile. Be careful to avoid chipping the neighboring tiles.
2. Clean off the subfloor with a putty knife; remove all the old adhesive. Sand the space smooth and patch any dips.
3. Spread, or *butter*, the back of the replacement tile with adhesive. Keep the adhesive fairly thin, especially at the edges. Press the tile in place, and clean up any excess adhesive that seeps out.
4. Hold the tile firmly in place until it dries. See Step 2 above.

Repairing Sheet Vinyl

1. Cut a patch larger than the area you're repairing. Tape the patch over the damaged area, matching the pattern exactly.
2. Using a utility knife, cut through both the patch and the original layer. Remove the patch and heat the damaged area to loosen the adhesive.
3. Follow steps 2 through 4 under *Replacing a Tile*.

Small Holes

Mix epoxy and paint according to the manufacturer's instructions. Mask off the damaged area with tape and spread the epoxy in the hole.

Repairing Blisters

1. Using a sharp utility knife, slit the blister the entire length plus another 1/2 inch on each end.
2. Heat the area with a covered iron as described above in Step 1 of repairing *Curled Tiles*. Carefully lift the flooring through the slit and force adhesive into the pocket. Press down and roll flat with a rolling pin. Clean off any excess adhesive. Weigh the area down as described in Step 2 of repairing *Curled Tiles*.

Manhours

Manhours to Install Resilient Flooring			
Type	**Unit**	**Manhours**	**Suggested Crew**
Vinyl sheet flooring	SY	.25	1 floor layer
Vinyl tiles	100 SF	2.3	1 floor layer

For information on related topics, see:

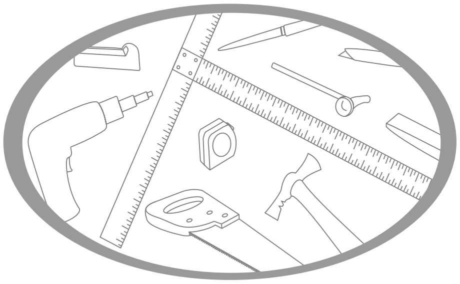
Adhesives, page 25

Asbestos, page 31

Floor Framing, page 299

Flooring, page 359

Trim, page 673



Roof Framing

Building a roof presents a wider range of variables, choices and options than any other phase of framing. First, there are two distinct systems of framing a roof: stick framing with rafters, or manufactured trusses. And there are many roof styles, which include gables, dormers, valleys, hips and ridges (see Figure 1). Let's review the basic roof styles:

Flat roof: The most basic roof is a flat roof. This roof presents little more challenge than floor joists.

Shed roof: A shed roof is basically a flat roof with a rise. As the rafters for a shed roof are cut with a birdsmouth, you might more accurately describe it as one side of a gable roof.

Gable roof: A gable roof is built with two sloping roofs that rise to meet each other at a peak. When viewed from the end, the triangle formed by the roof is known as the gable.

Hip roof: A hip roof eliminates the gable ends by running hip rafters from the outside corners to the peak, at an angle that maintains a constant slope on all sides of the roof.

Gambrel roof: A gambrel roof is similar to a gable roof except that there are two angles on each side, with the lower being steeper than the upper. The advantage of a gambrel roof over a gable roof is the additional attic space provided by pushing out the roof with the double slope.

Mansard roof: A mansard roof is a hipped gambrel roof.

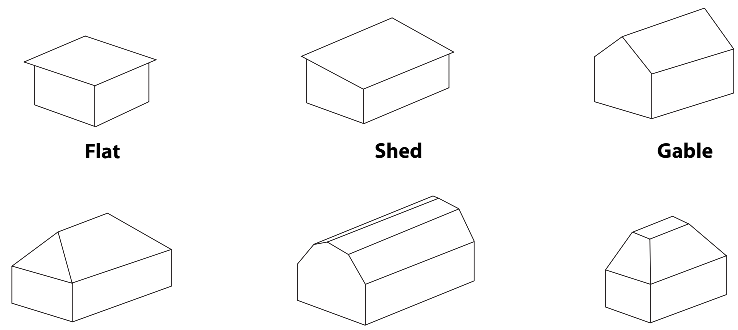


Figure 1
Basic roof styles

Roof System Design and Engineering

Most roof joists, rafters and trusses are laid out at 24 inches on center. The load they'll carry determines their size and spacing. Rafters supporting a tile roof in a heavy snow area of the north will be larger and closer together than a composition roof in the south.

The building designer or structural engineer will calculate the size and the spacing of the roof members, depending on the pitch, span and anticipated loading. The role of the engineer is to design a roof system that's structurally sound. The role of the contractor or framer is to build and install the system in accordance with that design. If you run into problems, don't make any job site alterations without consulting the designer or engineer. Unfortunately, contractors or framers must be as aware of legal liabilities as they are of framing techniques. Job site changes in engineering present a dangerous legal exposure.

Measuring the Angle of the Roof

The basis of measurement used to determine the steepness of a roof is the *slope*. The horizontal measurement is known as the *run* and the vertical measurement is known as the *rise*.

- The *overall run* is the distance from the outside of the top plate to the center of the ridge.
- The *overall rise* is the distance from the top of the top plate to the theoretical top of the ridge. As the top of the ridge is flat, the theoretical point is where the tops of the two rafter slopes intersect.

While you'll work with the overall rise and run in building the roof, the slope or pitch is based on the unit rise and unit run. The unit that is referred to is 12 inches.

- The *unit run* is constant and always refers to 12 inches.
- The *unit rise* is variable, but as with the unit run, is always measured in inches.

The relationship between the variable unit rise and the constant unit pitch indicates the slope of the roof. A 4 in 12 slope (also written 4/12) indicates that for every 12 inches of run, the roof rises 4 inches. A 12/12 indicates that for every 12 inches of run, the roof rises 12 inches. Whether ordering trusses or cutting rafters, you'll always refer to the angle of the roof by the relationship between the rise and run. The rise (the variable) is always given before the run, which will always be 12.

Another way of referring to the roof angle is the *pitch*. While in most areas slope and pitch are used interchangeably to refer to the slope, pitch actually refers to the ratio of the rise to the span, and slope uses the ratio of the rise to the run. While slope uses a constant of 12 inches, pitch uses a constant of 24 inches. A roof with a rise to run slope of 6 in 12 has a ratio of rise to span of 6 to 24. This is known as a quarter-pitch roof. While pitch and slope refer to two different methods of measurements, in common usage, the terms are synonymous. If you're asked for the pitch when ordering trusses, you'll probably get a funny look if you respond quarter-pitch instead of 6/12. Figure 2 shows the relationship between the rise, run and span of the roof.

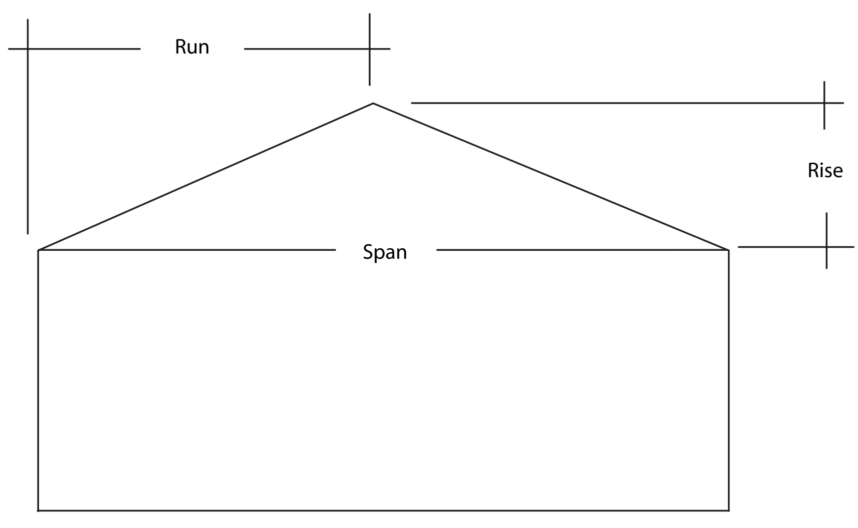


Figure 2
Roof rise, run and span

On an architectural drawing, the rise and the run will be indicated on the elevation with a vertical and horizontal line at a right angle. Beside the vertical line will be a number indicating the rise. Above the horizontal line will be 12, indicating the run.

To find the slope of an existing roof, you'll have to start with the rise and the run. You can find the run of an existing roof by measuring from the center of the span (plumb down from the ridge) to the outside edge of the building. Find the rise by measuring the plumb line from the peak of the ridge to the bottom of the ceiling joist (see Figure 3). With the rise and the run in hand, you can calculate the slope.

An alternative method involves a level and a framing square. Level the framing square with 12 inches (or 24 inches for better accuracy) at the lower end of the rake. Check the vertical arm of the square to see where the rake intersects. If the rake crosses at 4 inches (or 8 inches if you've used 24 inches for the horizontal measurement) the slope is 4/12.

Rafter Framing

Roof framing involves a number of basic components. Figure 4 is an illustration of a rafter-framed roof with the components labeled.

Traditional rafter framing presents the most complicated aspect of framing and requires the most skill and knowledge for the framing carpenter. In many areas of the country, roof trusses have replaced rafter framing for almost all roof styles. With stick framing needed for only minor build-outs, many carpenters may find their skills a little rusty when confronted with an intricate stick-framed roof. But rafter framing, while intimidating, is just a matter of following the rules. If you follow the set procedures, like cutting hips and valleys in pairs, you can eliminate much of the head scratching.

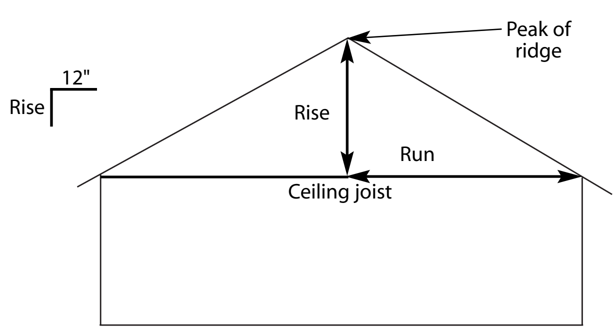


Figure 3
Finding slope of an existing roof

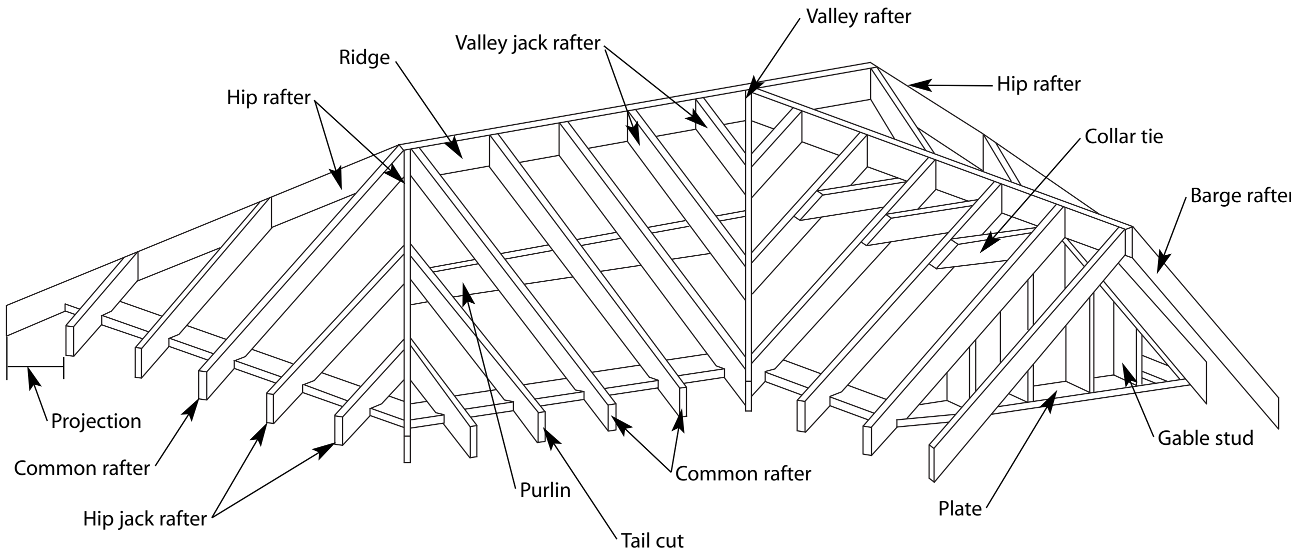


Figure 4
Roof framing components

Roof Framing Tools

Before we start on the specifics of roof framing, let's pause to look at the tools you'll use.

Steel Square

The tool most commonly associated with roof framing is the steel square. Unfortunately, for most of us, it's one of the most under-used tools we own. A steel square can simplify many of your roof-framing tasks. It's well worth your while to become familiar with this tool and the tables stamped on it.

Speed Square

The speed square is a modern update (and supposedly simplified version) of the steel square. Its compact size is convenient for carrying in a tool pouch. The speed square is marked with degrees as well as slope markings. You can use it to quickly mark a rafter by working off of a pivot point and aligning the appropriate slope marking.

Rafter Length Tables

Rafter length tables are available in book form. These tables list the rafter runs in 1/4-inch increments. By matching the rafter run with the rafter pitch, you can easily find the rafter length.

Hand-Held Calculator

All of the calculations needed to determine slope, rafter lengths and cuts can be done on a hand-held calculator. Many of us use calculators every day, so they seem more "user friendly" than the tables on the steel square or rafter length tables. For those of you interested in using your calculator for roof framing, Craftsman offers a book specifically on this topic. It's called *Roof Framing*, and you'll find it on the order form at the end of this manual. You can also check out all of the Craftsman books at www.craftsman-book.com.

Task-Specific Calculators

You can get calculators from specialty suppliers that are programmed specifically for calculating problems involving rise and run for both roof and stair building. Calculated Industries, for example, has a Construction Master Pro calculator that figures in feet, inches and fractions, as well as calculations especially for roof framing. You'll find this on the order form too.

Building Tools

In addition to these specialty tools, you'll need the standard tools required for framing, including a hand saw, circular saw, plumb lines and levels.

Rafter Framing Measurements — Theoretical and True

When you're calculating lengths for any type of rafter, there are two types of measurements involved. The two types are *theoretical* and *true* measurements. The end objective of all rafter measurements is finding the true measurement. That's the measurement that you'll actually use to cut the rafter.

Let's look at an example to explain the difference. Assume you're building a 2-foot by 2-foot square box with two sides that run through and two sides that butt. The theoretical length of each of the four sides is 2 feet. If you build the box out of 2 × 4s, the true measurement for the first two sides will be 2 feet. But the true measurement for the second two sides would allow for the thickness of the two 2 × 4s they butt against. To find their true measurement, you need to subtract $1^1/_2$ inches from each end. That leaves an actual length of 1 foot 9 inches for each of the other two sides.

Think of the theoretical measurement as a line or a string. Figure 5a illustrates the line around the 2-foot by 2-foot box in our example. You can see from the example how you have to alter the true measurements to accommodate the material used to construct the box (Figure 5b). This same concept also applies to rafter lengths with ridge lines. You must subtract the thickness of half of the ridge from the rafter length.

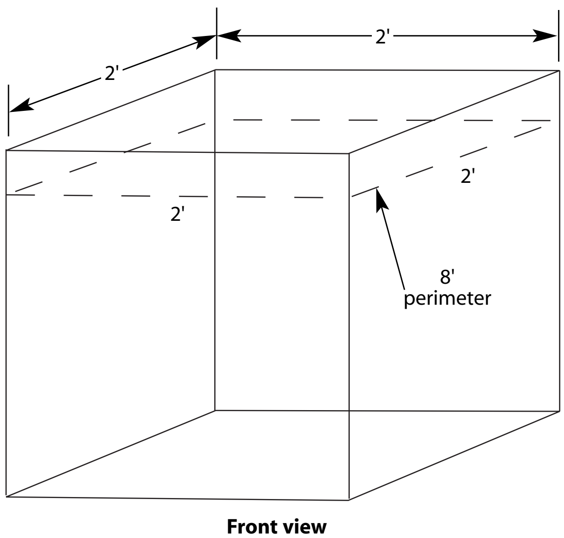


Figure 5a
Theoretical measurement

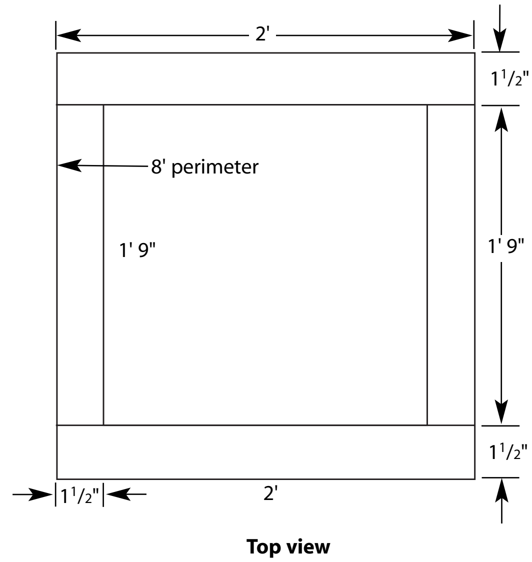


Figure 5b
True measurement

Types of Rafters

Depending on the type of roof being framed, there are a variety of rafter types you'll use. The most basic of these is called a common rafter. The common rafter runs from the wall plate to the peak of the roof. Hip roofs are built with a combination of common rafters and hip rafters, which angle from an outside corner to the peak. The hip rafter is then finished out with hip jack rafters that run from the wall plate to the hip rafter. When a building has an inside corner (like an L-shaped house), the roof includes a valley. A valley rafter angles from the inside corner to the peak. Valley jack rafters run from the valley rafter to the ridge board.

Common Rafters

As the name implies, common rafters are the standard or most common rafters on a roof. This is always true with a gable roof, though some hip roofs actually have more hip and valley jacks than common rafters.

The common rafter is a good place to become familiar with basic rafter cuts. Figure 6 illustrates common rafters with the required cuts. At the peak is a plumb cut. This is a vertical cut that you make to fit the rafter against the ridge board.

At the opposite end of the plumb cut for the ridge is the tail cut. The most common tail cut is also a vertical plumb cut. When the roof includes a fascia and soffit, you make a second level cut on the rafter tail at the soffit line.

Finally, a notch allows the rafter to sit on the top plate. This notch is called a birdsmouth. The level cut of the *birdsmouth* is called a *seat cut* and the plumb cut is called a *heel cut*.

This section will cover the steps required to lay out a common rafter. For the purpose of laying out the initial or pattern rafter, we'll treat the birdsmouth as the pivotal point, and then figure the tail length and theoretical length from this point.

Once the pattern rafter is laid out, many carpenters feel that the real work is done. All that remains is marking the remaining rafters using the pattern, then cutting and pounding nails — the fun stuff. Rafter layout isn't something to dread once you understand how to do the calculations.

Marking and Cutting the Birdsmouth

A birdsmouth is a notch cut into the rafter where it rests on the top plate of the wall. The cuts for the birdsmouth are a plumb cut (heel cut) and a level cut (seat cut).

Make sure you locate the birdsmouth on the pattern rafter in a position that will still leave adequate material for the tail length. This is the approximate length of the overhang plus about 6 inches. If you plan a 24-inch soffit, allow approximately 30 inches from the tail of the rafter to the birdsmouth for the pattern rafter.

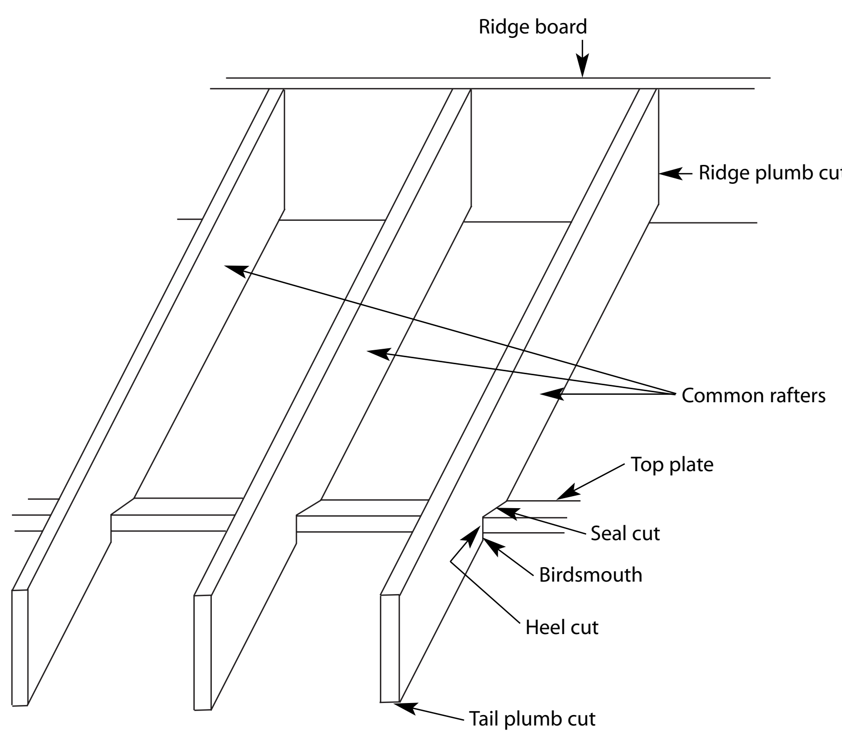


Figure 6
Rafter cuts

When you make a birdsmouth cut, you should never remove more than one-third of the rafter depth. Measure this distance on a squared line through the rafter, not along the plumb cut of the heel. On wider rafters, this won't be a problem, but watch carefully when working with 2 × 4s and 2 × 6s. The distance between the birdsmouth seat cut and the top of the rafter is called *height above the plate* or HAP. Figure 7 shows how you measure the HAP.

Follow these steps to mark and cut the birdsmouth:

1. Place the rafter material on the sawhorses with the crown placed away from you (crown up).
2. Using a framing square like the one shown in Figure 8, set your framing square guides at the desired pitch. For our example set the guides so the 4 on the tongue and the 12 on the body are precisely on the edge of the rafter.
3. Mark along the tongue of the square for the plumb, or heel cut (Figure 9 a).
4. Move the square up the rafter so that the body of the square is in position to make the level or seat cut. Measure squarely across the rafter to make certain that the birdsmouth doesn't remove more than one-third of the depth of the rafter (Figure 9 b). The steeper the pitch of the roof, the deeper you can cut the heel of the birdsmouth without exceeding one-third of the depth.

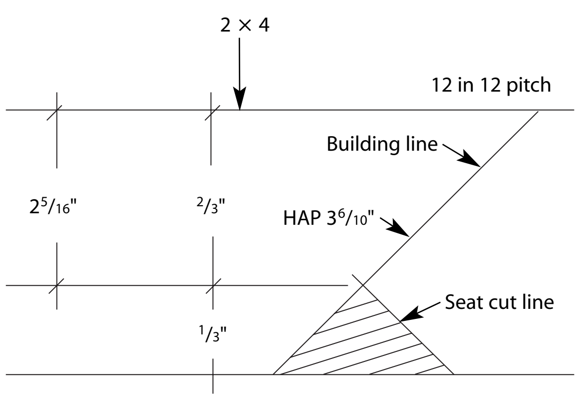


Figure 7
Measuring height above plate (HAP)

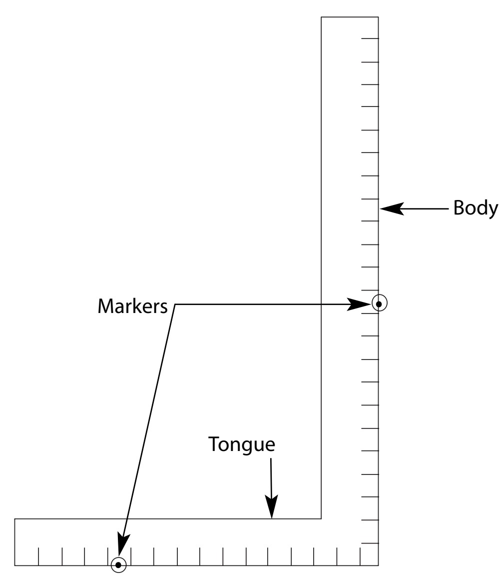


Figure 8
Rafter or framing square with markers

5. With the depth and seat size confirmed, mark along the body of the square for the seat cut mark (Figure 9 c).

6. Figure 9 d shows the birdsmouth cut marked on the rafter. With a circular saw, cut inside the lines marked for the birdsmouth. Don't cut beyond the lines, as this will weaken the rafter.

7. Use a hand saw or reciprocating saw to complete a clean, square cut.

Calculating Common Rafter Length

To calculate the length of a common rafter, you need the rise, the run and the slope. For the methods we'll cover here, we'll use a 24-foot span as an example unless otherwise stated. With a 24-foot span, the run will be 12 feet as measured from the outside of the top plate to the center of the ridge board. If a 4/12 slope has been called out on the plans, the rise will be 4 feet. Based on this information, we'll cover three ways to figure the rafter length.

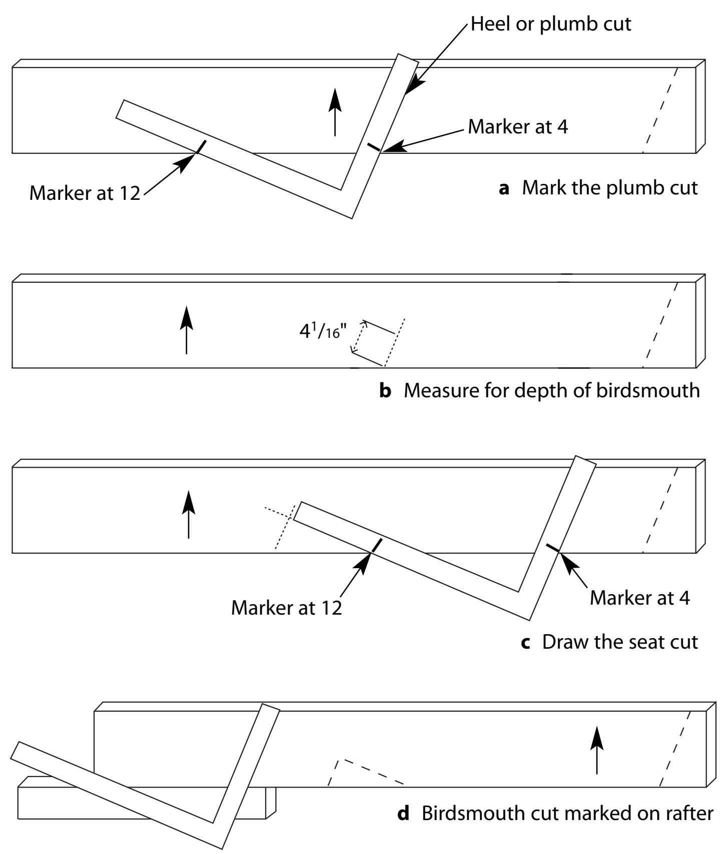


Figure 9
Making the birdsmouth cut

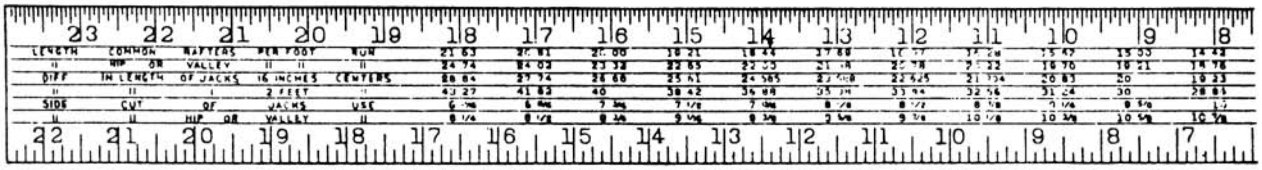


Figure 10
Rafter table on steel square

Stepping Off — Stepping off is perhaps the least-used method, but it's the best illustration for calculating the length. To step off the length, set the square at the slope and step the number of feet of the run. In our case, that's 12 times. The disadvantage of stepping off is that there's a high possibility of error. If the square is set wrong, your measurement will be way off. That's why I don't recommend it as your method for finding the rafter length.

We'll go through the steps to illustrate how the square tables and rafter length manuals use this method. We'll mark off a rafter for a 12-foot run and a 4-foot rise. Be as precise as possible with the placement of the square and the markings. It's slight errors made in placement that make this system less reliable than the others.

1. Locate the base of the heel cut of the birdsmouth. Make a mark about 6 inches plus the anticipated length of the overhang from the tail of the rafter. If you're using a 24-inch overhang, mark the base of the heel cut 30 inches from the tail.
2. Place the 12 on the body of the square on this mark. Place the 4 on the tongue of the square on the edge of the rafter. Make a mark along the tongue of the square.
3. Slide the body of the square up the rafter until the 12 on the body is precisely on the mark you made along the tongue in step 2. Again, place the 4 on the tongue exactly on the edge of the rafter. Mark the tongue.
4. Repeat step 3 until you've made a total of 12 steps from the base of the heel of the birdsmouth. On the 12th step, mark along the tongue the full width of the rafter. This mark is the plumb cut for the rafter peak. This is the full rafter length before reducing it for half the thickness of the ridge board.

Steel Square Rafter Tables — The traditional way to calculate rafter length is to use the tables stamped on the steel square (see Figure 10). These tables give the unit length of the slope. For a 4/12 slope, the measurement is made from the 12 on the body of the square to the 4 on the tongue of the square. The result of the measurement is a unit length of approximately 12 5/8 inches. The square also includes a table for finding the unit length of the slope. Fractions on the table are given in hundredths. You'll have to convert them to inches. It's best to save this conversion for the last step.

To find the length for a sample rafter with a 12-foot run and a 4-foot rise, follow these steps:

1. Find the rafter table on the body of the face side of the square. Some inexpensive squares targeted for homeowners don't have these tables. You need a professional model. The table is aligned so there are columns under the inch marks on the square from 2 to 18 inches. When using the table, the inch markings refer to the unit rise of the rafter. The top line of the table will read *Length Common Rafters Per Foot Run*. This is where you'll find the information to determine rafter length.
2. To find the unit slope length for a 4/12 slope look to the *Length Common Rafters Per Foot Run* row under the 4-inch mark. You'll find the number 12 65. This represents 12.65 inches, or approximately 12 5/8 inches.
3. To calculate the overall rafter length from the bottom edge of the birdsmouth to the bottom edge of the ridge plumb cut, multiply the run times the unit slope length. In our example, that's 12 (the run) times 12.65 (unit slope length). The result is 151.8 inches, or 12 feet 7 13/16 inches before adjusting it for the thickness of the ridge.

Rafter Length Tables — Many builders choose to use rafter length tables to find their rafter lengths. Rafter length books are available from a number of publishers, but the tables themselves should be virtually identical, as they're all the result of mathematical calculations.

As an example, we'll use the *Roof Framer's Bible* available from Craftsman. (There's an order form in the back of this book.) Let's determine the rafter length for our example roof with a 12-foot run and 4-foot rise. Look in the book under Rafter Tables for Regular Equal Pitched roofs, and turn to common rafters, 4/12 — 18° pitch (See Figure 11.) Follow down the Run Feet column to find the 12 feet row. Look across to the Common Rafter Length column and you'll find 151 ¾. This is the rafter length in inches. Again, you'll have to adjust for the ridge thickness. That's the subject of the next section.

Converting Theoretical to True Length

The common rafter length we found in the last three examples assumed that the rafters will run to the centerline of the ridge. If there's a ridge board, these are just theoretical lengths. They're theoretical because they're measured to a point that they can't reach. To make these lengths true rafter lengths, you must compensate for the ridge thickness. This is known as a ridge reduction.

4/12 — 18º			
Run Feet	**Common Rafter Length**	**Rise**	**H/V Rafter Length**
1	12 5/8	4	17 3/8
2	25 1/4	8	34 7/8
3	37 7/8	12	52 1/4
4	50 5/8	16	69 3/4
5	63 1/4	20	87 1/8
6	75 7/8	24	104 5/8
7	88 1/2	28	122
8	101 1/4	32	139 1/2
9	113 7/8	36	156 7/8
10	126 1/2	40	174 3/8
11	139 1/8	44	191 3/4
12	151 3/4	48	209 1/4
13	164 1/2	52	226 5/8
14	177 1/8	56	244 1/8
15	189 3/4	60	261 1/2
16	202 3/8	64	278 7/8
17	215	68	296 3/8
18	227 5/8	72	313 7/8
19	240 3/8	76	331 1/4
20	252 7/8	80	348 3/4
21	265 5/8	84	366 1/8
22	278 1/4	88	383 5/8
23	290 7/8	92	401
24	303 5/8	96	418 1/2
25	316 1/4	100	435 7/8

Figure 11
Roof Framer's Bible *page for regular equal-pitched roofs*

To make a ridge reduction, simply subtract one-half the thickness of the ridge board (see Figure 12). If you're using a 1-by ridge board, subtract 3/8 level inch off of the rafter. For a 2-by ridge board, subtract 3/4 level inch off of the rafter. This reduction, or shortening of the rafter, will make the length and angles all fit as calculated.

Marking and Cutting a Common Rafter Pattern

When you've calculated the true length of the common rafters, you can mark and cut a pattern rafter, complete with the birdsmouth. Then you can use it to mark and cut the rest of the common rafters. I recommend that you cut two rafters and test them on the roof before cutting the entire group. If necessary, refer to the steps found in

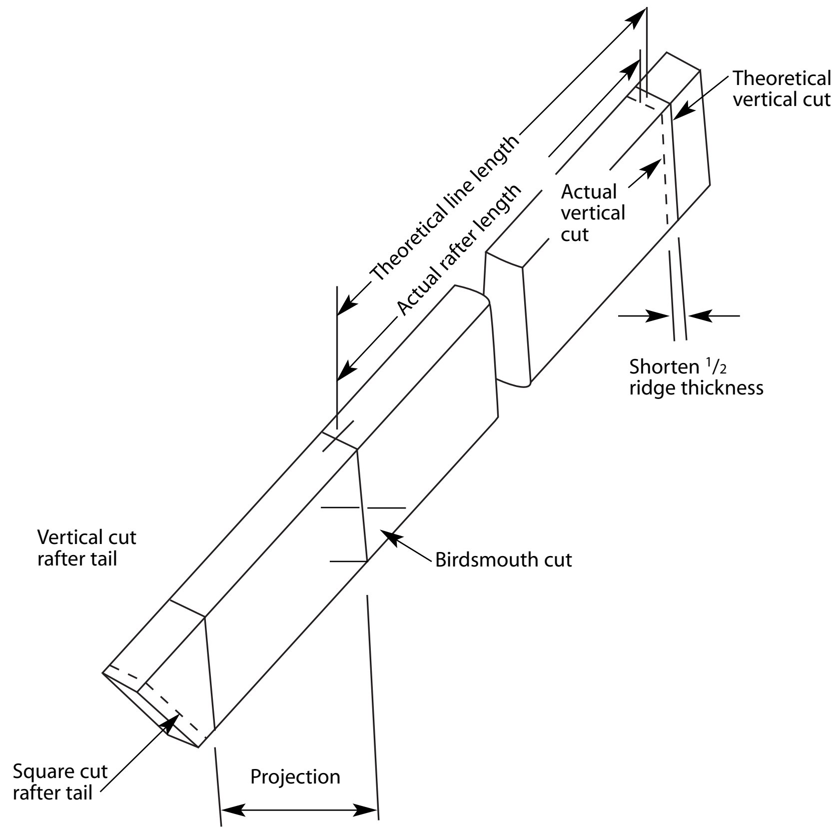


Figure 12
Ridge reduction on common rafter

Erecting a Gable Roof on page 542 for information on finding the ridge height and testing the rafters.

Here's how to make your pattern rafter:

1. Sight the rafter stock to find the crown. When lumber curves, the side with the hump is the crown. Rafters should always be marked and cut "crown up."
2. Transfer the true rafter length measurement to the rafter stock, from the bottom of the heel cut to the bottom of the ridge cut.
3. Refer to the steps given for marking and cutting a birdsmouth.
4. Mark the ridge cut using the framing square with the body of the square set at 12, the unit run. Set the tongue of the square at the unit rise. For a 4/12 roof pitch, the tongue should be set at 4 inches. Be sure that both the body and the tongue measurements are taken from the outside markings on the square or that both are taken from the inside markings. Never combine an outside and inside marking or the angle won't be true.

5. Cut out the first common rafter. You can then use this rafter as your pattern.
6. After testing the pattern rafter, use it to mark the remaining rafters, "crown up."
7. Cut the rafters using a circular saw. You'll need a hand saw to cut the corner out of the birdsmouth left by the circular saw.

Gang Cutting

Gang cutting with a large circular saw is possible if the rafters aren't too large. To gang cut, stack the rafter stock on sawhorses, clamping them together with bar clamps to prevent them from moving during the cuts. Use the pattern to mark the rafter at each end of the stack. Snap a line over the intermediate rafters. Using the large circular saw set at the angle required for the ridge cut, saw along the line. You can also make the tail cut as well as the heel cut of the birdsmouth in this manner.

Hip and Valley Rafters

Hip roofs have a level ridge like the ridge on a gable roof. But because the hip roof on a rectangular structure is four-sided instead of two-sided, there are also four sloping ridges. These ridges run diagonally from the corners of the structure to the ends of the level ridge. The framing that creates this sloping ridge is the hip rafter. The rafters that span from the hip rafter to the wall plate are called hip jacks.

Valley framing is basically inverted hip framing. The backbone of the valley is the valley rafter, which runs from the inside corner where the exterior walls meet to the ridge. Valley rafter jacks finish off the valley framing by running from the valley rafter to the ridges.

You use the same methods to find the lengths of hip and valley rafters and hip and valley jacks. Because of this similarity, we'll cover both in this section.

Hip and valley rafter layout and cuts are the same as those on common rafters — the ridge, birdsmouth and tail. Although the same layout and cuts are made, they are made differently. Because the hip and valley rafters run diagonally, their slope is different from the slope of the common rafters running perpendicular to the walls and ridge. You've got to account for this change when laying out and cutting ridge rafters.

Hip and Valley Pitch

The pitch of a common rafter is always indicated by the relationship between the unit run of 12, a constant, and the rise, which is a variable. To compensate for the change in slope because of the diagonal placement, you use 17 as the run constant for hip and valley rafters.

The rise is the same variable as that for the common rafters. So anytime you lay out a 4/12 common rafter, you'll lay out a 4/17 hip rafter.

Hip and Valley Rafter Length

Because hip and valley rafters run diagonally, they'll have a longer length than the common rafters. The length is found using the same steps as those for common rafters, but with figures that compensate for the change in pitch.

In finding hip and valley rafter lengths, there are also theoretical and true lengths. The theoretical lengths are based on the centerlines of the ridge and hip and valley rafters. The true lengths are the actual cut lengths.

Stepping Off Hip and Valley Rafter Lengths — You can step off hip and valley rafter lengths almost like you step off common rafters. There's one difference: you'll use a constant unit run of 17 instead of 12. Remember that a common rafter on a 4/12 pitch is stepped off 12 times for a 12-foot run, with the square set at 12 for the unit run and 4 for the unit rise. The hip and valley rafters are also stepped off 12 times, but with the square set at 17 for the unit run and 4 for the unit rise.

Steel Square Rafter Tables — Rafter tables are stamped on the body of most quality steel framing squares. The second line of this table is marked *Length Hip or Valley Per Foot Run* (refer back to Figure 10). On this line, you'll see numbers below the inch marks from 2 to 18 inches. The inch marks represent the unit rise. To use this table for a 4/12 roof pitch, look beneath the 4-inch mark. You'll find the number 17 23. This number represents 17.23 inches. To find the length of a hip or valley rafter for a 4/12 roof with a 12 foot run, multiply 17.23 times 12. The theoretical rafter length is 206.76 inches, or 17 feet 5$^{1}/_{4}$ inches.

Rafter Length Books — You can also find the hip and valley rafter lengths using the *Roof Framer's Bible*. To find the hip rafter length for our 4/12 roof, look again at the 4/12 - 18° page (Figure 11). Follow the Run Feet column down to the common rafter length we're using; 12 feet. Now look across to the H / V Rafter Length (Hip and Valley) column and you'll find 209$^{1}/_{4}$, or 17 feet 5$^{1}/_{4}$ inches.

Finding True Hip and Valley Rafter Lengths

Remember that all of these methods help you find the theoretical rafter length. Now you've got to adjust it for the thickness of the framing material. The ridge, common rafters or other framing members will prevent the end of the hip or valley rafter from reaching the theoretical end of the ridge, called the framing point. The framing point is where the centerline of the ridge meets the centerlines of the hip rafters. The theoretical lengths are figures to this point. But before you begin laying out and cutting, you need to find the true lengths of the hip and valley rafters.

To find the true length, deduct from the overall length any framing members that prevent the hip or valley rafter from reaching the framing point. The process of finding the true length by deducting from the theoretical length is called rafter reduction or shortening.

The Ridge Cut for the Hip and Valley Rafter

The angle of the hip and valley rafter ridge cut is simply a plumb cut using the rise along with the 17 unit run. Because the hip rafter must fit diagonally between two common rafters, you make 45-degree cuts, called double cheek cuts. Valley rafters go between two ridges and also need double cheek cuts. To determine the amount of shortening required to obtain a true length, as well as marking and cutting procedures, follow these steps along with the accompanying illustrations.

1. Figure 13 illustrates how the hip rafter intersects with the ridge and the common rafters. It also shows the intersection of a valley rafter with the two ridges. You can easily locate the framing points for the hip and valley rafters on this drawing.

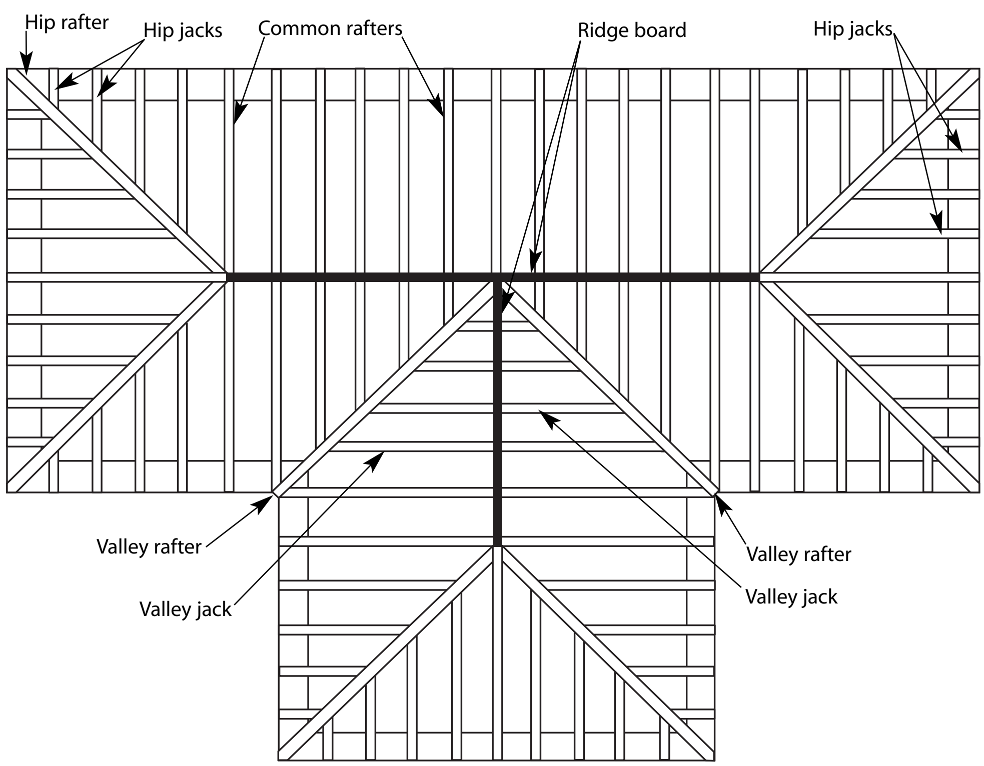


Figure 13
Plan of intersecting roof

2. Shorten the theoretical rafter length by the diagonal distance from the corner of the ridge to the framing point to find the true length.
3. Mark the true length at the center of the rafter as indicated in the illustration in Figure 14.
4. Indicate the cheek cuts on the rafter by marking 45 degrees back on both sides of the center mark starting at the mark from step 3.
5. With the framing square set at the roof unit rise and using the hip and valley unit run of 17, mark the plumb cut on either side of the rafter off of these marks.
6. Set a circular saw at 45 degrees and cut along these lines.

Marking and Cutting the Birdsmouth for Hip and Valley Rafters — Use the same procedure to mark and cut the birdsmouth on a hip rafter as you would on a common rafter. A level cut (seat cut) and a plumb cut (heel cut) are the two cuts that form the birdsmouth.

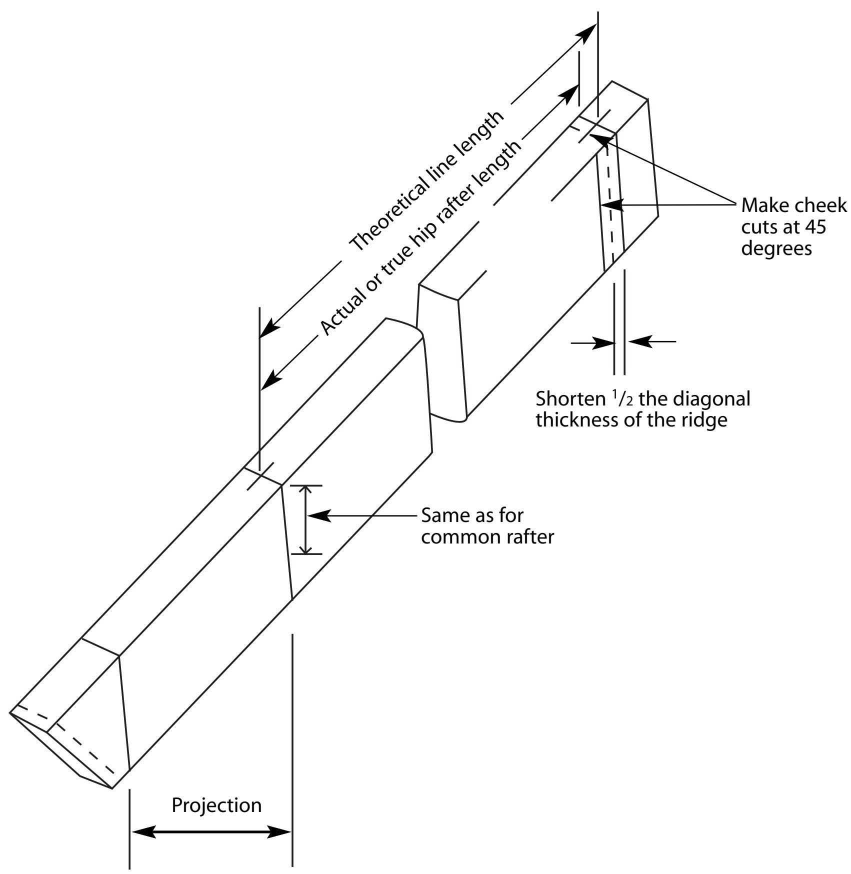


Figure 14
Shortening a hip or valley rafter

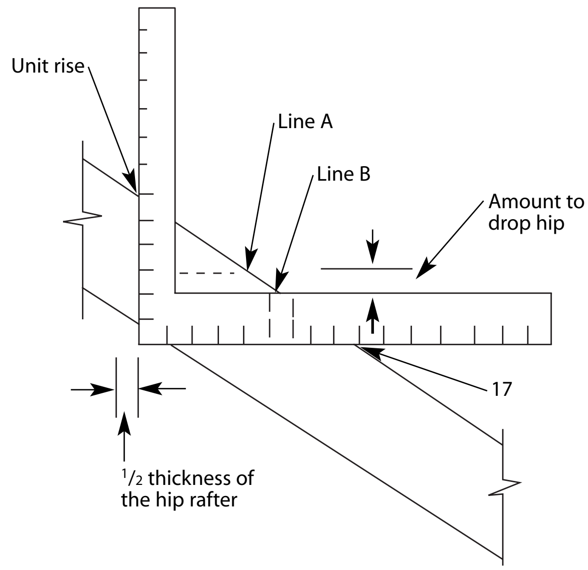


Figure 15
Finding the drop for a hip

Because you place the hip and valley rafters diagonally, remember that you use a different slope than with common rafters: 17 is the constant unit run instead of 12. The rise is the same variable used for the commons. If the pitch of the common rafters is a 4 in 12, the birdsmouth cuts for hip and valley rafters should be made at 4 in 17. Again, make sure the birdsmouth isn't deeper than one-third the depth of the rafter.

Valley rafters are cut the same as common rafters with the exception of using the unit run of 17 instead of 12. For hip rafters, however, there's an additional problem to consider. If you cut the same depth birdsmouth in the hip rafter as in the common rafters, the centerline of the hip rafter will be at the same height as the top of the common rafters. That means the shoulder will be high. There are two ways to lower the shoulders. The most common method is to drop the hip. Or you can chamfer the top edges of the rafter, which is called a backing chamfer.

Dropping the Hip Rafter — This method lowers the hip so that the shoulders rather than the centerline are in line with the tops of the common rafters. You cut a deeper birdsmouth to drop the rafter:

1. Place a framing square on the rafter with the body on 17 for the run. Place the tongue on the rise being used for the roof as shown in Figure 15.

2. Mark the plumb line on the tongue and the level line on the body.

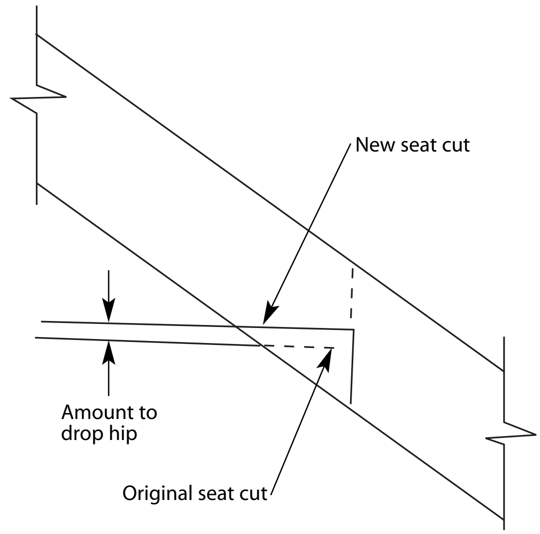


Figure 16
Dropping the hip

3. Move the square down the rafter so that the tongue is $^1/_2$ the thickness of the hip from the first plumb mark you made. For a $1^1/_2$-inch rafter, you'll move it $^3/_4$ inch from line A.
4. Mark a new level line (line B) with the square still placed in the position given in step 3.
5. When measured plumb, the distance between the two level marks is the amount of backing chamfer or hip drop required.
6. To drop a hip, add this amount to the depth of the seat cut of the birdsmouth (Figure 16). When the birdsmouth is deepened to drop the hip, you don't chamfer the shoulders.

***Backing Chamfer on a Hip Rafter* —** Backing the chamfer is an accurate way to bring the shoulders of the hip rafter in line with the common rafters, but it's seldom used because it's time-consuming. Follow the steps above to find the amount of chamfering you need. Then cut that amount from the outside edge, tapering to the centerline.

Hip and Valley Jacks

When you've set the common rafters and the hip or valley rafters, there's still an area that's not finished. The rafters used to finish the areas that run from the wall plate to the hip rafter are called hip jacks. Those that run from the valley rafter to the ridge are called valley jacks.

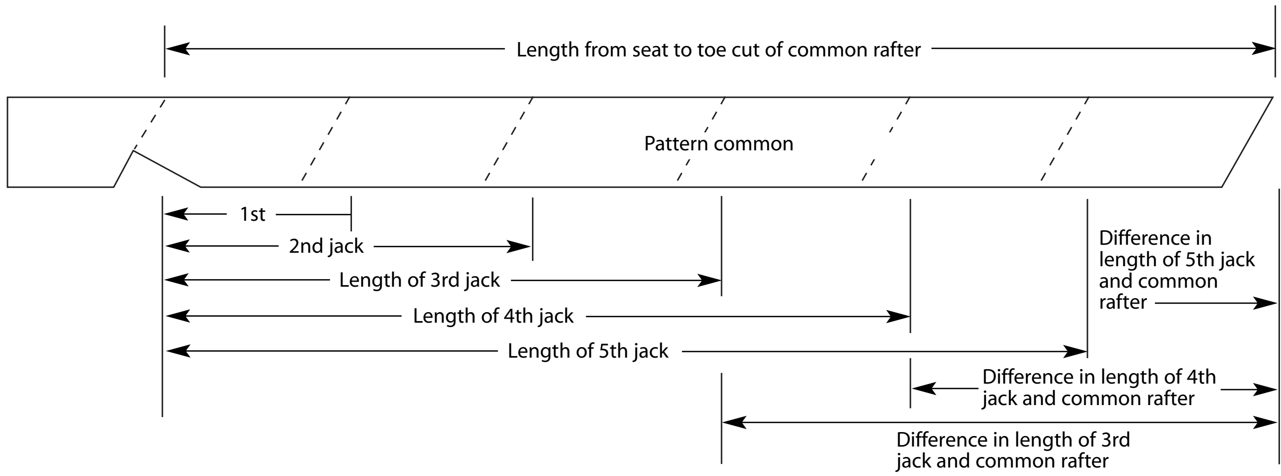


Figure 17
Hip jack layout

Hip jacks have just about the same basic cuts as common rafters. The birdsmouth and tail cuts are the same, but the ridge cut is different. Because the hip rafter serves as the ridge and runs diagonally, the ridge cut is a 45-degree cut called a cheek cut. Hip jacks are placed in pairs so that they meet at the hip rafter. Each pair is cut to the same length, but with cheek cuts on the opposite sides.

Valley jacks have a ridge cut that's the same as the commons for placement at the ridge. A cheek cut is used for placement at the valley rafter.

Finding Hip Jack Lengths

To find a hip jack length, calculate the theoretical length and shorten it to compensate for the hip rafter thickness to determine the actual length. Once again, you can use the tables on the steel square or from a rafter framing manual. The length given on the rafter table or in the rafter length manuals is known as the common difference. The common difference is the length that each jack is different from the jack on either side of it.

The common difference is different for every roof pitch and every rafter spacing. You've got to know the exact pitch and spacing. After you've found the length of the first jack, you can cut the remaining jacks using only the common difference, as seen in Figure 17.

Factor Chart				
Common Rafter Run	X	1.054	=	Common Rafter Length
Common Rafter Run	X	0.333	=	Rise
Common Rafter Run	X	1.453	=	H/V Rafter Length

First Jack Deduction	- 16″ O.C. (LP)	16 3/8″
Jack Difference	- 16″ O.C.	16.87″ or 16 7/8″
First Jack Deduction	- 24″ O.C. (LP)	24 7/8″
Jack Difference	- 24″ O.C.	25.30″ or 25 1/4″
Jack Rafter Length per inch of layout	1.05″	
Pitch of the Hip Rafter	4/17	
Hip Drop (for 2x rafter)	1/8″	
Hip Backing Bevel	14°	

Figure 18
Factor chart from Roof Framer's Bible

Finding Jack Rafter Lengths

You can use a steel square or a rafter length manual to find jack rafter lengths.

Using a Steel Square — Follow these steps to use a steel square to find the jack rafter lengths for a 4/12 roof with 24-inch rafter spacing:

1. On the fourth row of the table is the line marked *Diff In Length Of Jacks 2 Feet Centers* (refer back to Figure 10).
2. Locate the inch mark above the table representing the unit rise. For a 4/12 pitch roof this is the 4-inch mark. On row 4 below the 4-inch mark you'll find 25 5/16. This is the length of the first hip jack, and the amount to add to each jack as you step up the hip rafter. So the first hip jack is 25 5/16 inches, the second is 50 5/8 inches, and so on. Remember, these are theoretical lengths. Now you have to reduce them to true lengths.

Using a Rafter Length Book — We'll continue to use our example of a 4/12 roof with rafters spaced at 24 inches on center using *Roof Framer's Bible* to find jack rafter lengths.

Look at the factor chart from Roof Framer's Bible in Figure 18. Go down to the Jack Difference for 24" O.C. The factor is 25.30" or 25-1/4 inches. In this rafter table book, the calculations are rounded to the nearest 1/8 inch, which is why you may find a 1/16 inch discrepancy. If you're really good with a saw and think it'll make a difference, use your calculator and you'll find that 25.30 is really 25 5/16. Remember again, these are theoretical lengths.

Converting Theoretical Jack Lengths to True Lengths — To find the true hip and valley jack lengths, shorten the theoretical lengths by the diagonal distance to the framing point. Then you can find the second jack, and subsequent jack lengths, by simply adding the common difference (25 5/16 inches in the sample we've been using) to the true length of the first jack. If you add the common difference to the true, or adjusted length, the result will be a true length. Add it to a theoretical length and the result will be theoretical. You'd still have to adjust it.

Once you have the common difference, you can start with the longest jack rafter and subtract, or start with the shortest one and add the difference.

Marking and Cutting Jack Rafters

You mark and cut jack rafters in much the same manner as commons, except for the 45-degree cheek cut. Mark the tail cut and birdsmouth with a pattern from the common rafters. The actual cutting of the tail and birdsmouth are straightforward cuts made exactly the same as for the commons.

Figure 19 illustrates shortening hip jack rafters. Note that there's a short point on the rafter, centerline point and long point. It's the centerline that the theoretical lengths are based on and that the true lengths are derived from. You can do the actual marking and cutting from either the short or long point. The illustration shows the intersection of the hip rafter and hip jack. The centerlines represent the theoretical lengths.

Shorten valley jacks for both the ridge cut and cheek cut. Subtract the reductions for both the ridge cut and the cheek cut to obtain the true length at the centerline.

Marking and Cutting the First Jack Rafter — To mark the cheek cut on the first jack rafter, follow these steps:

1. Mark the heel cut of the birdsmouth the full depth of the rafter so that it extends to the top side.
2. Mark the true rafter length, measuring on the top of the rafter from the heel cut plumb mark. This measurement represents the centerline length.
3. Square the true length across the center of the jack rafter stock.
4. Mark the center of the top of the jack rafter stock.
5. Mark a 45-degree line through the center mark. This will give the short point, center point and long point on the top of the stock.
6. Use a framing square or pattern to mark a plumb cut down the width of the rafter off either the short or long point. Mark the side that is easiest to cut with the circular saw you'll be using.

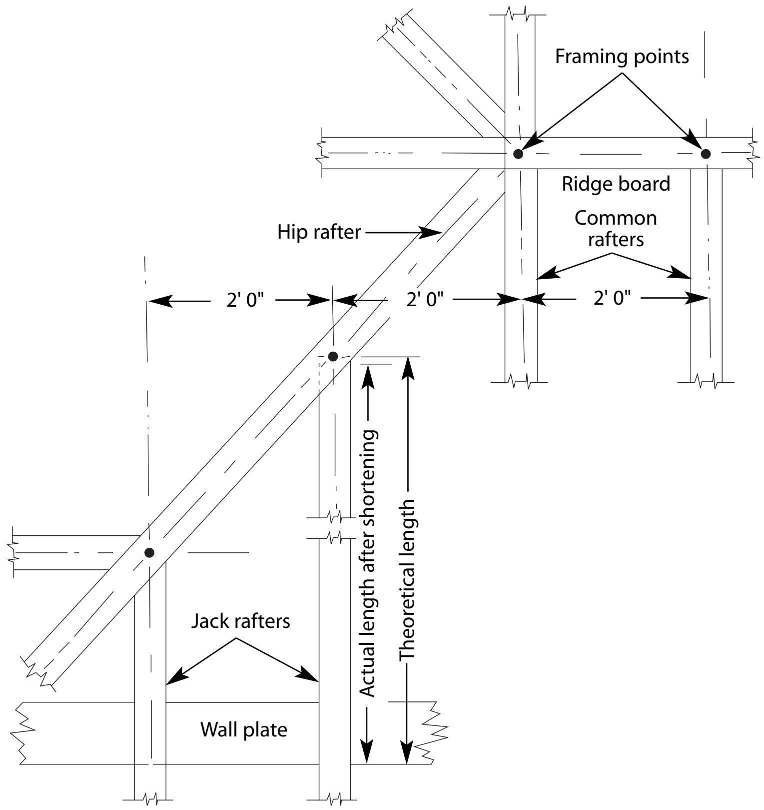


Figure 19
Shortening jack rafters

Second and Subsequent Jacks — After you've measured and cut the first jack rafter, measure the second and subsequent jacks as follows:

1. Decide whether you prefer cutting from the long point or short point.
2. For the short point measurement, mark a square line across the top of the first jack from the short point of the 45-degree angle. Measure the distance from the centerline true length to the short point. Deduct this length from the true length for the short point length. Add this length to the true length to determine the long point length.
3. Now you can find the lengths for the short point or long point for second and remaining jacks without any further adjustments. Add the common difference found on the square table or manual to these lengths to step up. Subtract the common difference to step down. Then simply use a square or pattern to mark the plumb cut. With a circular saw set at 45 degrees, cut the cheek along the line you marked.

An Alternative Method for Marking and Cutting Jacks

Using rafter tables or manuals to find the jack lengths is the method I recommend. But there's another way you should know about. Some roof framers prefer to take direct measurements of the jack lengths, following these steps:

1. The layout for the rafter at the wall plate for hips, and ridge for valleys, will continue in the same layout pattern as the common rafters already placed.
2. Pull a measurement off of a straight common rafter already in place to locate the layout for the hip or valley rafter.
3. Find the hip jack length by measuring from the outside of the wall plate on the common rafter side of the layout to the point you marked on the hip rafter in step 2. Find the valley jack length by measuring from the layout on the ridge to the point marked on the valley rafter.
4. For a hip rafter, measure from the intersection of the heel and seat cuts of the birdsmouth to the top edge of the rafter stock to mark the top point of the cheek cut. This is a true measurement with no shortening or adjustments necessary.
5. For a valley rafter, measure from the mark made on the valley rafter in step 2 to the top of the ridge. If you made the mark with the tape hooked over the common rafter, this measurement will be to the long point of the top of the jack.
6. Mark the plumb cuts with a framing square.
7. For cheek cuts, cut along the plumb cut with the saw set at 45 degrees.
8. Install the jack rafter.

Cutting Rafters in Pairs

When you cut longer common rafters, you'll probably only be able to cut one rafter from each piece of framing lumber. However, you can cut short commons and rafter jacks in pairs. By cutting in pairs, you can make two ridge cuts at a time. But you still have to crown the rafters before you pair them for cutting.

Common rafters: If the tail cut of a common rafter is a plumb cut like the ridge, you can cut multiple rafters off of the same stock with the crown always on the same side. Use the pattern rafter to lay out the rafters. Either cut one at a time before marking again, or leave the thickness of the saw kerf between layouts. Most saw blades remove a $^1/_8$-inch kerf.

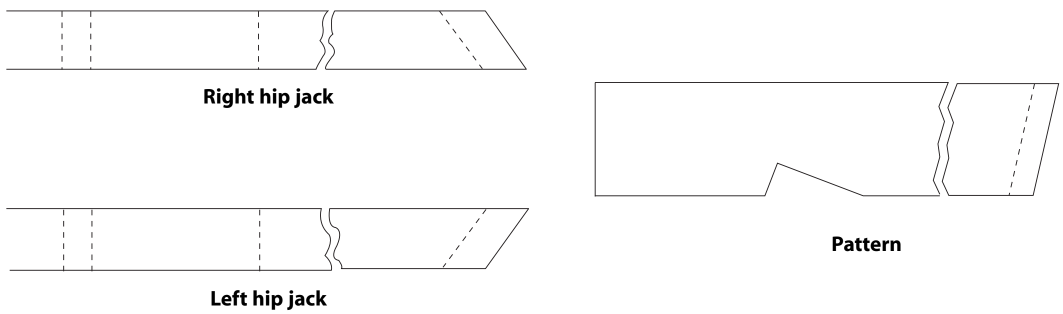


Figure 20
Cutting pairs

Hip jacks: You can use a pattern for the birdsmouth and tail cut of a hip jack. As hip jacks are installed in pairs, the lengths will be the same for the pairs. The angles for the cheek cuts, however, are opposite. Figure 20 shows how to cut multiple hip jacks from the same rafter stock. Cutting the pairs together works well. To do this, mark and cut the first hip rafter using the steps found earlier in this section. Then flip the rafter stock, match the first hip jack to the stock and mark the birdsmouth and tail cut. The tail cut will then be the starting point for the next pair.

Valley jacks: Like hip jacks, valley jacks can be cut in pairs. When you make a cheek cut, the cut left on the rafter stock will be the cheek cut for the other valley jack in the pair. Since you install hip and valley jacks in pairs, cutting them in pairs is a logical sequence that creates less waste.

Rafter Framing Layout

The first step in framing rafters is the layout. Your plans will most likely call out spacing that's 24 inches on center, though some are 16 inches. For a flat roof or sloping roof where the rafters also serve as the ceiling joists, you only need a rafter layout. For all other roofs, you'll need both a ceiling joist and rafter layout.

Complete the layout by placing the ceiling joists at the specified spacing, preferably next to the rafters. In most cases, the ceiling joist spacing is acceptable at 24 inches on center. If the spacing is the same as the rafters, make certain the joists and rafters are side by side. If the joist spacing is different than the rafters, such as rafters on 24-inch centers and ceiling joists on 16-inch centers (or vice versa), make a layout to place a rafter and joist together at least every 4 feet.

There are only two basic layouts needed for all of the roof types we discussed. Full perimeter layouts cover hips, mansards, and flat roofs with overhangs. Only two sides need a layout for gable, gambrel, shed and flat roofs without an overhang.

Gable Roofs

Gable roofs are made up entirely of common rafters. If there's an overhang, a barge rafter is supported by lookouts. You can fill the gable end with gable studs built off of the double plate or a rake wall that follows the slope of the roof.

With a two-sided layout, the rafters are flush with the outside walls at both ends. Lay out the remainder of the rafters on the specified centers, starting from the same end on each side.

The ridge board should be the same length as the side bearing walls plus the length of the overhang at each end. Lay out the rafter positions on the ridge board to match the layout marked on the top plates of the bearing walls. When starting the layout, leave adequate material for the overhang projection. Trim the projection to length.

Hip Roofs

Hip roofs require a layout for all four sides of the roof. The hip roof is made up of common rafters, hip rafters and hip jack rafters. The common rafters run from the wall plates to the ridge. The length of the ridge is the length of the building minus the length of the run for each end that's hipped. See Figure 21.

The rafter spacing is equal for the distance from the single common rafter on the end to the corner, and from the first common rafter on the length to the corner. This will always be true if the roof slope is the same on both sides. The diagonal line running from the end of the ridge to the corner of the building represents the hip rafter. Hip jacks run from the wall plate to the hip rafter. All of the rafters outside of the corners will be full length commons.

Laying Out the Hip Roof

1. Start the layout for a hip roof with the end of the roof. First, measure the width of the end and find its center. Then measure $^3/_4$ inch on either side of the center to mark the location for a 2-by rafter. The rafter coming off of the ridge (the only common rafter on the end) will end within these marks.
2. Use the same center measurement from step 1 to mark the location of the first common rafter on the length of the building perpendicular to the ridge.
3. Repeat steps 1 and 2 at the opposite end of the building using the same measurements.

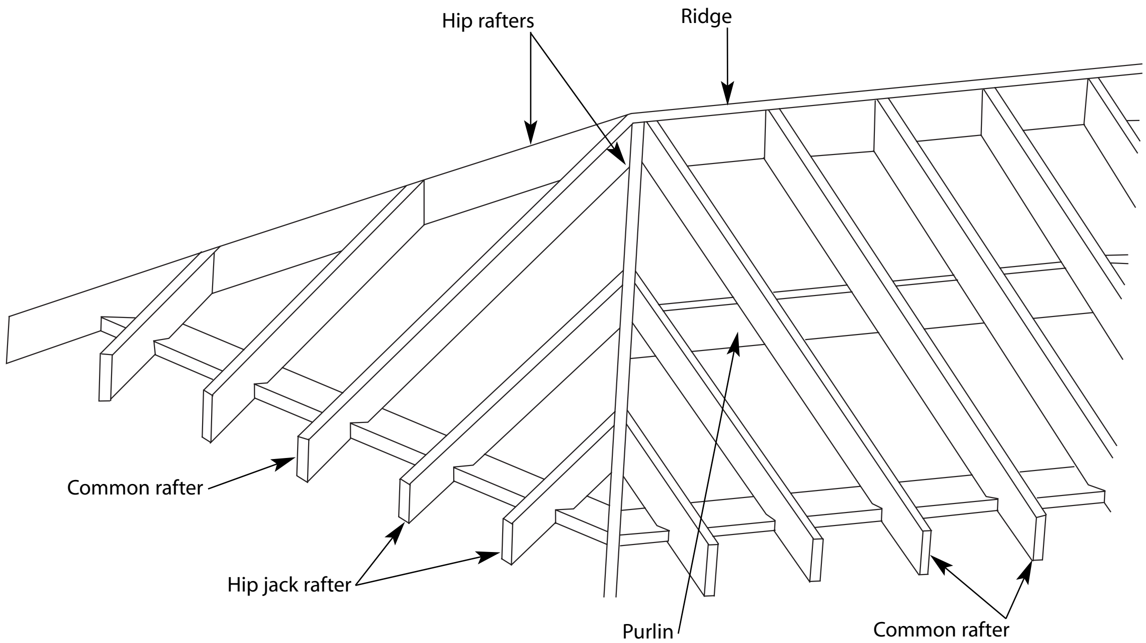


Figure 21
Hip roof framing

4. To find the ridge length, measure to the outside of each of the common rafters you've marked at each end of the roof. To make the end common rafters the same length as the other commons, add $^3/_4$ inch to each end of the ridge (if you're using a 2-by ridge). Remember, you'll have to shorten the other commons by $^3/_4$ inch to allow for half of the ridge thickness. Add $^3/_8$ inch to each end if you're using a $^3/_4$-inch ridge board.
5. Now that you've marked three common rafter positions at each end, you can lay the ends out. Lay out the hip rafters by measuring 24 inches on center off of the three commons that you've defined. This will lay out so that all of the hip jacks will be in pairs with points hitting together on the hip rafter.
6. Lay out the remaining common rafters starting with the two commons that you've set at the one end of the building. On even-numbered runs, the spacing might work out. In most situations, however, module spacing will be broken when meeting common rafters at the opposite end of the run.
7. Lay out the ridge board to match the common runs on the length of the building. If the last space is off, be sure that this is reflected on the ridge board as well.

Erecting the Rafters

Before you start erecting any rafters, make sure the exterior walls are straight. If there's a hump or a dip in the double top plate, it will throw off the rafter tails and create more work later with the fascia. This is also the last chance to check the exterior walls to make sure they don't bow in or out.

Check the plate by stretching a string along the inside — or if the sheathing doesn't interfere, the outside plate. Place the string on nails angled into the top corner so you can check the plate for humps and bows at the same time. If there are any humps, chisel out a notch for the rafter or truss on the layout mark. If there's a dip, mark it and be prepared to use a metal shim when you install the roof. Add braces as required to straighten out any bowed walls.

Determining the Ridge Height

To understand how to find the ridge height, look at Figure 22. The lines representing the roof's theoretical lengths and heights pass from the top outside corner of the top plate to the point dictated by the pitch. To find the theoretical height of the ridge, multiply the number of units of run times the rise. Then add the height above the plate at the top of the outside corner of the top plate to the theoretical peak height to find the true height. Let's run through an example to see how this works.

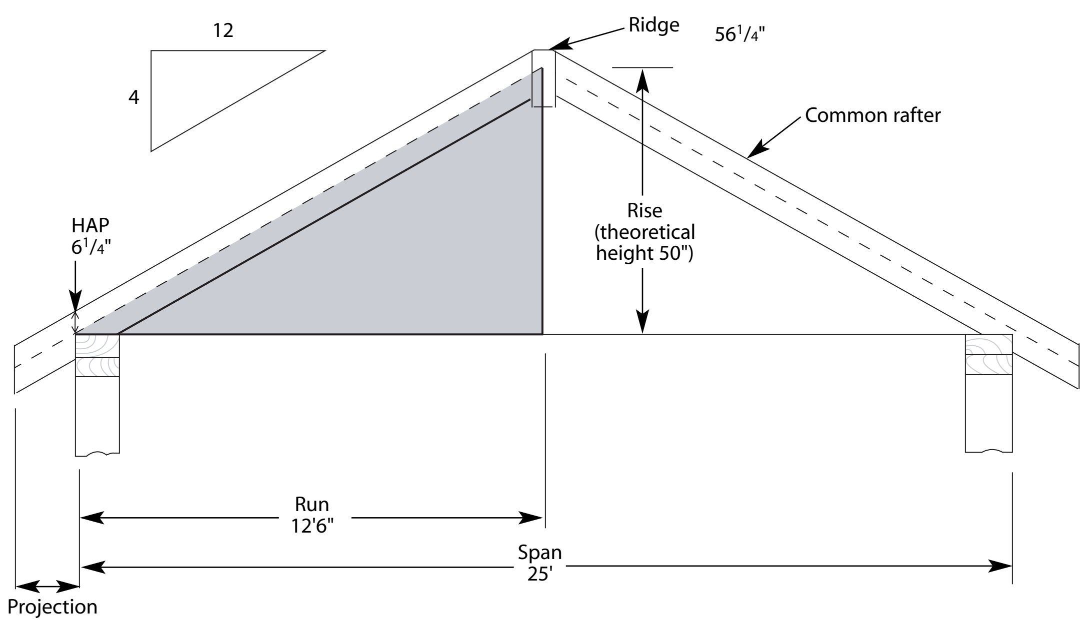


Figure 22
Finding true ridge height

Example: Finding True Ridge Height

We'll find the true ridge height of a roof with a 4 in 12 pitch (4/12) and a 25-foot span, making the run 12 feet 6 inches.

1. Find the number of unit runs in the overall run. Because the unit run is always 12 inches, there are $12\frac{1}{2}$ unit runs in a 12 foot 6 inch run.
2. Multiply 12.5 times the unit rise of 4 inches to arrive at the theoretical height of 50 inches.
3. Measure the height above the plate. That's the plumb line of the heel cut of the birdsmouth from the seat cut to the top edge of the rafter. For example, this might be $6\frac{1}{4}$ inches. This would then be the height above the plate.
4. Add the height above the plate to the theoretical ridge height to obtain the true ridge height. In this case, adding $6\frac{1}{4}$ inches to 50 inches results in a true ridge height of $56\frac{1}{4}$ inches above the top plate.

Erecting a Gable Roof

A rafter-framed gable roof is built entirely with common rafters and a ridge. If you're not experienced in roof cutting, take the time to cut one pair and try the fit in place before cutting the rest of the common rafters. To test the fit, use a block to represent the ridge between the two rafters. Then follow these steps to erect the roof:

1. Mark a board with the true ridge height and position at each end of the roof. Nail it to the outside wall in a position where it will be next to the ridge when the ridge is in place. This serves both as a height gauge and as a brace when you erect the first rafter and ridge.
2. Select four rafters, two for each end of the ridge board. Place them in their approximate positions.
3. Nail two of the rafters onto the ridge board, one at each end on the same side. Face nail through the ridge board into the ends of the rafters with three or four 16d nails, depending on the size of the rafters.
4. Raise the ridge to the height marked on the gauge board. Temporarily fasten it in position to the gauge/brace. Nail to the wall plate with three 16d nails toenailed through the seat of the birdsmouth.
5. Position and attach the two end rafters for the opposite side by face nailing them at the ridge and toenailing them at the wall plate as well.

6. Plumb the ridge with a level or a level placed on a straightedge for extra length. Brace the ridge by running supports from the top point of the two ends back to the floor. Use braces that are long enough so that they're at no greater than a 45-degree angle (a 12/12 pitch or less). Use additional braces if you feel you need more stability for the number of rafters being placed.
7. Raise and position the remaining rafters, placing them in pairs. That will help keep the ridge board straight during assembly.
8. Place permanent bracing as dictated by the engineering and governing codes.

Placing the Gable Studs

After you've framed the gable roof, it's time to frame the gable ends if there's no rake wall. Gable studs run from the top of the wall plate to the rafter. Here's how to place the gable studs:

1. Lay out the top wall plate so the gable studs will be in line with the full-length studs below the wall plate. This makes installation of the wall sheathing and siding easier.
2. Plumb from the layout to the rafter to locate the stud placement on the rafter. Mark the short or the long side, depending on the side you prefer measuring and cutting from.
3. Hold the stud material in the layout position. Mark under the rafter on the edge of the stud.
4. Cut the overall length so the stud won't extend above the rafter. Set the saw at a depth the same as the thickness of the rafter.
5. Mark and cut the gable stud angle.
6. Place the stud in position. Attach it by toenailing the base to the wall plate with four 8d nails. Attach it to the rafter by face nailing with 16d nails through the rafter into the gable stud.

Erecting a Hip Roof

Hip roofs are framed using a combination of ridge board, common rafters, hip rafters and hip rafter jacks. Again, I recommend cutting one pair and checking their fit before you cut the entire group. While you can find the true lengths of hip and jack rafters "on paper," don't cut them until you've placed the common rafters.

For a square hip roof, have at least the ridge board and six common rafters ready before you begin. Erection of a hip roof involves four phases. The first phase is erecting the ridge board and the common rafters. The second phase is installing the hip rafters. The third stage is installing the hip jacks, and the fourth is permanent bracing.

Erecting the Ridge Board and Common Rafters

1. Mark a board with the true ridge height and position at each end of the ridge board. Nail to the roof joist or deck. This is your height gauge and brace for erecting the first rafter and ridge.
2. Select six common rafters, two for each side of the ridge board and one for each end. Place them in their approximate positions.
3. With the ridge board down, nail two of the rafters onto the ridge board, one at each end on the same side. Face nail through the ridge board into the ends of the rafters with three or four 16d nails, depending on the size of the rafters.
4. Raise the ridge to the height marked on the gauge board. Temporarily fasten in position to the brace. Nail to the wall plate with three 16d nails toenailed through the seat of the birdsmouth.
5. Position and attach the two end rafters for the opposite side by face nailing at the ridge and toenailing at the wall plate.
6. Plumb the ridge with a level or a level placed on a straightedge for extra length. Brace the ridge by running braces from the top point of the two ends back to the floor. Use braces that are long enough so that they are at no greater than a 45-degree angle (a 12/12 pitch or less). Use additional braces if you need more stability. The two end common rafters will provide further bracing when they're extended from the ends of the ridge board to the end wall plates.
7. Place the two end common rafters and attach to the ends of the ridge and the top wall plate. Toenail the ridge attachment through the two common rafters placed in the earlier steps. Toenail to the wall plate in the same manner as the other commons.
8. Raise and position the remaining common rafters, placing them in pairs with one rafter on each side of the ridge.

Installing the Hip Rafters

1. Place the hip rafter at the ridge diagonally between the two common rafters.
2. Attach by nailing at the ridge with three or four 16d nails depending on the rafter size. If the hip is dropped instead of chamfered, place it at the ridge so the shoulders meet the edges of the commons on either side.
3. Toenail the hip rafter to the plate with three 16d nails.

Installing Hip Rafter Jacks

1. Lay out jacks on the hip rafter.
2. Alternate from side to side as you place the jacks. Placing the hip jacks in pairs prevents the hip rafter from bowing due to uneven pressure on one side or the other.
3. Attach the jacks to the hip rafter with three or four 16d nails depending on the size of the jacks.
4. Attach the jacks to the wall plate using three 16d nails toenailed through the seat cut of the birdsmouth.

Finishing Off the Hip Roof Framing

Because of the way the rafters are positioned, hip roofs are naturally braced. But you may need more bracing. The final step is placing the final bracing and any hurricane ties or truss anchors required by the engineering and local codes.

Framing the Valley for an Intersecting Roof

When roof lines intersect, they form a valley. There are two ways to frame a valley. The standard method is simply called valley framing. It uses a valley rafter that supports the valley jacks. Standard valleys are most common when the intersecting ridge lines are at the same elevations, such as an L-shaped structure.

The second method of framing a valley is called framing a blind valley. A blind valley is built over a main gable roof. You can use it in new construction and when tying in an addition. A blind valley doesn't use a valley rafter, but instead places the valley jacks on the previously framed roof. Blind valleys are most frequently used for a T-shaped roof line, especially where the intersecting ridge is lower than the main roof. First the main roof is framed and sheathed. Then the intersecting roof is framed over the first.

Framing a Valley

A standard valley is framed with a valley rafter and valley jacks, following these steps:

1. Place the top of the valley rafter at the intersection of the two ridges.
2. Nail it in place at the peak with four 16d nails face nailed through the ridges into the valley rafter.

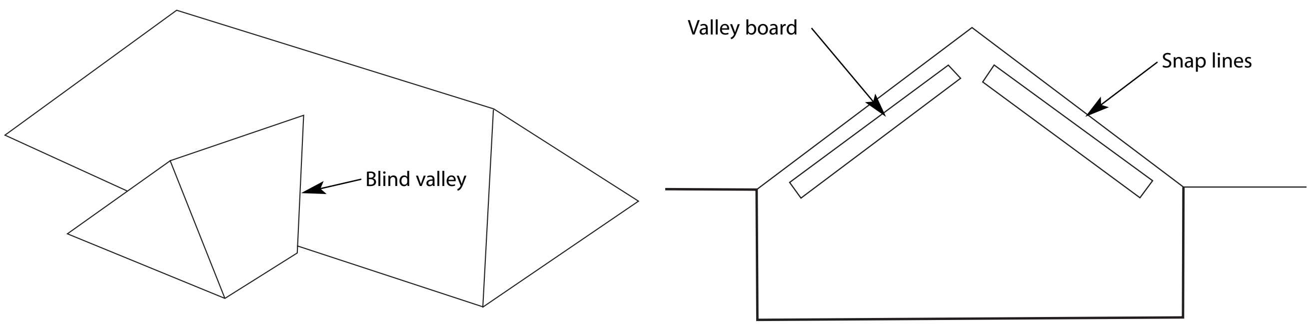


Figure 23
Valley boards add support for a blind valley

3. Attach to the wall plates with 16d nails toenailed through the seat of the birdsmouth.
4. Lay out the valley rafter.
5. Place and attach the valley jacks in pairs, alternating from side to side on the valley rafter. This will help the valley rafter remain straight.
6. Attach the valley jacks to the valley rafter with 16d nails nailed through the cheek cut into the valley rafter.
7. Attach the valley jacks to the ridge with 16d nails face nailed through the ridge into the jacks using a number of nails appropriate for the size of the jack.

Framing a Blind Valley

Because blind valley framing overlays an existing roof, there's no valley rafter. The bottom of the valley jacks bear on the previously-framed roof. This is true whether the main roof was framed that morning or twenty years earlier. In both cases, the roof sheathing will be on the main roof before the valley framing is tied in. It's good framing practice to give additional support for the roof framing by running 1-by valley boards over the roof sheathing up the valley line. Depending on the size of the valley jacks, use a 1 × 10 or a 1 × 12. Figure 23 shows a blind valley and the valley boards.

There are three stages in building a blind valley. The first stage is establishing the ridge line and setting the ridge. Second, establish the valley line and install the valley boards. The final stage is placing the valley jacks.

Establish the Ridge Elevation

The first step in building a valley is to establish the ridge line and install the ridge. An intersecting roof will have a ridge at the same elevation as the main roof if the pitch and span are the same. In new construction, frame a roof like this using standard valley framing with a valley rafter. If the intersecting roof is lower than the main roof, you've got to find the point where the ridge of the intersecting roof meets the slope of the main roof.

When you're using trusses, you can find the intersection point on the main roof by stretching a line over the peaks of the trusses. For rafter-framed roofs, you can use a ridge elevation gauge/support board to help in locating the ridge height. First set the elevation board, then stretch a line off of the mark indicating the height. Then use a line level on the line to find the ridge elevation on the slope.

Find the length of the ridge for a rafter-framed intersecting roof line by measuring from the ridge intersection point to the outside edge of the wall top plate. Most framers will run the ridge long and then trim it to length when they finish out the eaves.

Install the ridge with the common rafters:

1. Cut the intersecting ridge board for the slope of the main roof.
2. Prepare two common rafters for installation at the gable end.
3. Support the ridge temporarily with the elevation board.
4. Place backing under the roof sheathing to support the ridge. The backing should span between the rafters or trusses.
5. Nail the ridge point to the roof slope. Toenail through the sides of the ridge board through the sheathing and into the backer board.
6. With the ridge board supported by the main roof slope and the temporary elevation board, plumb up off of the wall plate to locate the end rafter.
7. Lay out the ridge to correspond with the wall plate using the end location found in step 6 as the reference point.
8. Install the remaining common rafters by toenailing through the seat cut of the birdsmouth into the wall plate and face nailing through the ridge board into the ridge end of the rafter.

Locate the Valley Line and Place the Valley Board

1. Snap a line on the main roof sheathing from the shoulder of the point of the intersecting ridge to a point where the line is touching the main roof sheathing and also brushing the top of the common rafters. When the line is touching both at the same time without distortion, you've located the valley line.

2. Place the valley board away from the valley line so that the top outside edge is in line with the theoretical roof slope. This outside edge will be the end point of the valley jacks. Find the distance from the valley board to the valley line by placing the top point of the valley board next to the ridge point. Slide the valley board down until the top outside edge of the valley board is even with the shoulder of the ridge board. When these edges are even, you've found the distance the valley board should be placed from the valley line.
3. Nail the valley board in place using 8d nails nailed through the sheathing and into the rafters.

Blind Valley Jacks

Because you don't use a valley rafter when framing a blind valley, you don't use a cheek cut. In its place, make a cut to fit the slope of the roof. Find the valley rafter lengths, mark and cut them using these steps for the first jack:

1. Make your layout for the jack rafters at the ridge the same as the layout of the common rafters, usually 24 inches on center.
2. Locate the layout on the valley board by pulling a measurement off of a straight common rafter already in place.
3. Find the jack length by measuring from the ridge layout to the point marked on the valley board in step 2.
4. Using this measurement, lay out the valley jack as shown in the illustration.
5. Mark the ridge cut plumb, using a framing square.
6. Cut the ridge cut along the plumb mark with a saw that's set square.
7. Mark the base cut with a level mark, again, using the framing square.
8. Cut the level cut with the saw set to match the roof pitch.

For the second and subsequent jacks, find the measurement by using the common difference found on the table on the framing square or in rafter length manuals. Or you can continue to pull the layout off of the last common as you did for the first jack.

Installing Valley Jacks in a Blind Valley

With the ridge and common rafters erected and the valley board in place, you can install the valley jacks. Find the lengths and cut the jacks as described in the steps for blind valley jacks. The layout of the ridge will continue on the same layout as the commons. Then:

1. Find the placement on the valley board by measuring from a straight common. Make certain that you make the measurement with the tape placed parallel with the ridge. Mark the layout by hooking the tape over the common to find the long point placement.
2. Place the top point of the jack against the ridge in the layout position. Face nail through the ridge into the jack with at least three 16d nails.
3. Place the bottom point of the jack on the layout mark on the valley board. Toenail the jack to the valley board.

Roof Trusses

Roof framing with trusses varies greatly around the country. In some areas a builder can still design and build trusses on the job using plywood gussets and nails. In other places only engineered and factory-built trusses are accepted. Then you need to present stamped engineering plans to get a building permit. The inspector will look for the machine-rated stamp on the top and bottom chords as well as the installation, connections and bracing. While this might sound constrictive if you're not used to it, the system can work quite well. And there's the added bonus of additional liability protection for the builder.

In most areas, the truss fabrication plant will be able to engineer and build almost any type of roof system, including all hips and valleys, completely from trusses. The only stick framing needed on the roof is for the bracing and eaves. In areas where there's only limited factory fabrication because trusses are site built, only common trusses may be available. In these cases, you'd combine the steps for setting common trusses and the steps for rafter framing hips and valleys.

The Components of a Truss

The primary components of a roof truss are the upper and lower (or top and bottom) chords that make up the perimeter members. The internal members are composed of a web of dimensional lumber configured to carry the designed load. (See Figure 24.)

The web members are held in place by gussets. Manufactured trusses use metal gussets, but plywood gussets are sometimes used on field-fabricated trusses. With either type of gusset, the truss engineering will specify the size and location of the gusset along with the type and number of fasteners required. In addition to fasteners, plywood gussets are glued, typically with either resorcinol or casein glue. Gussets are also called truss plates or truss clips.

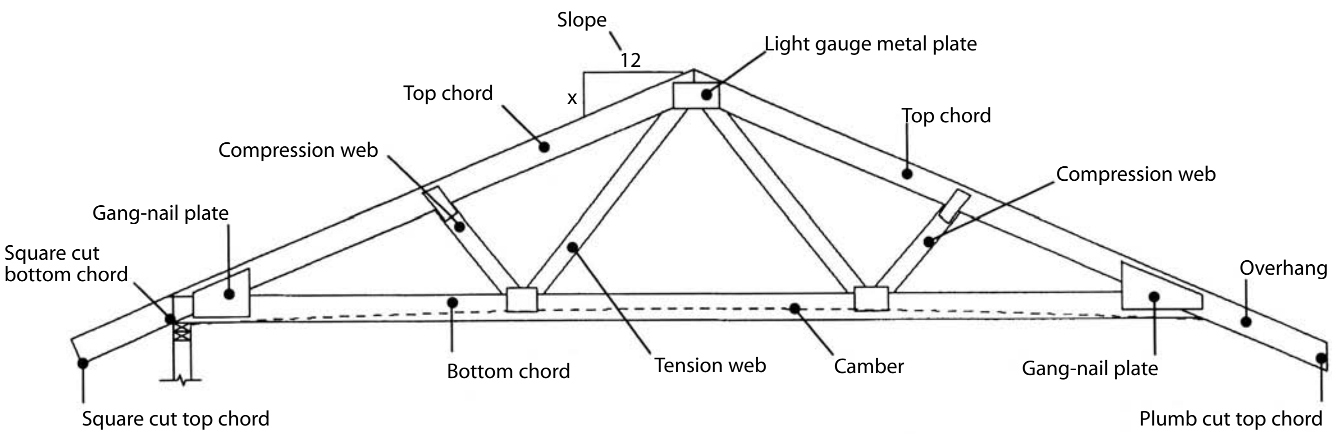


Figure 24
Roof truss

Trusses are designed in many different ways to fit the wide variety of roof designs in today's housing, as shown in Figure 25. The most common truss designs are:

- Simple kingpost
- Howe or kingpost
- Scissors
- Mono or half truss
- W or fink
- Hip
- Attic
- Flat

A garage or a basic rectangular house with a simple gable design uses the same trusses all the way through. But on most housing, the roof combines several different designs. A hip roof uses the largest variety of trusses and may include W or kingposts, hip and half trusses. If there are vaulted ceilings, you may also need scissors trusses.

You should be able to take your plans to local truss fabrication plants to have the truss work priced. But first you'll need to know the loading for your area. In mountainous areas you'll need to know the elevation of your project. The snow load in some areas is based on site elevation. In addition to the snow load, be sure to note any additional nonstandard loads such as a slate or tile roof. You can't add these loads to a roof that's not designed for them.

Truss fabrication plants typically use national engineering services. After they've designed the truss types and layout, they send the design to an engineering center to confirm the engineering and stamp the design. The engineering center will show the design, loading and engineering of each type of truss for your project. It will also include the layout and permanent bracing instructions.

Handling Trusses

There are specific ways to handle trusses. The truss fabrication plant will include information on handling and erection. In general, you've got to take care in handling trusses to protect their connections. The gussets are placed to support their designed loads when they're in their permanent vertical position. Improper handling may damage them.

Carrying or laying a truss in a flat position can place loads on the gussets that they aren't designed to handle. If a gusset is pulled loose or a member broken, contact the truss manufacturer to either repair the damage or recommend a remedy. Don't try to make the repair yourself. If you do, you'll be assuming the engineer's liability.

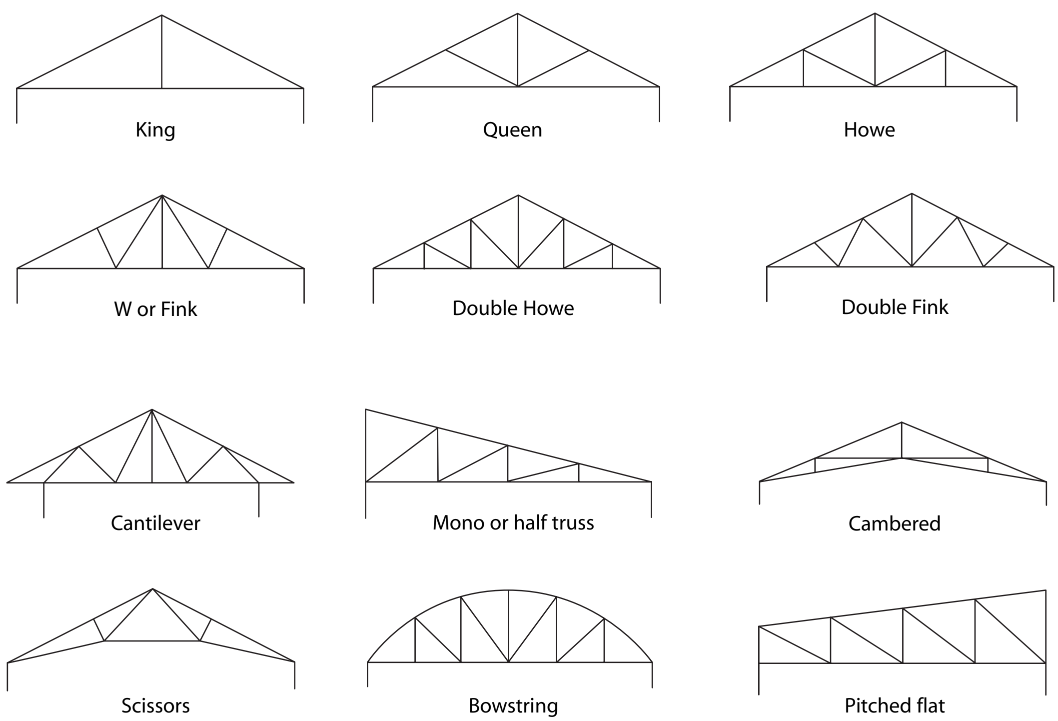


Figure 25
Types of trusses

The safest and easiest way to carry trusses is upside down and vertical. Support the center or other vulnerable points when laying them down. Proper handling prevents the delay and expense of dealing with a damaged truss.

Roof Truss Installation

First mark the truss locations from the layout sheet provided with the engineering design. In most cases the truss layout will be 24 inches on center. Mark the layout on the top outside wall plates and also on a temporary spacing board.

Installing a Gable Roof

Begin the installation by organizing the trusses in the order that they'll be erected. This is usually an easy task for a simple gable roof, because the trusses should arrive packaged with the end trusses on the outside of the package. On a short run, you can pull all the trusses onto the plates and place them from the same end. Set the gable truss first, then all the intermediate common trusses. Finally, set another gable truss at the opposite end.

Follow these steps to hand-set trusses on a gable roof:

1. Nail a horizontal board on each side of the roof just below the plate line where they won't interfere with the setting of the trusses.
2. Hang several trusses from these supports.
3. Working off of scaffolding, pull the outside truss onto the roof. The first truss up should be the gable end truss if there is one. If the interior walls have been built, slide the truss flat with the interior walls supporting the center. If the interior walls haven't been built or if there are voids created by large rooms, have someone carry the peak of the truss to keep it from swinging down. You can do this from floor level using a 2 × 4 with a notch in the end to keep it from slipping off the truss.
4. When the truss is in position, set it into place with the assistance of the ground floor point man with the 2 × 4.
5. Center the truss and nail it to the wall plates. The first truss set should be an end truss or over an interior wall so you can straighten the bottom chord and nail it at the center.
6. With the bottom chord straight, plumb the peak off of the bottom chord. Take extra care with this first truss to make sure that it's plumb. Brace the truss securely so that it will support the next several trusses. The remaining trusses will be set with a spacer board, assuming that you've done a good job of plumbing the first truss.

7. Bring the second truss into position and set it in the same manner as the first. Place the spacer board near the peak, parallel to the ridge. Place it in position so that the truss is laid out with the spacing marks on the board. Temporarily nail it in place using duplex nails or 8d nails left slightly out so they can be pulled later.
8. Repeat this process to set the remaining trusses. Add additional bracing as you erect the trusses to ensure their stability.
9. When there are only three or four trusses remaining, bring up the rest of the trusses and swing them up to rest against the erected trusses. Bring up the end truss last. Then set the end truss, followed by the remaining common trusses working back to the first group of trusses you set. The sequence for a set of 12 trusses would be 1, 2, 3, 4, 5, 6, 7, 8, 12, 11, 10, and 9.
10. The important final step in setting the trusses is to permanently brace the trusses in accordance with the engineering requirements and local codes. Most roof failures that result in the collapse of the trusses during hurricane force winds are due to inadequate bracing. You should also place "hurricane anchors" or truss anchors required by applicable building codes at this time.

Typical bracing should include V bracing across the bottom chords. The point of the V should be at the center of the end wall. The two legs should angle back and tie into the outside walls. On gable roofs, place braces from the top outside points which angle back toward the center and tie into the bottom chords at the base. Nail braces to each truss they pass using 16d nails.

Installing a Hip Roof

Lay out the trusses as directed in the engineering report. Set and brace the common trusses following the steps for a gable roof. The hip trusses will all be marked and numbered. Locate and install them in the order provided with the engineering report. Finish off the roof with permanent bracing and truss anchors as required by the engineering and applicable building codes.

Installing Trusses Using a Crane

You will probably need to erect larger trusses using a boom or crane. These trusses will come with a diagram showing where to place the connections. Use a spreader bar to distribute the weight when you place trusses with a crane. There's less chance of damaging a truss when you have the weight distributed. Trusses are designed for a distributed load rather than one intensive point load. Lifting a truss from a single point not designed for that purpose is likely to cause truss failure or damage. Complete the layout, installation sequence, connections and bracing as detailed in the engineering.

Finishing the Roof

After you've erected the rafters or trusses, in most cases the roof will still require additional work to finish out the framing. This finish framing includes cutting the rafter tails, installing sub-fascia and lookouts for soffits, and lookouts and bargeboards for the sub-framing of gable ends.

Rafter Tails

To complete a roof, you must cut the rafter tails. Depending on the style of the house, there are three general roof overhang treatments: no overhang, exposed rafter tails, and an enclosed overhang.

Flush Cut Tails

If the design doesn't call for an overhang, you flush cut the rafter tails. Flush cut rafters for structures without an overhang don't actually have a birdsmouth cut, though the markings would indicate one. Instead of a heel cut, you make a plumb cut the full depth of the rafter. Then take off the seat cut. See Figure 26 a.

Exposed Rafter Tails

Exposed rafter tails may be plumb cut or configured in a variety of decorative angles or cuts. Make a plumb cut by determining the amount of overhang from the birdsmouth. Mark the cut using the framing square placed for the pitch you're using.

For a 4/12 pitch, place the 12 on the body of the square on the top edge of the rafter. Place the 4-inch mark on the tongue of the square on the top edge of the rafter. Mark along the tongue for a plumb cut. Mark decorative exposed rafter tails with a pattern and cut the desired design. Figure 26 b shows a simple plumb cut rafter tail.

Enclosed Overhangs

For a roof with an enclosed overhang, you'll usually cut the rafter tails with both a plumb cut and a level cut. Make the level cut on the same elevation as the lookout coming from the wall to box in the eaves. Depending on the fascia size, you may not need a level cut on smaller rafters. Figure 26 c illustrates a rafter tail with a plumb cut and level cut. The level cut is known as a *plancher cut*.

Cutting Rafter Tails

You can mark and cut the rafter tails on the pattern rafter along with the birdsmouth and ridge cut. Then cut the tail on the ground with the other cuts. If the ridge and the walls are running straight and parallel, the tails will also run true. But if there are any irregularities, they'll show up in the tails.

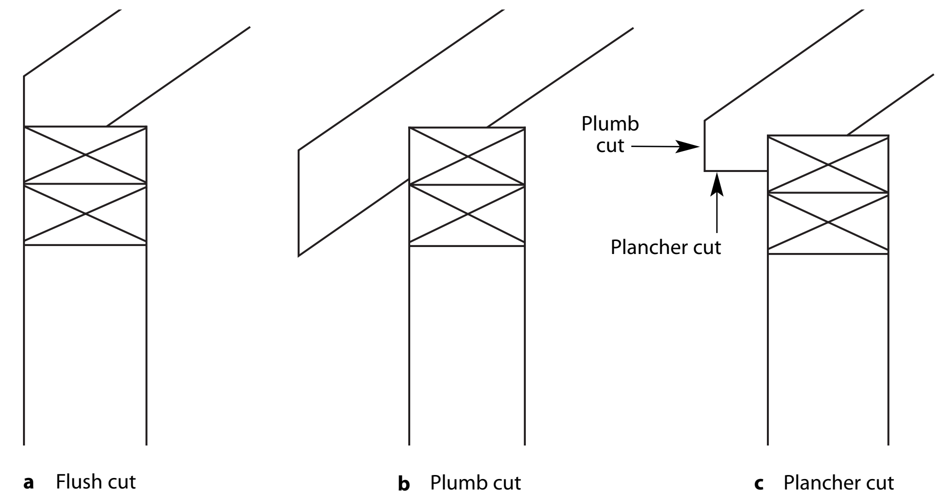


Figure 26
Styles of rafter tails

Some carpenters choose to run the rafter tails wild, then cut them in place. If you choose to do it that way, here's how to cut the rafter tails after the rafters are installed:

1. Measure from the corner of the structure, on a level line, the distance of the soffit. For a 24-inch overhang, measure 24 inches from the sheathing.
2. Plumb this mark and mark the top of the rafter.
3. Repeat steps 1 and 2 at the opposite end.
4. Snap a line over the intermediate rafter tails.
5. Using a pattern, mark the angle of the cut from the chalk line.
6. Cut the tails from a secure platform or scaffolding.

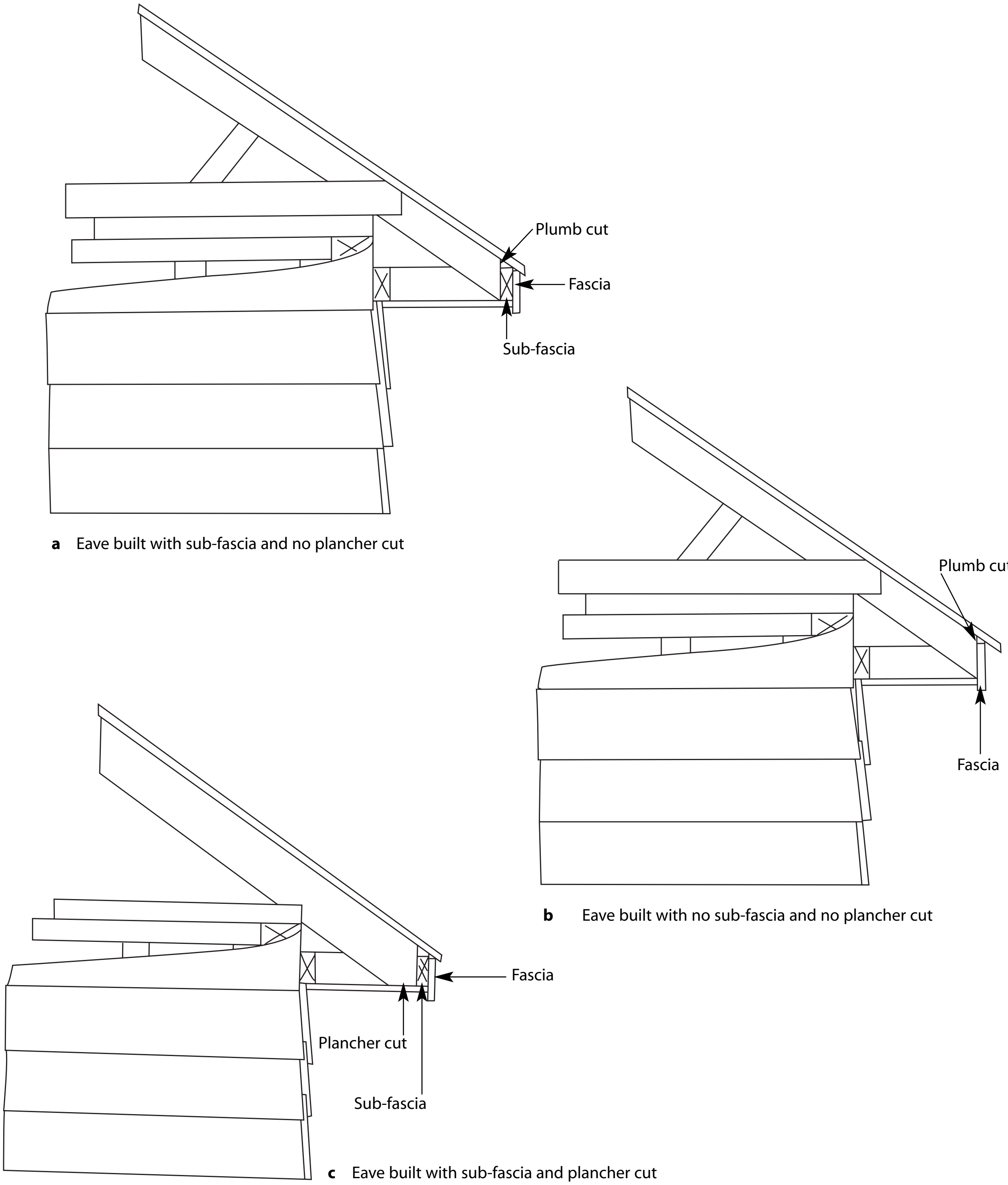
Eave and Gable Framing

Boxed in eaves and gables require frame backing. For eaves, this usually includes a ribbon board along the structure, sub-fascia at the rafter ends and lookouts running between the two. You frame the gable ends with a ladder composed of lookouts and a fly rafter or bargeboard.

Eave Framing

A sub-fascia is a 2-by framing member placed at the ends of the rafter tails. The dimension of the sub-fascia depends on the size of the fascia. With 2 × 4 rafters on a trussed roof, you could use a 2 × 4 sub-fascia with a 1 × 6 fascia. For wider rafters, you'd need a plancher cut.

Figure 27 illustrates three finished eaves. The first (a) is an eave built with sub-fascia and no plancher cut. The drawing in (b) shows an eave built with no plancher cut and no sub-fascia. The third (c) shows an eave built with a plancher cut and sub-fascia.



a Eave built with sub-fascia and no plancher cut

b Eave built with no sub-fascia and no plancher cut

c Eave built with sub-fascia and plancher cut

Figure 27
Three types of finished eaves

Framing Eaves Without a Plancher Cut —

1. Cut the rafter tails to length.
2. Place the sub-fascia across the ends of the tails. Use a straightedge to place the sub-fascia at an elevation where the outside top edge is in line with the slope of the roof.
3. Face nail the sub-fascia to the rafter ends using two 16d nails.
4. Nail a 1 × 4 ribbon board to the outside of the structure. Nail through the sheathing into the studs using two 8d nails at each stud.
5. Cut 2 × 4 lookouts to span from the ribbon board to the sub-fascia. Toenail the lookouts to the ribbon board using four 8d nails. Face nail two 16d nails through the sub-fascia into the end of the lookout. You can face nail one 16d nail through the lookout into the side of the rafter tail to pull the two together.

Installing Sub-Fascia With a Plancher Cut — Use a plancher cut to cut down the ends of the eaves to accommodate a smaller fascia board. Cut the rafter to length with a plumb cut. Then, using a pattern or a line and a level, mark a level line for the plancher cut. After making the plancher cut, you can follow the steps for framing eaves without a plancher cut.

Framing Eaves Without Sub-Fascia — As a cost-saving measure, many builders choose to frame eaves without a sub-fascia. You can use a ploughed fascia instead (Figure 28), then insert the soffit material into the ploughed groove. The groove supports the side of the soffit material. Here's how to do it:

1. Cut the rafter tails to length.
2. Nail a 1 × 4 ribbon board to the structure using two 8d nails at each stud.
3. Toenail the lookout to the ribbon with four 8d nails.
4. Face nail the lookout to the end of the rafter using two 16d nails.
5. Nail the fascia directly to the rafter ends.

Installing a fascia without a sub-fascia board works best with a 2-by fascia, such as rough-sawn cedar. A 1-by fascia is more likely to bow without a sub-fascia.

Gable Framing

Gables on both rafter-framed and truss-framed roofs are built in much the same way. You place a fly rafter or bargeboard at the end of the structure. This rafter is the equivalent of fascia or sub-fascia, depending on whether you use a backing. It's supported by lookouts that span from the second rafter and cantilever across the end rafter to support the fly rafter.

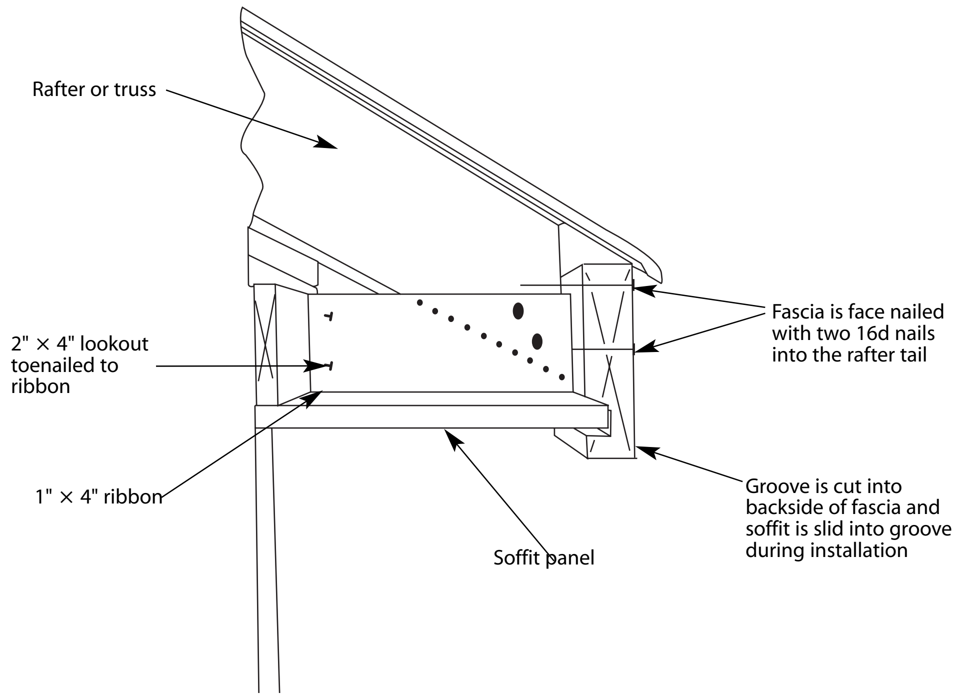


Figure 28
Ploughed fascia

Installing a Fly Rafter —

1. Cut a fly rafter using the same lengths as for the common rafters, with one exception. Don't shorten for the ridge board because the two fly rafters will meet at the peak and be fastened into the end of the ridge.
2. Cut lookouts from 2 × 4 stock the length of the overhang for support.
3. Notch the end rafter for the lookouts. You'll place them flat, every 4 feet. Make the notches $1^1/_2$ inches deep by $3^1/_2$ inches wide for 2 × 4 lookouts.
4. Nail the lookouts in place using 16d nails. Face nail two nails through the second rafter into the end of the lookout.
5. Position the fly rafter in place, spanning from the sub-fascia to the center of the ridge board. Nail the peak of the fly rafter to the ridge board. Nail the tail to the sub-fascia.
6. Face nail the fly rafter to the lookouts with 16d nails.
7. Stretch a string from the peak to the tail, or sight in the fly rafter. When the fly rafter is straight, nail through the lookouts where they sit in the notches on the end rafter.

Installing Roof Sheathing

To get a roof "weathered in," many builders install sheathing before cutting the rafter tails and framing in soffits and gables. Getting the bulk of the sheathing on and under asphalt paper protects much of the framing from wet weather. If weather isn't a threat, you can finish out the roof framing before applying the sheathing. That's the standard procedure.

There are several different types of sheathing and installation used around the country. Sawn cedar shingles were traditionally applied over spaced boards. While this method is still in use in some areas, builders in most areas use plywood sheathing. This change was dictated by preference as well as by building codes.

The vast majority of roofs are sheathed with plywood or oriented strand board (OSB). You can even get OSB that's textured on one side, so it's safer for crew members to walk on. Both of these products are available in 4 × 8 sheets and are installed the same way. Just be sure you're using panels rated for roof sheathing, and providing the necessary support.

Plywood Roof Sheathing Installation

1. Install roof sheathing starting at the bottom of the roof. Chalk a line 4 feet up from what will be the bottom edge. Set the first several panels on the chalk line, tacking them in the corners only until you can confirm the proper alignment. You can use plywood clips for both spacing and support. If you don't use plywood clips, space the panels $^{1}/_{8}$ inch apart to allow for expansion.
2. When the alignment is complete, nail the panels at 6 inches on center on the edges and 12 inches on center on intermediate supports. Gluing isn't recommended for roof sheathing.
3. Stagger rows by two supports for spacing up to 24 inches on center.

Manhours

Manhours to Install Roof Framing (Rafters and Ceiling Joists), per 1,000 BF		
Component	**Manhours**	**Suggested Crew**
Gable rafters	25	1 carpenter, 1 laborer
Hip rafters (no dormer)	30	1 carpenter, 1 laborer
Intersecting (valley) rafters	30	1 carpenter, 1 laborer
Rafter supports and collar beams	25	1 carpenter, 1 laborer

Manhours to Install Roof Framing (Trusses), per each		
Component	**Manhours**	**Suggested Crew**
30-foot span, placed by hand	3	2 carpenters, 2 laborers
40-foot span, placed by hand	4	2 carpenters, 2 laborers
40- to 60-foot span, placed by crane	3	1 operator, 2 carpenters
80-foot span, placed by crane	4	1 operator, 2 carpenters

Manhours to Install Roof Sheathing (Plywood), per 1,000 SF		
Component	**Manhours**	**Suggested Crew**
Plain gables	12	1 carpenter, 1 laborer
Hips and valleys	16	1 carpenter, 1 laborer

For information on related topics, see:

Fireplaces and Chimneys, page 291

Floor Framing, page 299

Framing Materials and Planning, page 363

Insulation, page 395

Porches and Decks, page 485

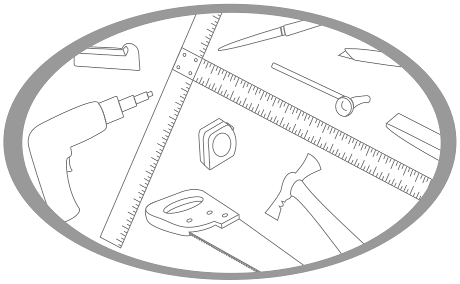
Roofing, page 561

Trim, page 673

Ventilation, page 701

Wall Framing, page 709

Windows and Skylights, page 747



Roofing

In roofing, the angle a roof rises is referred to as the pitch or slope. Although the two words are used interchangeably, they actually mean two different things. The slope indicates how many inches a roof rises in every 12 inches. A 6:12 (also described as 6/12, 6 to 12, or 6 in 12) slope would mean that for every 12 inches of length, the roof rises 6 inches.

Pitch also refers to the rise, but in mathematical terms, pitch is the ratio between the total rise and the total span. It's also expressed in a fraction, with the span being a constant of 24 inches. So the pitch of the same 6-inch rise per 12 inches is written as 1:4, because it is a ratio of the 6-inch rise in a 24-inch span. On the job site the two terms are used interchangeably, but the figures given are almost always for slope. (See *Roof Framing*, Measuring the Angle of the Roof.)

Roofing Systems

There is a wide variety of materials and roofing systems that you can use to cover a roof. Cost, aesthetics, structural capabilities, climate, architectural style, and roof pitch all help to determine which system you'll use. We'll take a brief look at the systems that are available for use. Of these roofing systems, built-up, EPDM, seamless metal, and some types of shingles, such as concrete and tile, are usually complicated enough that they're best left to roofing professionals. We'll take an in-depth look at the more common roofing materials later in this section.

Built-Up Roofing (BUR)

Built-up roofing is used most often for flat or low-pitched roofs. Its name is derived from its application process: waterproof layers of bitumen are placed on the roof and then sealed by mopping over the membrane with hot asphalt or by heat welding. Often the final layer of a built-up system is a layer of gravel, which serves to protect the upper layers of the roof from deterioration by sunlight, weather, and airborne chemical waste. The gravel helps to keep the felt in the layers from burning up in the sun.

Ethylene Propylene Diene Monomer (EPDM)

Ethylene propylene diene monomer is also referred to as single-ply roofing. It's ideal for flat or barrel roofs. Components for this system include a rubber membrane, bonding and seam adhesives, and sealants. EPDM membranes are capable of being stretched to more than 400 percent of their original size, which allows them to accommodate structural movement without splitting or cracking. EPDM also withstands extreme temperature fluctuations and remains watertight even in sub-zero temperatures.

Roll Roofing

Roll roofing is another system used primarily for flat or low-pitched roofs, although some types can be used on roofs with up to a 6/12 slope. Although it looks similar to built-up roofing, roll roofing isn't nearly as durable. It's a lightweight roofing material that's installed in a single layer and fastened with cement and nails. Its main advantages are its low cost and easy installation. Roll roofing is usually only used where looks aren't important, such as on outbuildings or flat porch roofs.

Shingles

Shingles are traditionally thought of as asphalt, fiberglass, or wood. More technically, shingle roofing refers to individual units, which also include clay tile, concrete, slate, metal, and vinyl. Because there's a vast weight difference between tile and asphalt, a building needs to be engineered for the type of shingle roofing material that will be used. Shingles require a minimum slope, usually no less than a 3/12 and more often a 4/12, although some asphalt shingles are designed for a slope as flat as a 2/12.

Seamed Metal Roofing

Seamed metal roofing uses aluminum or copper-coated steel, pre-painted aluminum or galvanized steel, or various alloys. The sheets are anchored with clips, galvanized nails or screws, an interlocking seam, or a combination of these. Seamed metal roofs are lightweight, highly durable, and low maintenance. Depending on the seam type and the material used, seamed metal roofs can be used on slopes as low as $^1/_4$ in 12. An advantage to seamed metal roofing is that it comes in a variety of colors that can add to the aesthetic quality of the structure.

Corrugated and Crimped Roofing

Corrugated and crimped roofing may be metal, plastic, or fiberglass. It's fastened with self-tapping screws, bolts, welded studs, screws, clips, nails, or a combination of these.

There's a table at the end of this chapter that summarizes the roofing systems you'll commonly use, including the weight, relative cost, ease of installation and life span.

Estimating Roofing Materials

You estimate roofing materials by the square, which is the amount of material required to cover a 10-foot by 10-foot square area, or 100 square feet. Finding the roof area you need to cover is easy on a roof without hips or valleys. Simply multiply the length of the ridge by the length of the rake for each slope; add in for the ridge (which will vary with the roofing material and exposure), the starter rows (as needed), and include another 5 to 10 percent for waste. A cut-up roof is more complicated to estimate, but it's not difficult.

Estimating for a Hip or Intersecting Roof

Use the following calculations to determine the number of squares you need to cover a hip or an intersecting roof.

Hip End

1. Multiply the length of the rafters by half the length of the eaves to find the area for one end.
2. If both ends are equal, multiply the length of the eaves by the full length of the rafter to find the combined areas.

Hip Side

1. Add the length of the ridge and the length of the eaves together and divide by two.
2. Multiply this number by the length of the rafter.

Estimating for Conical or Circular Roofs

1. Measure the distance around the roof at the eaves.
2. Multiply this figure by half the rafter length.

Roofing Tools

As with all areas of construction, the right tools will make the work easier. For asphalt roofing materials and wood shingle and shakes, the specialized equipment is minimal. You will need a few special but inexpensive tools:

- Roofing hatchet — One end is a hatchet and the other a hammer. The hatchet end has a gauge that you can use as a quick and accurate measuring guide.
- Hip pad — A pad that straps around your waist and leg. It gives a little extra cushion on hard surfaces, provides additional grip, and helps insulate against a hot roof.

Tools and Materials

- *Sturdy ladders*
- *Hammers*
- *Utility knives*
- *Tape measure*
- *Chalk box*
- *Tin snips*
- *Hand saw*
- *Keyhole saw*

- Roof jacks — Large metal hooks that you nail to the roof to support a length of board; slip a straight 2 x 4 or 2 x 8 into the hooks to give you a solid place to walk on a roof. The boards should not span more than 10 feet.

Roofing Safety

Check the worker's compensation insurance rates of any state and you'll find roofing premiums at the top. In addition to worrying about worker's comp, the long arm of OSHA (Occupational Safety and Health Act) pays particular attention to job-site safety on the roof. The following are basic guidelines for roof safety.

1. Wear shoes that provide good traction, such as rubber-soled shoes. Avoid leather-soled shoes because they don't grip well.
2. Use a sturdy ladder that's rated Industrial IA (300-pound support), Type I (250-pound support), or Type II (225-pound support).
3. Set the ladder only on flat, stable ground. The distance between the base of the ladder and the wall should be at least one-quarter the working height of the ladder. For example, if the roof line is 12 feet up, the ladder should extend out 3 feet at the base.
4. The ladder should extend at least 3 feet above the roof line. Always rest the ladder against the eave, not the gable end.
5. Haul tools to the roof in a bucket or attached to your belt, rather than hand carrying them up the ladder.
6. Whenever possible, walk *across* the roof surface rather than up and down.
7. Use safety lines and belts when working on slopes of 5:12 or greater. For roofs higher than 16 feet from eave to ground, use safety lines and belts regardless of slope. Local regulations and OSHA may have additional safety requirements in your area. Be aware of their rules to avoid injuries as well as possible fines.

Asphalt Roofing

Asphalt is a dark brown to black cementitious material, which is usually a by-product of petroleum processing. Roofing materials made out of asphalt fall into one of two categories: roll roofing or shingles (see Figure 1). They are often referred to by their reinforcement material. The most common reinforcements are as follows:

- Organic felts, which are produced from various combinations of rag, wood, and other cellulose fibers.

- Fiberglass (glass fiber base mats), which are made with inorganic continuous or random thin glass fibers firmly bonded together with plastic binders.
- Asphalt shingles, which are, logically, reinforced with asphalt.

The type of roofing you select will often be determined by the slope of the roof. Figure 2 shows suggested asphalt materials for varying degrees of slope.

Temperature

Installing asphalt roofing material when it's too cold or too hot can create problems. Roll roofing, especially, is tough to install when the temperature dips below 45 degrees because the coating will crack as the asphalt is unrolled and laid flat. Likewise, asphalt shingles will break more easily with the cold. In hot weather, the surface will soften and be easily — and sometimes permanently — marked.

Roll roofing							
Product	Shipping weight per square (approx.)	Squares per package	Length	Width	Side or end lap	Top lap	Exposure
Mineral surface roll	75-90 lbs	1	36′ or 38′	36″	6″	2″ or 4″	34″ or 32″
Mineral surface roll, double coverage	55-70 lbs	1/2	36′	36″	6″	19″	17″

Asphalt shingles					
Product	Shingles per square	Bundles per square	Width	Length	Exposure
Wood appearance strip, more than 1 thickness per strip	67 to 90	4 or 5	11 1/2" to 15"	36" or 40"	4" to 6"
Wood appearance strip, single thickness per strip	78 to 90	3 or 4	12" to 12 1/4"	36" or 40"	4" or 5 1/8"
Self-sealing strip, 2, 3 or 4 tab	78 to 80	3	12" to 12 1/4"	36"	5" or 5 1/8"
Self-sealing strip, no cut-out	78 to 81	3 or 4	12" to 12 1/4"	36" or 36 1/4"	5"
Individual lock down or T-lock	72 to 120	3 or 4	18" to 22 1/4"	20" or 22 1/2"	N/A

Figure 1
Types of asphalt roofing

Material	Slope	Application method	Nail method
Asphalt roll	4:12 or more	Parallel to the rake	Exposed nail
	3:12 or more	Parallel to the rake	Concealed nail
	2:12 or more	Parallel to the eaves	Exposed nail
	1:12 or more	Parallel to the eaves	Concealed nail
19"-selvage double-coverage roll roofing	1:12 or more	Rain must be able to run off, not just puddle and evaporate	
Asphalt self-sealing strip shingles with tabs	4:12 or more	Use No. 15, non-perforated, asphalt-saturated felt placed horizontally	
	3:12 or more	Use two layers of felt placed horizontally	
	2 $^{1}/_{2}$:12 or more	Use two layers of felt set in hot asphalt or mastic	
Laminated asphalt shingles, T-locks, self-sealing without tabs	4:12 or more	Use No. 15, non-perforated, asphalt-saturated felt placed horizontally	

Figure 2
Slope

Roof Deck Requirements

Asphalt roofing material requires a solid-sheathed base, either oriented strand board (OSB) or plywood. For plywood, use $^{15}/_{32}$-inch thick material for rafters spaced 16 inches and $^{5}/_{8}$ inch for rafters spaced 24 inches. Space the plywood $^{1}/_{16}$ inch to allow for expansion. Occasionally, tongue and groove boards are also used for sheathing, especially when the roof deck will be seen from underneath. In this situation, rigid insulation is usually installed over the decking. Because of the greater distance the fasteners have to reach to a solid surface, a sub-roof should be installed over the insulation.

Fasteners

Use large-headed ($^{3}/_{8}$ inch or $^{7}/_{16}$ inch) sharp-pointed nails with barbed or otherwise deformed shanks. Either aluminum or hot-dipped galvanized steel nails are acceptable. Nails should be long enough to extend through plywood decks or at least $^{3}/_{4}$ inch into the sheathing, which ever is less. Refer to the chart in Figure 3 for specific lengths.

Staples can also be used for asphalt roofing. But it's essential to use the correct amount of air pressure. If too much air is used, the staples will be set too deep and might cut into the asphalt. Like nails, the staples must be corrosion resistant, with a minimum 16-gauge $^{15}/_{16}$-inch crown.

Follow the manufacturer's instructions for the number of fasteners to use. In general, you should use four fasteners per 36- to 40-inch strip. For shingles, use two fasteners per 9- to 18-inch shingle. Reroofing applications and nailing hips and ridges require longer nails.

In addition to nails and staples, adhesives are used in some applications. Follow the manufacturer's recommendations as to whether you should use lap cement, quick-setting cement, or cold or hot asphalt adhesives.

Underlayment

When a single-ply underlayment is required, use one layer of No. 15 asphalt-saturated (nonperforated) felt. Lay it horizontally. Local codes or area practices may require heavier underlayment, but it's not usually necessary. Unless code requires it, stick with the single layer of No. 15.

Most roofers prefer working with a single ply of No. 15 as opposed to heavier or multilayer felts. Two layers are more difficult to keep smooth or flat under the roofing material. The heavier felts will sometimes buckle in heat, forcing the shingles to buckle as well.

The exception to this is in areas where the January mean temperature is 30 F or less. Because ice build-up can be a problem, special underlayment should be placed starting from the eaves to a point 24 inches inside the inside wall line of the building. Use an adhered bitumen membrane, such as Vycor Ice & Water Shield, by Grace Construction

Fasteners	
Purpose	**Nail length**
Roll roofing materials on new decks	1"
Strip or individual shingles on new decks	$1^1/_4$"
Reroofing over old asphalt roofing materials	$1^1/_4$" to $1^1/_2$"
Reroofing over old wood shingles	$1^3/_4$"
Reroofing over 300 pounds or heavier asphalt	$1^1/_2$" to $1^3/_4$"

Figure 3
Selecting fasteners

Underlayment	Minimum Vertical Overlap	Minimum Horizontal Overlap
1-ply No. 15	4"	2"
2-ply No. 15 (or greater)	6"	19"

Figure 4
Minimum underlayment

Products. Just remove the paper backing and press it directly onto the plywood deck. It's also a good idea to run it up the valleys before the metal valley is installed. In high snow areas, use a self-adhering roofing underlayment on the entire roof in place of felt.

When code requires a double-ply underlayment, lay the felt horizontally. Begin at the eaves with a 19-inch-wide starter sheet. Follow with a full-width sheet.

Regardless of the number of layers or thickness of the felt, back-nail under the laps only as much as is needed to keep the felt in place before the roofing material is installed. Laps may be sealed with plastic asphalt cement. Figure 4 shows the minimum overlap for underlayment.

Drip Edge

To further protect the roof from water that might seep under the shingles and underlayment at the eaves and rakes, a drip edge should be installed. The drip edge should be, at a minimum, 28-gauge galvanized metal or an equivalent noncorrosive, nonstaining material. At the eaves, the underlayment should be placed over the drip edge. At the rake, place the underlayment between the metal and the roof deck.

The drip edge should extend back from the edge of the deck no more than three inches. Fasten it to the deck by spacing the nails every eight to ten inches along the inside edge. In high wind areas, space the nails 4 inches on center.

Installation of Roll Roofing

Unroll the material, and cut the sheets into 12- to 18-feet strips. Lay the strips in a flat pile on a smooth surface so they'll flatten out. If cold weather prevents the material from being pliable, you may have to warm it first.

Procedures will vary slightly, depending on whether you use the exposed- or concealed-nail method and whether the roofing material is laid parallel to the eaves or the rake. But all roofs will require a solid roof deck, underlayment, drip cap, and, where applicable, flashing. The materials and tools will be the same regardless.

Tools and Materials

- *Roof jacks*
- *Ladder*
- *Utility knife*
- *Roll roofing*
- *Fasteners*
- *Mastic*
- *Lap cement*

Exposed-Nail Methods

There are several variations of the exposed-nail method, depending on the type of installation.

Installation Parallel to Eaves

1. Lay the first strip of roofing so that the vertical and horizontal ends of the sheet extend $^1/_4$ to $^3/_8$ inch over the eaves and rake edges. At a point $^1/_2$ to $^3/_4$ inch down from the top edge, nail the sheet every 18 to 20 inches.
2. Apply a 1-inch-wide strip of mastic under the sheet along the eaves and rake edges. Follow with a row of nails placed 1 inch in from the edges. Drive the nails 3 inches apart, but stagger them slightly to avoid splitting the deck boards.
3. Place the second strip of roofing, overlapping the first by 2 inches. Nail it in place the same way as the first sheet, 18 inches apart and down $^1/_2$ to $^3/_4$ inch.
4. Evenly spread lap cement over the upper 2 inches of the first sheet. Press the second sheet onto the first, and nail through the lap every 3 inches on center and not more than $^3/_4$ inch up from the exposed edge of the sheet. Again, stagger the nail line slightly to avoid splitting the roof deck.
5. Spread mastic in a 1-inch-wide strip at the rake edge, and nail every 3 inches.
6. Apply succeeding strips, overlapping vertical ends by 6 inches and horizontal ends by 2 inches. The vertical ends will be double-nailed, 1 inch in on each side, 4 inches on center. As with other rows of nails, stagger the nails slightly. Stagger the end laps from course to course so that no end lap in one course will be over the one in the preceding course.
7. Trim the last sheet even with the ridge. Figure 5 shows this method of installation.

Installation Parallel to Rake

1. Begin at one end of the roof. Place the first sheet so it overhangs the rake and eaves edges $^1/_4$ to $^3/_8$ inch. Starting at the ridge, angle the strip toward the rake a minimum of $^1/_8$ inch per foot.

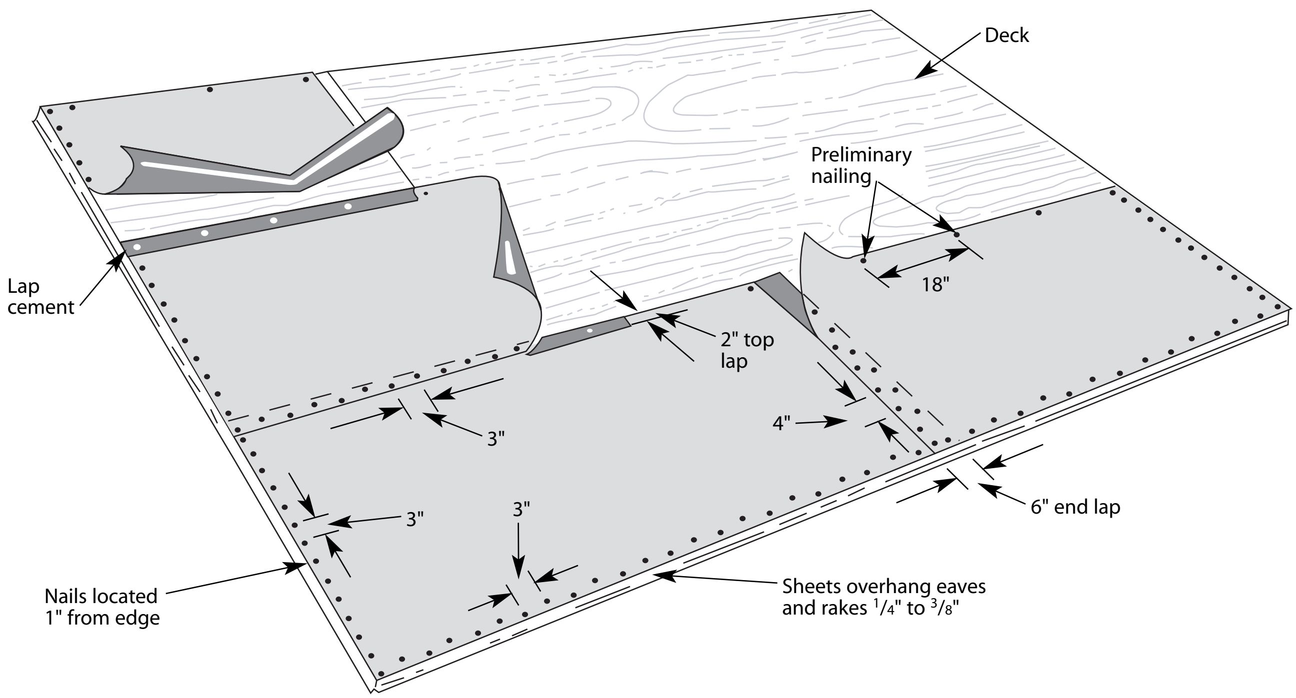


Figure 5

Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Exposed-nail method of applying roofing parallel to the eaves

2. Nail the sheet at the ridge and lap edge every 18 inches, $^1/_2$ to $^3/_4$ inch in from the edge. Spread a 1-inch strip of mastic under the sheet at the rake and eaves edges. Nail the sheet along the rake and eaves edges every 3 inches, staggering the nail line slightly.
3. Place the second sheet parallel to the first so that it also angles $^1/_8$ inch per foot down the roof slope. Overlap the first sheet by 2 inches. Nail the sheet at the ridge and lap edge every 18 inches and $^1/_2$ to $^3/_4$ inch in from the edge. Apply lap cement to the overlap and nail $^3/_4$ inch from the exposed edge every 3 inches in a slightly staggered line.
4. For horizontal ends, overlap pieces by 6 inches. Spread lap cement over the entire 6 inches of the underlying sheet. Nail the sheet 1 inch and 5 inches in from the exposed edge every 4 inches. Slightly stagger the nail line.
5. Repeat steps with succeeding sheets. At the eaves line, spread an l-inch-wide strip of mastic under the sheet, and nail every 3 inches. The last sheet should overhang the rake by $^1/_4$ to $^3/_8$ inch. Spread mastic and nail in the same manner as with all other rake and eaves edges. See Figure 6.

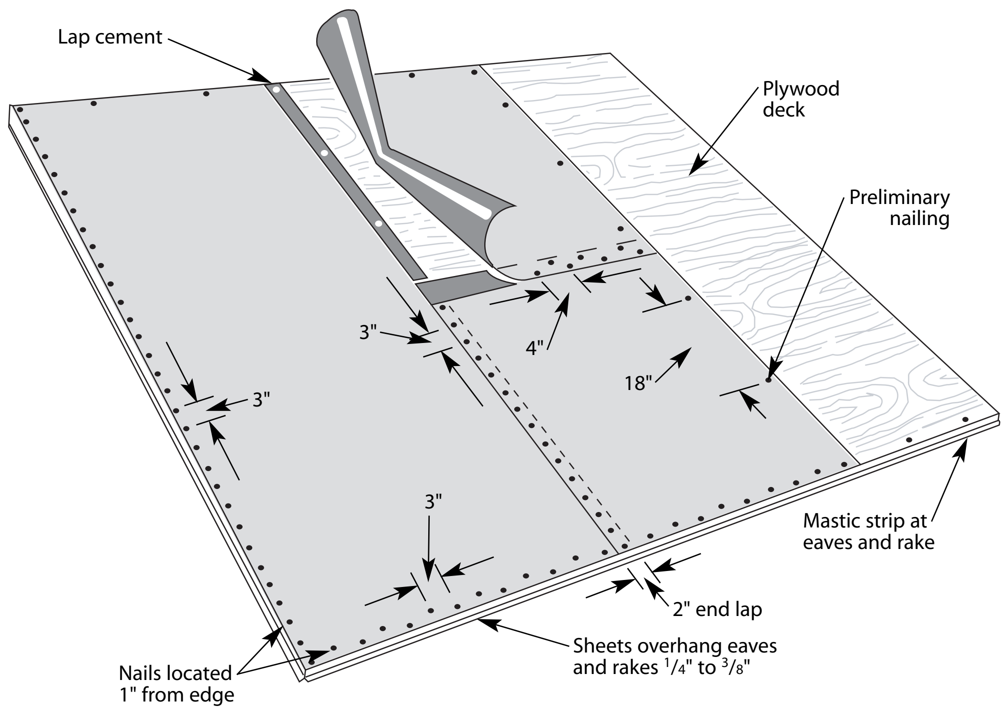


Figure 6 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Exposed-nail method of applying roll roofing parallel to the rakes

Hips and Ridges

1. Butt and nail edges of roll roofing along hips and ridges as shown in Figure 7.
2. Cut roll roofing into 12- × 36-inch strips. Bend the strips lengthwise across their centers.
3. Begin at the lower end of a hip or ridge, and apply the strips in shingle fashion.
4. Spread a 2-inch-wide strip of lap cement under each edge. Nail the edges every 3 inches.

Concealed-Nail Methods

As with exposed-nail methods, there are variations in the concealed-nail method depending on the installation.

Installation Parallel to the Eaves

1. Make edge strips by cutting 9-inch-wide pieces of roll roofing. Spread a 1-inch-wide layer of mastic along the eaves and rake edges. Place the 9-inch pieces so that the roll roofing overhangs the rake and eaves edges by $^1/_4$ to $^3/_8$ inch. Nail 1 inch in from each edge, 4 inches on center.

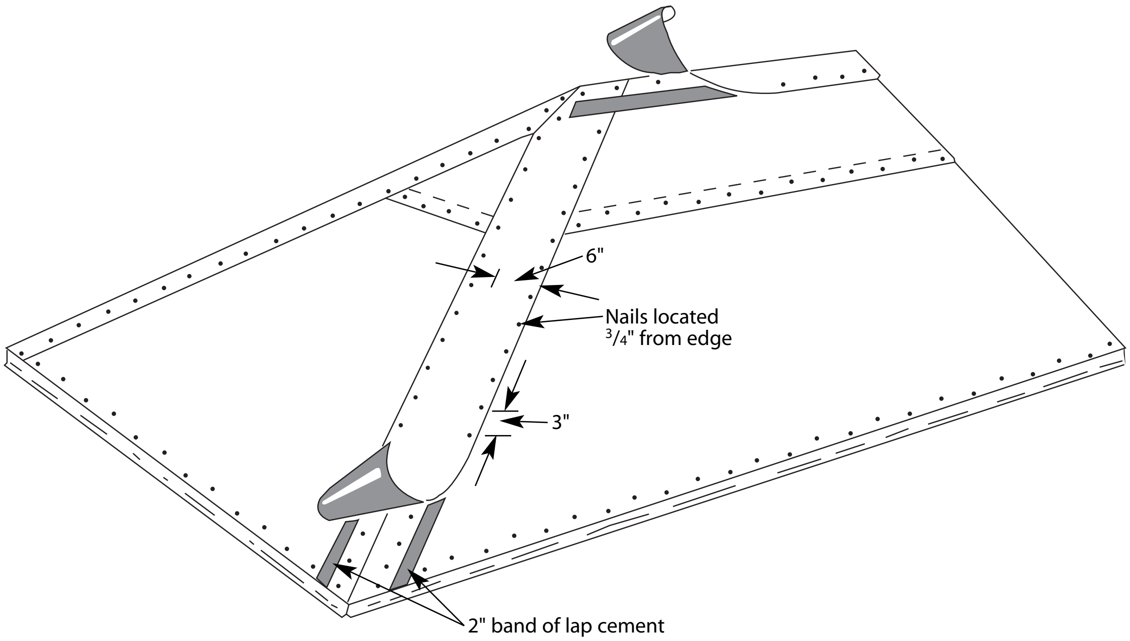


Figure 7 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)
Exposed-nail method of applying roll roofing to hips and ridges

2. Lay a full-width strip parallel with the eaves. Align the edges of the full-width strip with the edge strip. Nail the upper edge of the full-width strip, starting 18 inches from the rake edge. Space the nails 4 inches apart, and stagger them slightly to avoid splitting the deck. This row of nails should be placed within 2 inches of the top edge.
3. Spread the cement recommended by the manufacturer completely over the edge strips. Firmly press the full-width sheet onto the edge strips. Finish nailing the top edge to the rake, spacing nails every 4 inches.
4. Lay the next full-width sheet, overlapping the horizontal edge by at least 3 inches. Nail along the top edge in the same way as you did the first sheet, again starting 18 inches from the rake edge.
5. Spread the cement along the rake edge and in a continuous layer over the upper edge of the underlying sheet. Apply firm, uniform pressure over the entire cemented area so that a small bead of cement will appear along the edge of the sheet.
6. For vertical ends, overlap pieces by 6 inches. Spread lap cement over the entire 6 inches of the underlying sheet. Nail the sheet 1 inch and 5 inches in from the exposed edge every 4 inches. Slightly stagger the nail line. See Figure 8.

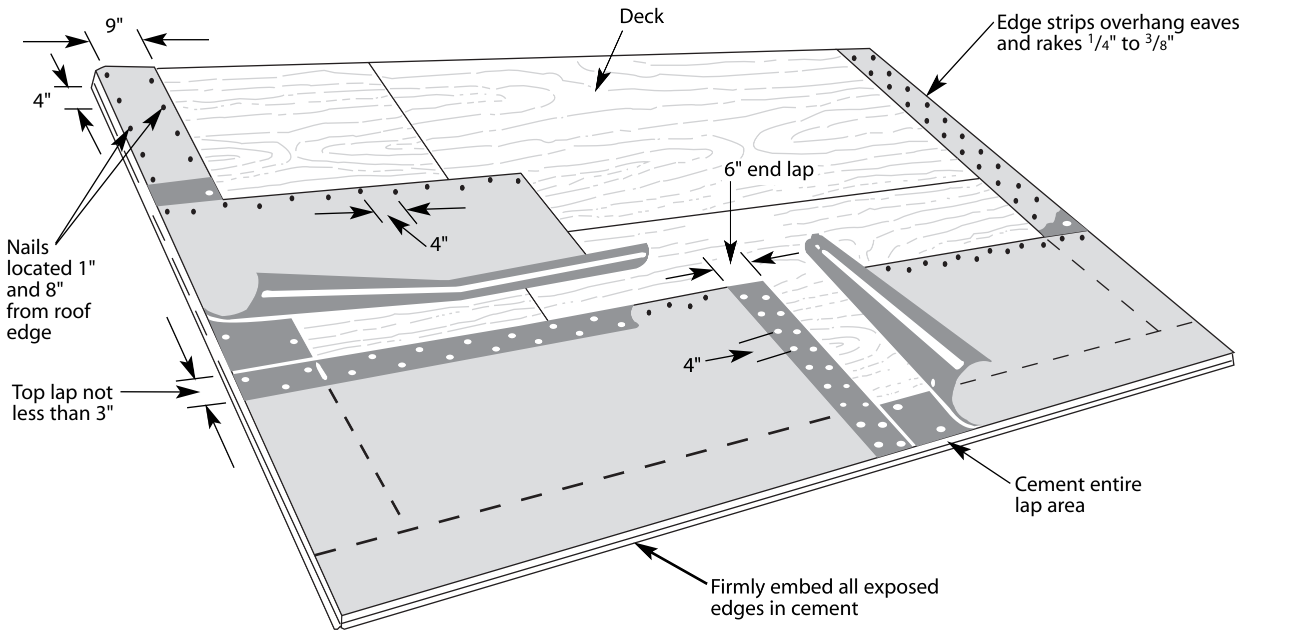


Figure 8 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Concealed-nail method of applying roll roofing parallel to the eaves

Installation Parallel to Rake

Follow the steps for installing roll roofing parallel to the eaves in terms of nailing and cementing. Start the sheets of roofing at the ridge, angling them toward the rake 1/8 inch per foot from ridge to eaves. Fasten the sheets at the ridge with three or four nails, and unroll toward the eaves. Before nailing the sheets and cementing the laps, allow the sheets to hang free until they lie flat and smooth on the roof surface.

Hips and Ridges

1. Follow Steps 1 through 3 for Exposed-Nail Method: Hips and Ridges.
2. Spread asphalt cement along the ridge or hip the length of the first strip. Press the folded strip into the cement. Nail the upper edge, which will be hidden by the next strip.
3. Apply the cement over the top 5 1/2 inches of the first strip and the length of the next strip. Lap the second strip over the first, embedding it firmly into the cement. Again, nail only the top edge.
4. Continue cementing, overlapping, and nailing to the end of the hip or ridge as shown in Figure 9. At the end of the job, double-check all laps to make sure they're secure. If any are loose, recement them.

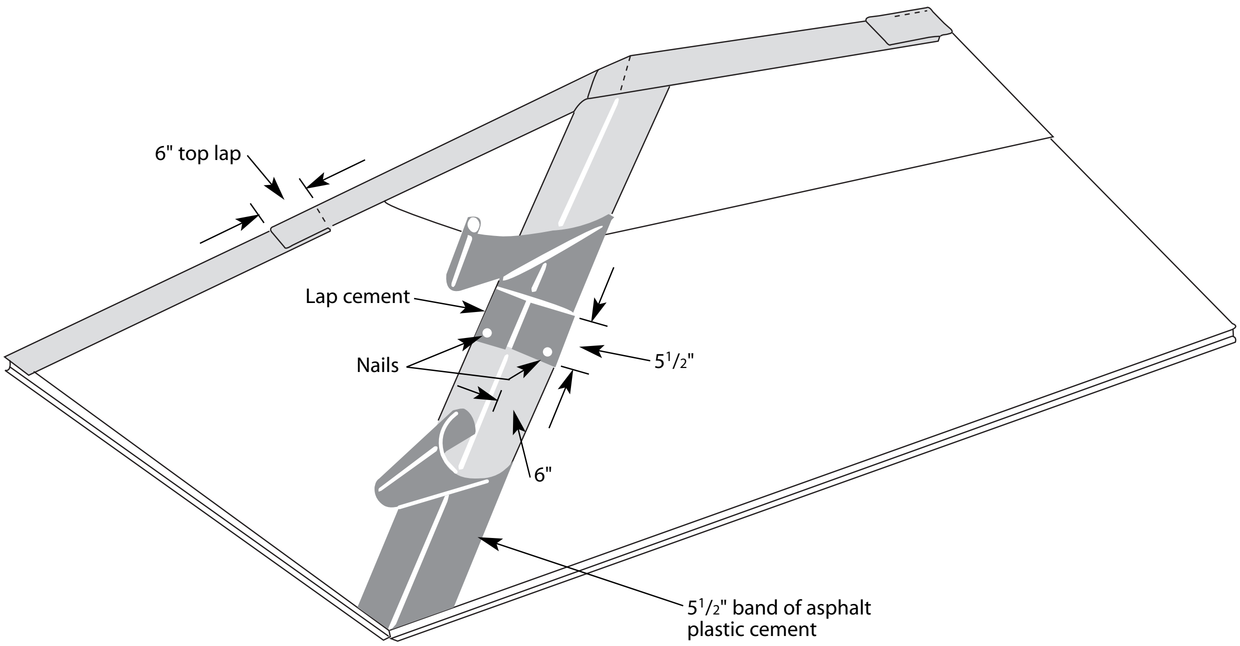


Figure 9 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Concealed-nail method of applying roll roofing to hips and ridges

19-Inch-Selvage Double-Coverage Roll Roofing

This particular type of roofing material comes 36 inches wide. The bottom 17 inches are designed as the exposure area; the top 19 inches are the selvage area and may be finished in a variety of ways. Because installation may vary slightly depending on the finish, the following application steps give a general overview. Refer to the manufacturer's guidelines for specific details.

Installation Parallel to Eaves

1. Cut off the 17-inch exposure portion and set it aside to use at the ridge. Place the 19-inch selvage portion parallel to the eaves so that it extends between $^1/_4$ to $^3/_8$ inch beyond the eaves and rake edges.
2. Cement the entire sheet in place. Nail it down with three rows of nails. Place the top row of nails $4^1/_2$ inches below the upper edge of the sheet. Nail the bottom row above the lower edge of the sheet and into the metal drip edge. The middle row of nails should go half way between the top and bottom rows. Place the nails within the rows 12 inches apart; stagger them slightly to avoid splitting the deck.
3. Place the first full sheet of material so that the end and lower edge are flush with the rake and eaves edges of the starter strip.

4. Spread a strip of mastic l-inch wide along the rake edge the length of the selvage. Press into place. Secure the sheet in place with two rows of nails driven into the selvage portion. Drive the first row $4^3/_4$ inches below the upper edge of the sheet. Place the second row $8^1/_2$ inches below the first row. Space the nails 12 inches apart and stagger them slightly.

5. Lay the next roll roofing sheet, lapping the first by the full 19-inch selvage. (See Figure 10.) Drive two rows of nails as explained in Step 4. Then lift the exposed portion, and evenly spread adhesive over the entire selvage to within $^1/_4$ inch of the exposed portion. Firmly press the two layers together.

Installation Parallel to Rake

1. Cut off the 17-inch exposure portion and set it aside to use at the opposite rake edge. Place the 19-inch selvage portion against the rake so that it angles toward the rake a minimum of $^1/_8$ inch per foot from ridge to eaves. It should extend between $^1/_4$ to $^3/_8$ inch beyond the eaves and rake edges.

2. Spread a l-inch-wide strip of mastic the length of the rake and eaves. Press the sheet in place, and nail it down with three rows of nails. Place the first row of nails $4^1/_2$ inches from the inner edge of the sheet. Place the next row just inside the rake edge of

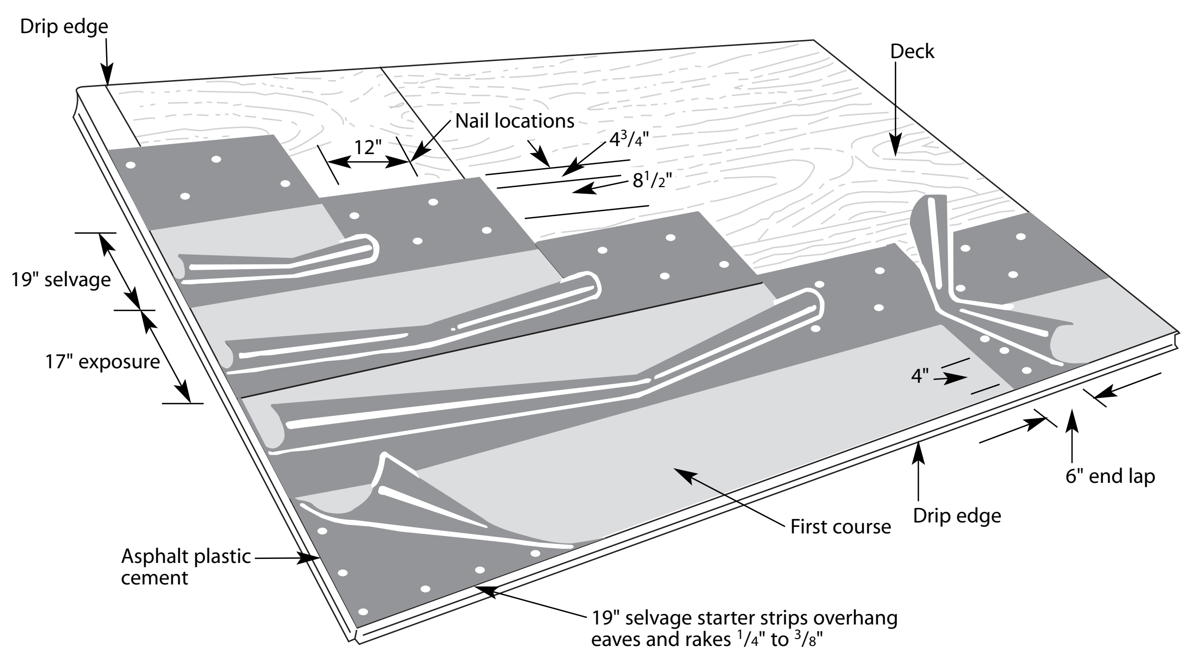


Figure 10 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)
Application of double-coverage roll roofing parallel to the eaves

the sheet and into the metal drip edge. The middle row of nails should go half way between the other two rows. Place the nails within the rows 12 inches apart; stagger them slightly to avoid splitting the deck.

3. Follow Steps 3 through 5 above, with the obvious change that the sheets are applied parallel to the rake rather than the eaves. Figure 11 shows this method of installation.

End Laps

1. Overlap ends 6 inches. Drive a row of nails 1 inch from the end of the normally exposed part of the sheet. Space the nails 4 inches apart.
2. Evenly spread asphalt cement over 5 1/2 inches of the 6-inch lapped area. Press the overlying sheet firmly into the cement.
3. Secure the overlying sheet with a row of nails. Place the nails 1 inch back from the edge only in the selvage portion of the sheet, spacing them 4 inches apart. Stagger the end laps so that they don't align from course to course.

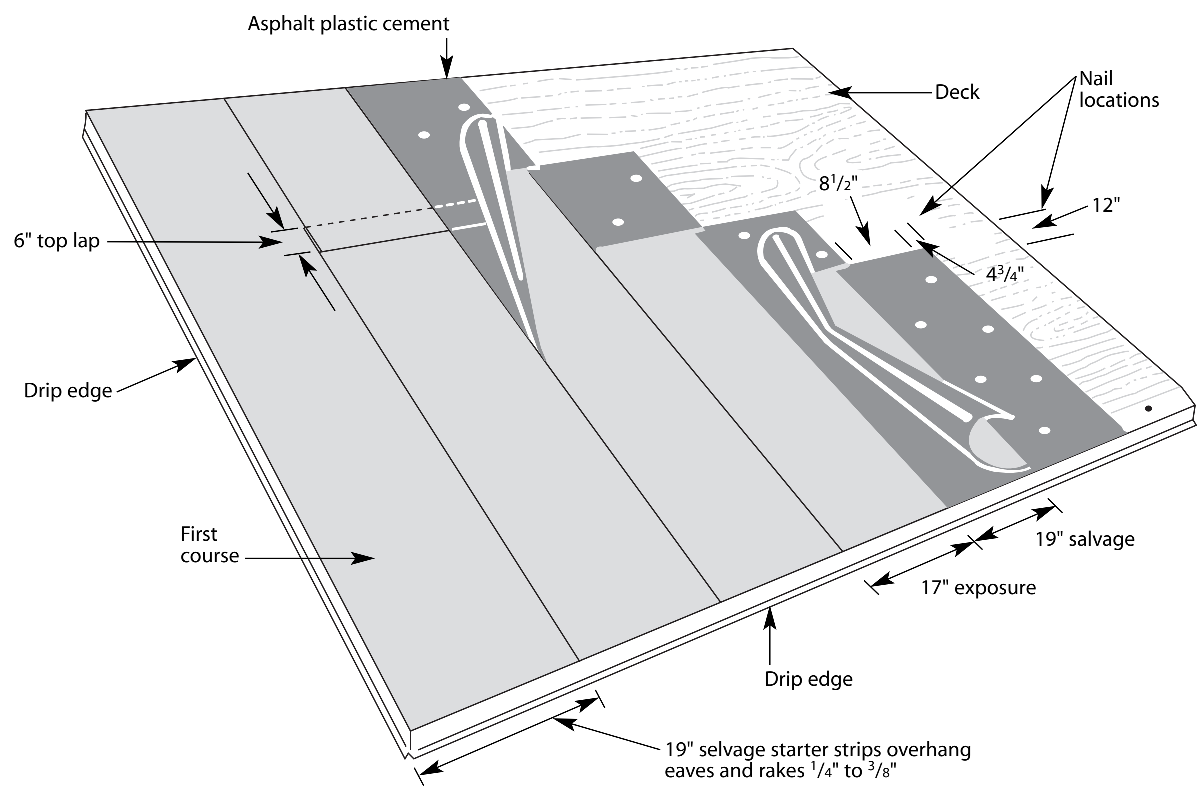


Figure 11

Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Application of double-coverage roll roofing parallel to the rake

Hips and Ridges

1. Follow Steps 1 through 3 for the Exposed-Nail Method: Hips and Ridges. The cut strips will still have the 17-inch exposed portion and the 19-inch selvage portion.
2. Cut the selvage portion from one strip, setting aside the exposed portion to use at the other end of the hip or ridge. Nail this starter strip to the roof, placing the nails 1 inch in from each edge and spacing the nails every 4 inches.
3. Spread asphalt cement over the entire strip. Firmly press the next folded strip into this. Nail the selvage portion in the manner described. Repeat this process to the end of the hip or ridge as shown in Figure 12.

Reroofing

New asphalt roll roofing material can be laid over an existing roof providing that the existing deck is strong enough for another layer, the deck is in good shape, and the existing layer is adequately prepared. (See *Roofing-Decks*.)

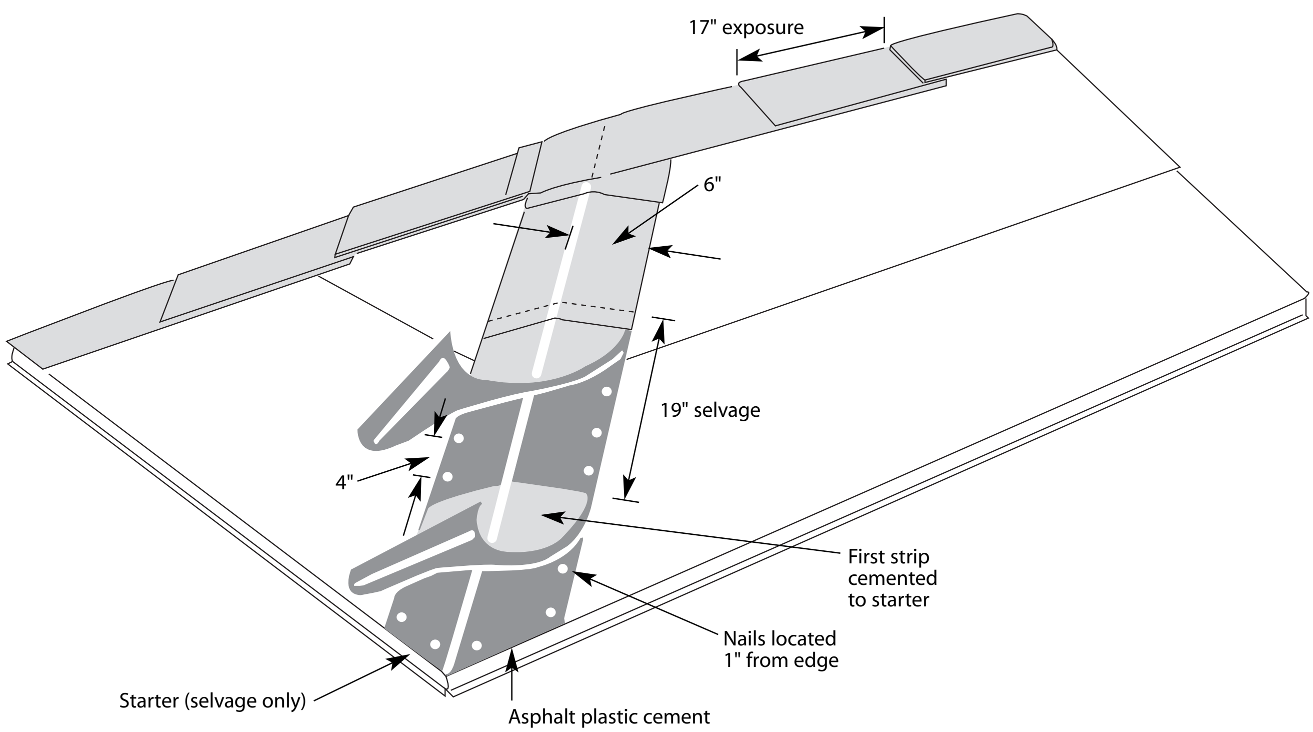


Figure 12 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)
Application of double-coverage roll roofing to hips and ridges

Repairing Roll Roofing

An occasional blister on roll roofing isn't a serious problem. However, if multiple blisters appear, or if the material is cracked or torn, spot repairs may be necessary.

Tools and Materials

- *Utility knife*
- *Putty knife*
- *Hammer*
- *Roofing cement*
- *Roofing nails*
- *Roll roofing*

To make repairs, follow these steps:

1. Cut out damaged area. Save the piece to use as a template for the patch.
2. Spread roofing cement over the exposed area. Push cement under the existing roofing material.
3. Cut patch to fit. Firmly press into adhesive. (A second patch may be need over the first to bring the patch flush with the surrounding roof.) Nail in place.
4. Cut a final patch 2 inches wider on each side. Spread roofing cement, and press the patch down, making sure all the edges are sealed.

Asphalt Shingles

Asphalt shingles are probably the most common type of roofing material that you'll find in use today. They have a long life, they're easy to install, reasonably priced, and they have a nice appearance.

Lay asphalt shingles over solid sheathing and underlayment. Although a drip cap isn't always required, it's a good idea to install one to better protect the eaves and rake edges. You should also have flashing in place, where applicable. In addition, you should have any gutters, vent pipes, soil stacks, and ventilators installed and flashed before you begin roofing.

Asbestos

Asbestos used to be a common roofing material, but with the increasing concern about health hazards involving asbestos, it's no longer used. (See *Asbestos*.) However, when you're reroofing a house, it's important to identify whether an old layer of roofing contains asbestos or not, particularly for disposal. Regulations change from year to year and vary from area to area, but in general, asbestos materials can only be removed by a certified asbestos abatement contractor. If you find asbestos shingles that are in good shape, and your new roof will be the second layer of roofing, you may be able to overlay the old shingles with new. In most cases, two layers of roofing material is all that's allowed, but in some areas, the local codes will allow three — depending on the type and the weight of the materials. In other areas you may be required to tear off all existing material down to the deck before applying new shingles. Check your local code.

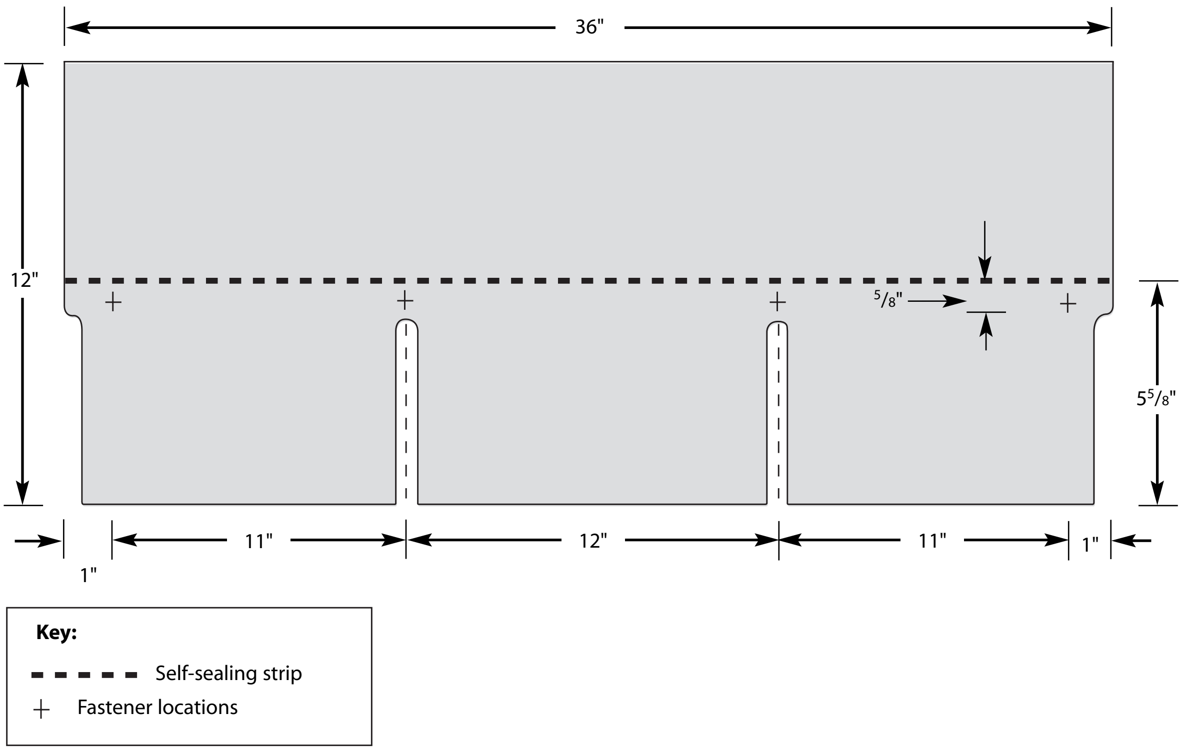


Figure 13
Three-tab strip shingle
Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

The more difficult problem is how to dispose of asbestos shingles. Asbestos requires special disposal, and so landfills will often take asbestos only on certain days. The landfill will require paperwork identifying the name of the owner and the address of the structure from which the shingles were removed, as well as the asbestos abatement contractor's name and address. Of course, all of this extra regulation costs more — often up to ten times what a load of asphalt shingles would cost for disposal.

Fastening Shingles

Asphalt shingles come with self-sealing adhesive strips. To prevent the shingles from sticking together in transit, a plastic strip covers the surface of the shingle below. It's not necessary to remove the plastic strip because it has nothing to do with the adhesion capabilities of the installed shingle.

In addition to the adhesive strip, you should use a minimum of four to six fasteners per shingle to secure them. You can use nails or staples, as recommended by the manufacturer. Figure 13 shows the fastener locations for a three-tab strip shingle.

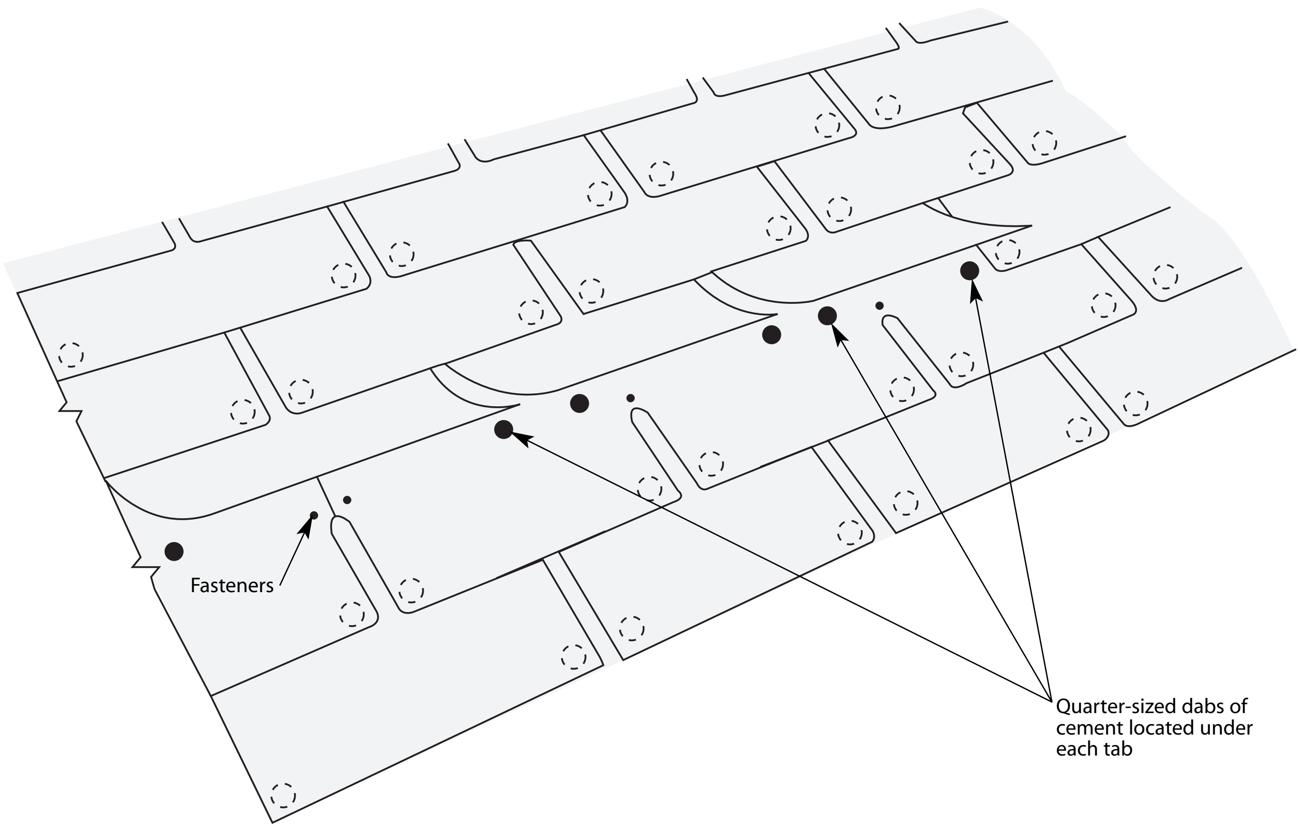


Figure 14 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)
Application of cement under free-tab shingles

During your installation, don't nail or staple into or above the adhesive strip. Take care to drive the fastener straight and make sure it adequately penetrates the roof decking. Never set the fastener too deep. A deep set will cut into the shingle, making it more likely that the shingle will break in high wind. A cut in the shingle also allows water to seep through and damage the roof. If you damage a shingle while fastening, remove the fastener, repair the hole with asphalt cement and place another fastener close by, or replace the shingle.

Some asphalt shingles come with factory-applied adhesive on the tabs or integral locking tabs (T-locks). Both types offer good wind resistance. Shingles that don't have this feature are called "free tab" shingles. To make free tab shingles more wind resistant, use a putty knife or caulking gun to dab a quarter-sized spot of quick-setting asphalt plastic cement under the loose portion of every tab (see Figure 14). Without bending the shingle back very far, place the dab as close to the bottom edge of the shingle as possible. Then press down on the tab, but don't squeeze the cement out.

Shingle Installation

Begin your shingle installation along the rake of the roof. Where a dormer or valley breaks the roof surface, start at the rake edge and work towards the dormer or valley. You determine which rake to use as a starting point by your hand preference. A right-handed roofer should start at the left rake; a left-handed roofer should start at the right one. If both rakes are equally visible, or with a hip roof or long runs, start at the center and work both ways.

The Starter Shingle

1. Lay the starter course of shingles, either a row of asphalt shingles or a 9-inch strip of roll roofing material. The starter strip protects the roof by filling the spaces under the cutouts and joints of the succeeding full course of shingles. If you're using shingles for the starter course, cut the exposed portion (the tabs) of the shingle off and trim 3 inches off the end.
2. Align the bottom edges of the shingles with the eaves edge. If you don't use a drip cap, extend the starter course $^1/_2$ to $^3/_8$ inch at the eaves and rake edges.
3. Fasten the shingles with roofing nails. Drive the nails 3 or 4 inches above the eaves edge. Place the nails so that they won't be exposed either at cutouts or at spaces between shingle tabs in the first course.
4. If you use roll roofing for your starter course, nail it 3 or 4 inches above the eaves, spacing the nails 12 inches apart.

Placing and Aligning Succeeding Courses

Start the first course of shingles with full shingles. Lay succeeding courses according to the shingle style and your desired pattern. Be absolutely consistent with the exposure length as you lay out the shingles. Follow the manufacturer's recommended amount, aligning the lower edges of the butts with the tip of the cutouts of the underlying course.

Typical patterns are laid out so that the shingle cutouts (the section that is cut out of an asphalt shingle) break joints on thirds, halves, or randomly. With random break joints, the joints should be at least 3 inches apart from adjacent courses. Figure 15 shows the cutout placements for three-tab shingles.

From the ground, it's easy to tell a professional roofing job from an amateur one. With good quality work the shingles line up diagonally from any point. Poor quality work will curve or have jags in the diagonal lines. This happens when the roofer isn't careful to line up the shingles for each succeeding course. Even when two experienced roofers work on a roof, the results can be less than satisfactory if each roofer uses a slightly different technique.

Cutout Placements for 36-inch 3-Tab Shingles						
	Course: (Amount to cut from shingle)					
Break Joints:	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**
Thirds	4 inches	8 inches	1 tab or 12 inches	$1^1/_3$ tabs or 16 inches	$1^2/_3$ tabs or 20 inches	2 tabs or 24 inches
Halves	6 inches	1 tab or 12 inches	6 inches	1 tab or 12 inches	6 inches	1 tab or 12 inches
6-inch	6 inches	1 tab or 12 inches	$1^1/_2$ tabs or 18 inches	2 tabs or 24 inches	$2^1/_2$ tabs or 30 inches	One full shingle
Random	Remove varying amounts of material from the rake tab of succeeding courses. Space cutouts at least 3 inches apart from course to course. Avoid repeating patterns closely.					

Figure 15
Cutout placements for 3-tab shingles

Regardless of whether the cutouts break joints on thirds, halves, or randomly, you need to be exact in keeping the exposure even and in aligning the shingles carefully and consistently.

Aligning Shingles with Marks of Previous Course — There are two common methods of aligning shingles. One method involves lining up notches. Each shingle comes with small notches or slits along the top edge. Each slit represents an offset amount. For example, for cutout break joints on thirds, you would align the second shingle course with the first notch of the shingle on the first course below, and repeat this offset with each succeeding course.

Horizontal and Vertical Chalk Lines — Even the most experienced roofer will occasionally make small variations over the course of a roof. The second method of aligning shingles will help you keep your layout even. Start by measuring the eaves and ridge into several sections. Snap a chalk line from the ridge to the eaves to use as a vertical guide. As an additional guide, snap horizontal chalk lines at least every seven courses.

Hips and Ridges

Some manufacturers make special shingles for hips and ridges. You can also make your own.

1. If you're using 3-tab shingles, cut them into 12-inch by 12-inch pieces. Cut 2-tab or no-cutout shingles into pieces a minimum of 9 inches by 12 inches.

2. Slightly taper the top portion of the shingle so that it's narrower than the exposed portion.

3. Bend the shingles lengthwise. Attach the shingles with a 5-inch exposure, beginning at the bottom of the hip. If shingling the ridge, start at the end opposite the direction of the prevailing winds.

4. Secure each shingle with one fastener on each side. Set the fastener $5^1/2$ inches back from the exposed end and 1 inch up.

Valley Applications

Open valleys applications are more common than closed-cut valleys, but let's look at closed-cut valleys first.

Closed Cut Valleys —

1. Install valley flashing. Starting with the lower or lesser slope, apply the first course of shingles along the eaves and across the valley. Extend the end shingle at least 12 inches onto the adjoining roof.

2. Fasten the shingles as you ordinarily would, with these exceptions:

   a.) Do not place fasteners within 6 inches of the valley centerline.

   b.) Place two fasteners at the end of each shingle crossing the valley.

3. Continue this process with succeeding courses, extending them across the valley and onto the adjoining roof. Press the shingles tightly into the valley as you work.

4. When one slope is completed, begin on the other. Again, start at the eaves and cross the valley onto the previously applied shingles.

5. Snap a chalk line over the shingles, measuring out 2 inches from the centerline on the side that you laid second. Trim the shingles back to this point. Clip 1 inch at a 45-degree angle from the upper corner of each end shingle to direct water into the valley. This clip will not be visible.

6. Embed each end shingle in a 3-inch width of asphalt plastic cement. This application method is illustrated in Figure 16.

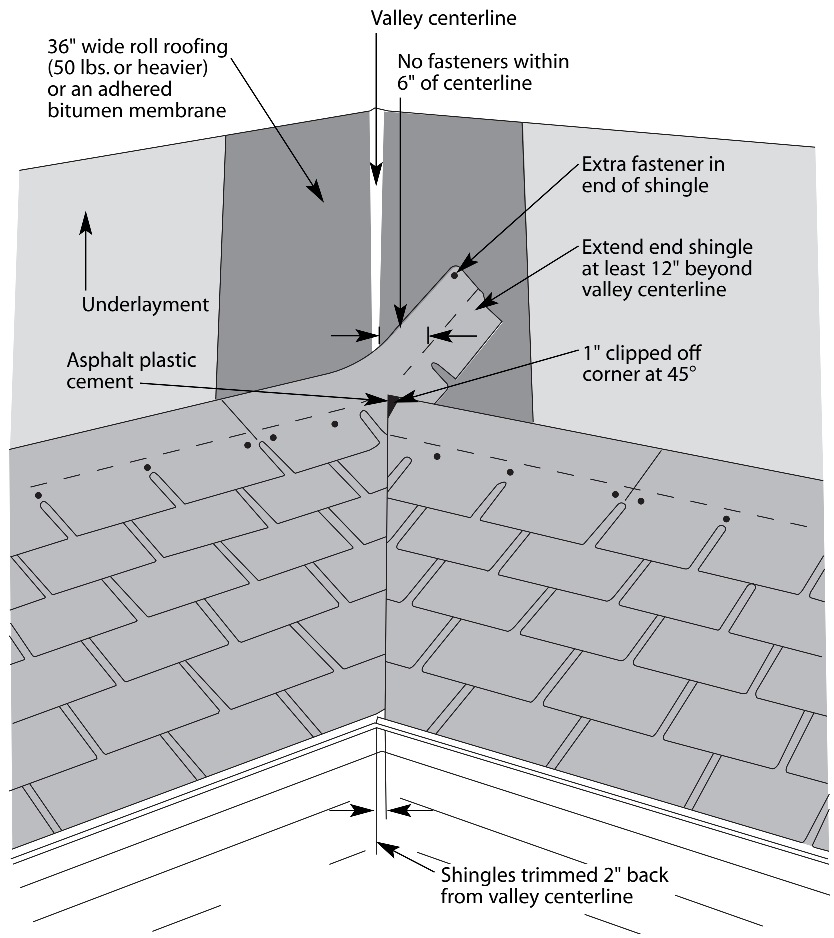


Figure 16 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Application of shingles in closed cut valley

Open Valleys —

1. Snap two chalk lines the full length of the valley flashing, each line starting 3 inches out from the valley centerline. The lines should angle outward $^{1}/_{8}$ inch per foot from the top to the bottom. So, for an 8-foot-long valley, the chalk lines would be 6 inches apart at the top and 7 inches apart at the eaves.
2. As you apply the shingles toward the valley, trim the last shingle in each course even with the chalk line. Clip 1 inch from the upper corner of the shingle at a 45-degree angle to direct water into the valley and prevent it from penetrating between the courses. (See Figure 17.)
3. To form a tight seal, cement the shingle to the valley lining with a 3-inch width of asphalt plastic cement. There should be no exposed nails along the valley flashing.

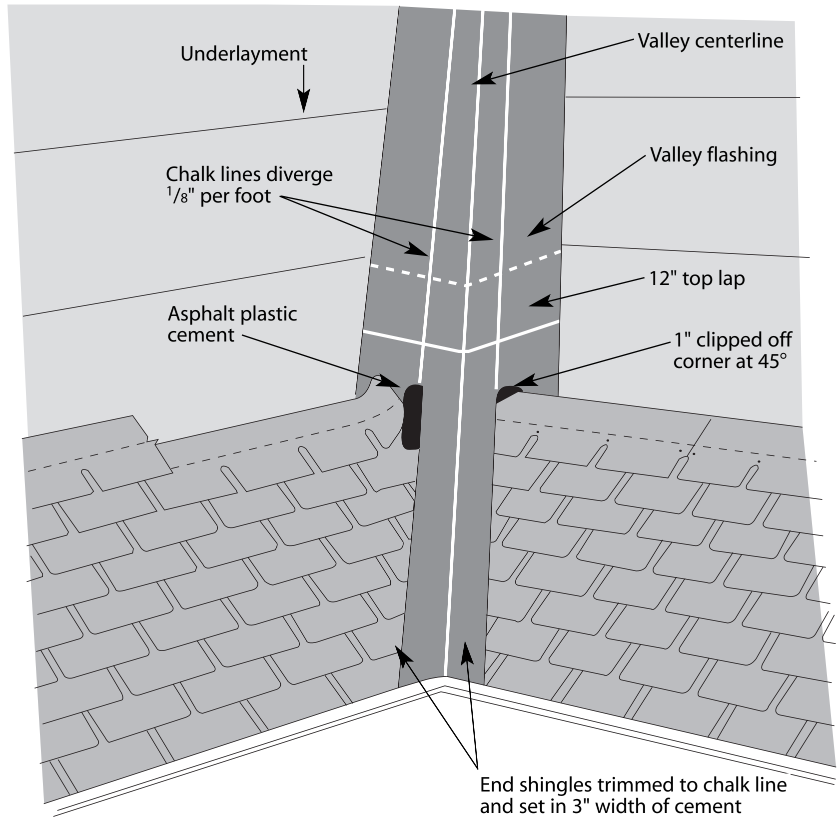


Figure 17 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Application of shingles in open valley

Woven Valleys —

1. Install valley flashing. Lay the first course of shingles along the eaves and across the valley. The shingle should extend at least 12 inches onto the adjoining roof area.
2. Lay the first course on the adjoining roof area and across the valley. As with the opposite side, extend the shingle at least 12 inches onto the adjoining roof area.
3. Lay succeeding courses alternately, first along one roof area and then along the other. Weave the valley shingles over each other. (See Figure 18.)
4. Press the shingles tightly into the valley. Fasten them as you ordinarily would, with the following exceptions:

   a.) Do not place fasteners within 6 inches of the valley centerline.

   b.) Place two nails at the end of each terminal strip.

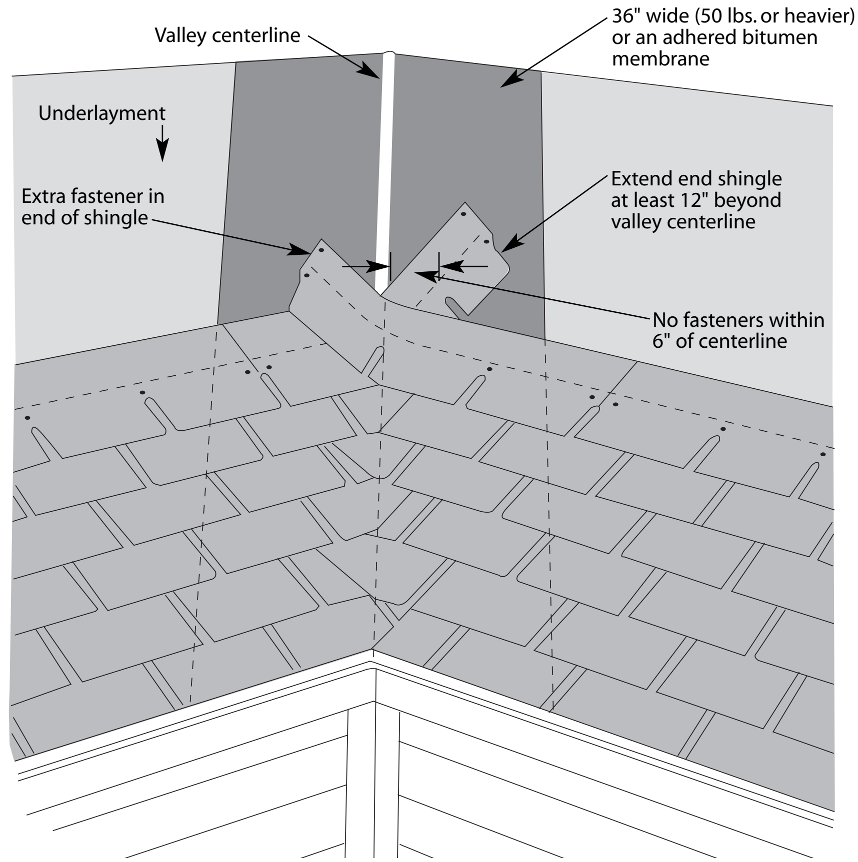


Figure 18 Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Application of shingles in woven valley

Steep Slope and Mansard Construction

The maximum slope that asphalt shingles are designed for is 21:12, or a 60-degree angle. Any steeper than this and you may have problems, especially in colder or shaded areas. You need to use special application methods to ensure a quality job. In addition, you need to provide through ventilation to avoid trapping moisture-laden air behind the sheathing.

1. Follow the manufacturer's guidelines for securing the shingles to the roof. For shingles with a 5-inch exposure, position the fasteners 5$^5/_8$ inches above the butt. Do not place fasteners in or above the adhesive strip. Use six fasteners instead of four.

2. Using a putty knife or caulking gun, dab quarter-sized spots of quick-setting asphalt under each tab. For a 3-tab shingle, you'd apply two spots under each tab, as shown in Figure 19. Place the cement directly over the cutout. For no-cutout shingles, use four spots, evenly spaced.

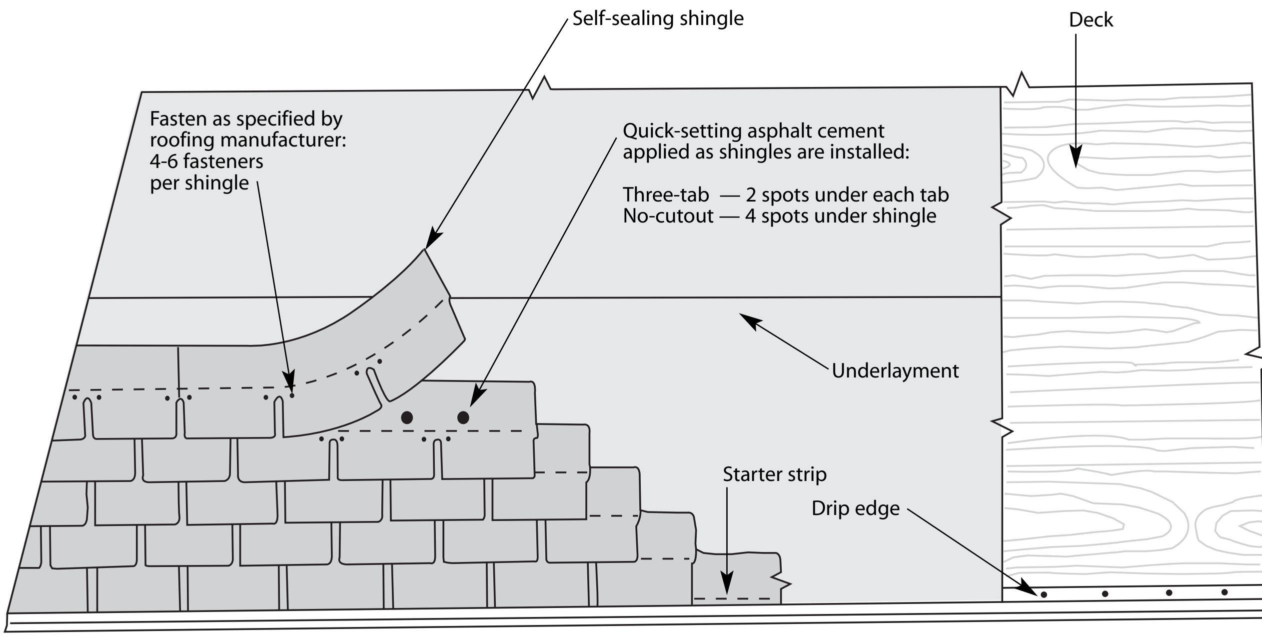


Figure 19

Application of shingles on steep slopes

Courtesy of Asphalt Roofing Manufacturers Association (ARMA)

Wood Shakes and Shingles

Wood shingles and shakes are available in a variety of woods such as red and white cedar, white pine, and oak. Of these, red cedar is by far the most commonly used wood because of its natural resistance to insects and excellent weathering qualities. In some regions of the country wood shingles and shakes are required by code to be treated for fungus and fire resistance. You can expect wood roofs to last 30 to 50 years if they're coated with a preservative every three to five years.

Some contractors use the terms shakes and shingles interchangeably, but they're two very different products, and they require different methods of installation.

Shingles are a smooth-sawn wood product manufactured in 16-, 18-, and 24-inch lengths with a uniform butt thickness per individual length. They come in four different grades ranging from premium to utility grade. Number 1 and 2 shingles are both acceptable for roofing; however, No. 1 shingles are a far better buy in the long run because they weather so much better. Number 3 shingles are adequate for secondary buildings, and when price is the primary concern. Number 4 shingles are never used for roofing.

Slope	Number 1			Number 2			Number 3		
	16"	18"	24"	16"	18"	24"	16"	18"	24"
3/12 to 4/12	$3^3/_4$"	$4^1/_4$"	$5^3/_4$"	$3^1/_2$"	4"	$5^1/_2$"	3"	$3^1/_2$"	5"
4/12 & steeper	5"	$5^1/_2$"	$7^1/_2$"	4"	$4^1/_2$"	$6^1/_2$"	$3^1/_2$"	4"	$5^1/_2$"

Figure 20
Maximum recommended exposure for roof shingles

Shakes are a rough-faced product. They are split from logs and shaped by the manufacturer into three different types: handsplit and resawn, tapersplit, and straight split. The handsplit and resawn shingles, which are the most common, have split faces and sawn backs, making them smooth on one side and rough on the other. This is accomplished by cutting the shakes first to a double thickness and then sawing them at a slight diagonal into two tapered shakes. The tapersplit shakes are split individually into tapered pieces. Straight-split shakes are not tapered, but are the same thickness throughout.

Estimating Wood Roofing

Shingles are packaged in bundles, with four bundles containing enough shingles to cover one square, or 10- by 10-foot area, when the exposure is 5 inches. Shakes are also packaged by the square, with five bundles to the square when the exposure is 10 inches.

With both roofing products, the allowable weather exposure length can vary by several inches, which throws off the actual coverage per bundle. The allowable exposure for shakes also depends on whether you install the material in a 2-ply or 3-ply system. A 2-ply roof means that the shingles are never overlapped more than two shingles thick; a 3-ply roof has shingles that are overlapped in a triple thickness. The charts in Figures 20 through 23 will help you determine the number of bundles to buy.

Shingles

As you can see in Figure 20, for slopes of 4/12 or greater, the recommended exposure length for shingles is 5 inches for 16-inch shingles, $5^1/_2$ inches for 18-inch shingles, and $7^1/_2$ inches for 24-inch shingles. When the slope is less than 4/12, the exposure should decrease as well. The standard exposure is then 3 $^3/_4$ inch for 16-inch shingles, $4^1/_4$ for 18-inch, and $5^3/_4$ for 24-inch.

Approximate square foot coverage of one square (4 bundles) of shingles based on the following exposures:									
	Exposure								
Shingle length	$3^1/_2$"	4"	$4^1/_2$"	5"	$5^1/_2$"	6"	$6^1/_2$"	7"	$7^1/_2$"
16"	70	80	90	100*					
18"		72.5	81.5	90.5	100*				
24"						80	86.5	93	100*

*Maximum exposure recommended for roofs

Figure 21
Shingle coverage

Slope	Maximum exposure recommended for roofs:	
	18"	24"
4/12 & steeper	$7^1/_2$"	10"*

*24" x $^3/_8$" handsplit shakes limited to 5" maximum exposure

Figure 22
Maximum recommended exposure for roof shakes

Let's look at an example. If the house you're roofing is 1,500 square feet, and you're using 18-inch shingles with a $4^1/_4$-inch exposure, determine the number of bundles you'll need. According to the chart in Figure 21, one square of four bundles covers $81^1/_2$ square feet. Divide 1,500 by 81.5 to find out how many squares you'll need. The answer is 18.4 squares, rounded to 20. Allowing for a 10 percent waste factor, you'll need to order another 2 squares, which will give you 22 squares or 88 bundles. Most suppliers will let you return unbroken bundles, so it's better to always round up. That way if there's any error, it's on the generous side, and you won't be short shingles.

Shakes

Figures 22 and 23 give you the maximum exposure and coverage for shakes.

Roof Deck Requirements

You can install wood shingles and shakes over either spaced or solid sheathing. Spaced sheathing promotes good air circulation, which is especially desirable for shakes. However, your local code may require solid sheathing for both shakes and shingles, particularly in earthquake areas. In areas where wind-driven snow occurs, solid sheathing is often required under shakes. It's also often required under treated shakes and shingles.

Shake	Coverage based on $^1/_2$" spacing between shakes				
	5	$5^1/_2$	$7^1/_2$	$8^1/_2$	10
18" × $^1/_2$", $^3/_4$" handsplit-and-resawn		55a	75b		
18" × $^5/_8$" tapersawn		55a	75b		
24" × $^3/_8$" handsplit	50c		75a		
24" × $^1/_2$", $^3/_4$" handsplit-and-resawn			75a	85	100b
24" × $^5/_8$" tapersawn			75a	85	100b
24" × $^5/_8$" tapersplit			75a	85	100b

(a) Maximum recommended weather exposure for 3-ply roof construction.
(b) Maximum recommended weather exposure for 2-ply roof construction.
(c) Maximum recommended weather exposure.

Figure 23
Shake coverage

You can use either plywood or waferboard sheathing panels. They should be a minimum of $^{15}/_{32}$ inches thick. In areas where you can have spaced sheathing, use 1- by 4-inch boards for shingles and 1- by 6-inch boards (or wider) for shakes. Space the boards on centers equal to the weather exposure at which you will be laying the shakes so that each shake or shingle will be nailed to the center of the board.

How you apply roofing felt depends on whether you're using spaced or solid sheathing. With solid sheathing you'll need an underlayment of felt over the entire roof. You don't need felt if you're installing shingles over spaced sheathing (see Figure 24). That's because the purpose of felt is to protect the roof from weathering; but at the same time, the felt stops air circulation. So a solid layer of felt over spaced sheathing defeats the advantages of using the spaced sheathing. However, when you're installing shakes you need an interlayment or "lacing" of felt between courses whether you use solid or spaced sheathing. The lacing is a layer of felt laid over the top portion of each course of shakes (Figure 25). The top of the felt must rest on and be attached to the sheathing. It acts as a baffle to keep wind-driven snow and foreign materials from getting into the attic during extreme weather conditions. In some fair-weather areas, you may be able eliminate the lacing. Check with your local code.

Fasteners

Use rust-resistant, hot-dipped galvanized coated nails or aluminum nails. Attach each shingle or shake with no more than two nails. The length of the nail you use will vary with the thickness of the shake or shingle, but it must be long enough to penetrate the roof sheathing by $^3/_4$ inch or go through the sheathing thickness, whichever is less. (See Figure 26.)

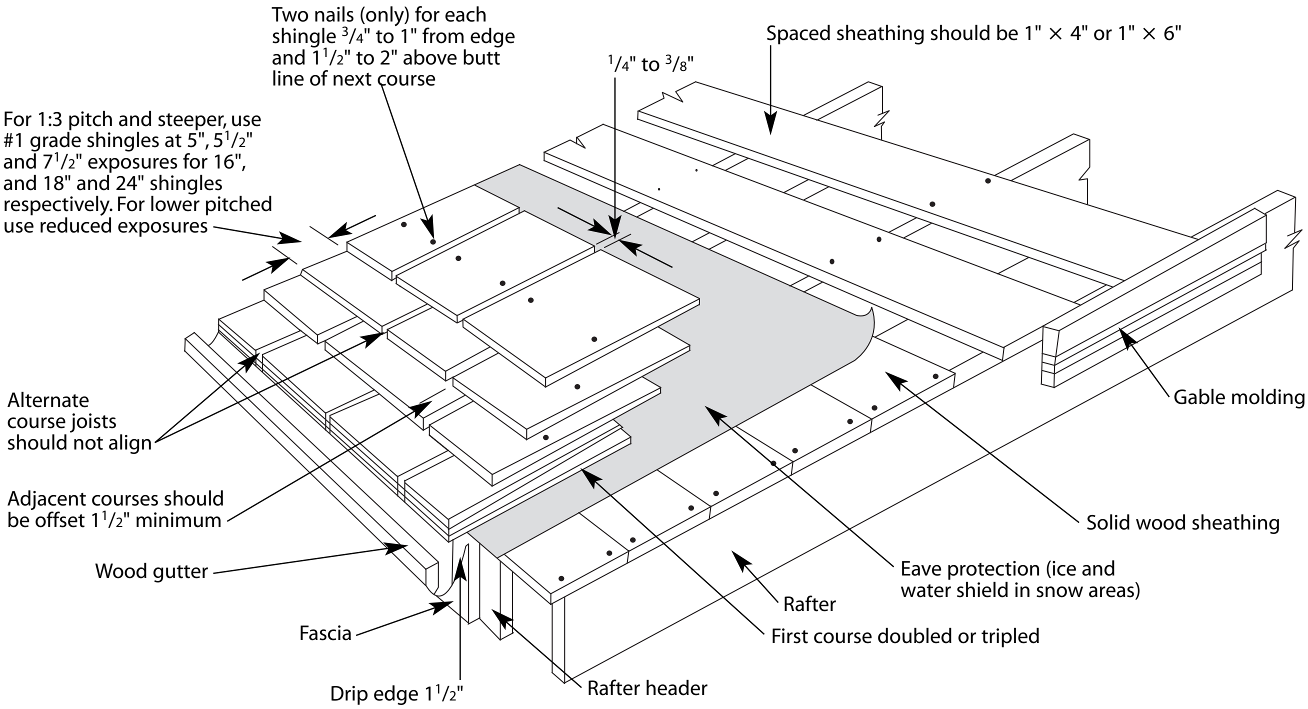


Figure 24 Courtesy of Cedar Shake & Shingle Bureau

Shingles applied over spaced sheathing

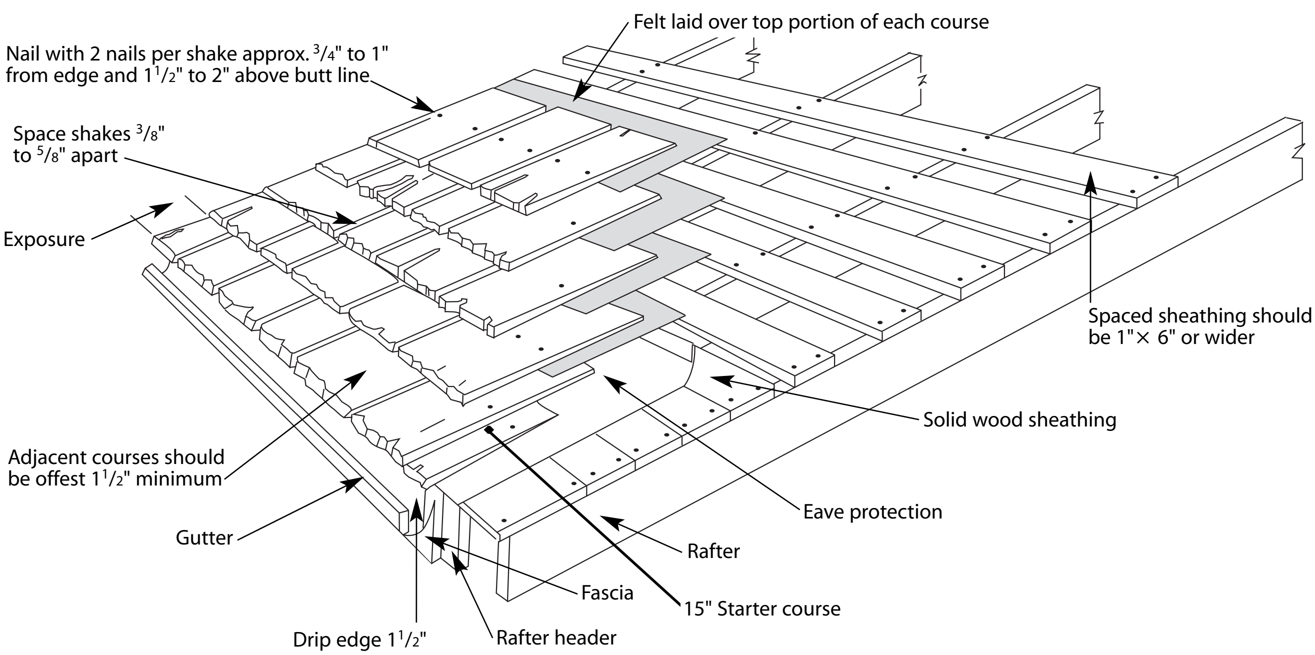


Figure 25 Courtesy of Cedar Shake & Shingle Bureau

Shakes applied over spaced sheathing

Type of shingle/shake	Nail type	Minimum length
Shingle – New Roof		
16" and 18"	3d	1 1/4"
24"	4d	1 1/2"
Shakes – New Roof		
18" straight-split	5d	1 3/4"
18" and 24" handsplit-and-resawn	6d	2"
24" tapersplit	5d	1 3/4"
18" and 24" taper-sawn	6d	2"

Figure 26
Nail chart

Courtesy of Cedar Shake & Shingle Bureau

It's more common to use staples rather than nails. The staples should be 16-gauge aluminum or stainless steel (Types 304 or 316). Use two staples per shingle or shake, and shoot the staples so the crowns are horizontal to the butt, placing them with the same guidelines as nails. Use a staple with a 7/16-inch crown. It will penetrate the sheathing by at least 1/2 inch. Drive it flush to (not into) the surface of the shingle or shake.

You'll need to use longer fasteners with reduced shingle or shake exposures because of the added thickness. The same applies if you are attaching shingles or shakes over an existing roof. Nailing at hip and ridge locations also requires a longer fastener.

Installation Methods

You can install shingles and shakes with a basic set of tools. To the novice, shingles and shakes appear to be very similar products, and so logically, you might think that you would install them in the same way. But there are small but significant differences. Note the following guidelines for wood shingles and wood shakes. Figure 27 summarizes the installation requirements.

Tools

- *Chalk line*
- *Tape measure*
- *Utility knife*
- *Metal straightedge*
- *Block plane*
- *Level*
- *Hammer*
- *Keyhole saw*
- *Shingler's hatchet (an extremely helpful addition for installing shingles and shakes)*

Steep Roof Installation

Shingles —

1. When the sheathing and felt are in place, attach a shingle at each end of a straight run of the roof. Nail the shingles to the fascia, using no more than two fasteners per shingle. Set the butts of the shingles 1 1/2 inches beyond the fascia or last sheathing board. (If you use gutters or eaves troughs, extend the shingle only 1 inch.)

Installation	Shingles	Shakes
Sheathing	Use either spaced or solid sheathing, depending on local code requirements.	Same as shingles.
Felt	Use No. 15 or heavier roofing felt as specified by your local code. Lay felt over entire surface of solid sheathing. Do not use felt over spaced sheathing.	At the eaves line, apply a 36-inch roofing felt, No. 15 or heavier, as specified by local code. After each course of shakes, lay an 18-inch strip of roofing felt (check your local building code for the weight requirements) over the top portion of the shakes and onto the sheathing. The purpose of the felt is to help deflect water, but if it's directly exposed to the weather, it will quickly deteriorate. So it must be laced, or woven, between layers of shakes. To do this, place the bottom edge of the roofing felt twice the exposure distance up from the butt. In other words, for a shake with an exposure of 10 inches, start the roofing felt 20 inches up from the butt. The felt will cover the top 4 inches of the shake and then extend onto the sheathing another 14 inches. The top edge of the felt must rest on the spaced sheathing. Staple the felt only at its top edge. (Refer to illustration in Figure 25.)
Flashing	Underlay flashing with No. 15 or heavier roofing felt as specified by local code. For roofs with slopes of 12:12 or greater, the flashing should extend at least 7 inches on each side. For slopes of less than 12:12, extend the flashing at least 10 inches on each side.	Underlay flashing with No. 15 or heavier roofing felt as specified by local code. Flashing should have a total minimum width of 20 inches.
First course	Double- or triple-course the first row of shingles at all eaves (refer to Figure 24).	Double- or triple-course the first row of shakes, using either wood shingles or 15- or 18-inch starter shakes as the first course.
Shingles/shakes	Place butts of the first course of shingles $1^1/_2$ inches beyond the fascia or last sheathing board. When gutters or eaves troughs are installed, reduce the shingle extension to 1 inch. At gable end, use a 1-inch overhang.	Same as shingles with these exceptions: a. When gutters or eaves troughs are used, you can reduce the overhang to $^3/_4$ inches. b. At gable ends, use a 2-inch overhang.
Fastening	Using no more than two nails or staples, fasten shingles $^3/_4$ inch from each edge and about 1 or 2 inches above the butt line of the course to follow. Drive the nails flush to the surface of the shingle, not into the fiber of the wood.	Fasten shakes 1 inch from edge and 1 to 2 inches above the butt line. Drive nail flush to the surface of the shake.

Figure 27

Wood shake and shingle installation

Installation	Shingles	Shakes
Joints	1. Leave a minimum of 1/4 inch and a maximum of 3/8 inch joint or slot space between adjacent shingles. 2. Separate joints in any one course at least 1 1/2 inches from joints in adjacent courses. In any three courses, do not let two joints fall in direct alignment. In lesser grade shingles containing both flat and vertical grain, do not align joints with the center line of the heart. 3. Split flat grain shingles wider than 8 inches in half before fastening. Treat knots and similar defects as you would a joint, and leave a 1 1/2-inch space between the defect and the joints of adjacent courses.	1. Leave a minimum of 3/8 inch and a maximum of 5/8 inch joint or slot space between adjacent shakes. 2. Same as shingles. 3. Same as shingles.
Valleys	Do not lay shingles with the grain parallel to the valley centerline. Angle cut the shingles to follow the valley line. Avoid having joints between shingles break in the valley whenever possible.	Same as shingles.
Hips and ridges	Install roofing felt over hip or ridge, regardless of whether you've used spaced or solid sheathing. Use premanufactured hip and ridge units to save money and to ensure a more uniform look. Otherwise, hip and ridge shingles should be a uniform width in a range of 3 inches to 5 inches. Attach them in an alternate overlap, making sure the exposure remains consistent with previous courses.	Use the same pattern, except the uniform width should be in a range of 4 inches to 6 inches.
Miscellaneous		Lay straight-split shakes with the froe end (the end from which the shake has been split and which is smoother) towards the ridge.

Figure 27 (continued)
Wood shake and shingle installation

2. Drive a shingle nail into the center of each butt. Stretch a line between nails. If the run is more than 10 feet long, add additional shingles to use as a benchmark to keep the line even. Fill in the rest of the first course, fastening each shingle to the fascia.
3. Place the next course of shingles on top of the first. Using the shingler's hatchet as a gauge, fasten the shingles 1 to 2 inches above the exposure line. Stagger the joints at least $1^1/_2$ inches between courses.
4. Using either the hatchet guide or a chalk line, lay the next course of shingles.

Shakes, Option One —

1. When the sheathing is in place, lay a 36-inch-wide strip of felt and staple the top edge to the sheathing. Attach a shingle or starter shake at each end of a straight run of the roof. Fasten the shingles or shakes to the fascia, using no more than two nails or staples per piece. Set the butts $1^1/_2$ inches beyond the fascia or last sheathing board. (If you use gutters or eaves troughs, extend the shingle or shake only $^3/_4$ inches.)
2. Drive a shingle nail into the center of each butt. Stretch a line between nails. If the run is more than 10 feet long, add additional shingles or shakes to use as benchmarks to keep the line even. Fill in the rest of the first course, fastening each shingle or shake to the fascia.
3. Stretch an 18-inch strip of felt just above the exposure line where the next course will start. Staple the top edge of the felt. Lay the next course of shakes directly over the first course. Stagger the joints so they're at least $1^1/_2$ inches apart. Fasten the shakes 1 to 2 inches above the exposure line.
4. Lay the next strip of felt twice the exposure distance up from the butt of the bottom course. In other words, for a shake with an exposure of 10 inches, start the roofing felt 20 inches up from the butt. The felt will cover the top 4 inches of the shake and then extend onto the sheathing another 14 inches. The top edge of the felt must rest on the spaced sheathing. Staple the felt only at its top edge.
5. Attach the next course of shakes. As a guide, align the row of shakes with the felt that shows through between the joints of the double course. Stretch the next strip of felt across the top of the shakes twice the exposure distance up from the butt of the current course. Repeat the pattern of shakes and felt for the rest of the roof.

Shakes, Option Two — Some roofing contractors lay the felt strips for the entire roof at one time rather than one course at a time. You fasten the felt at the top edge only, attaching it to the sheathing. Slip the shakes under the felt the same distance as in option one. Fasten the shakes at the same points. The main difference between these two options is the order in which you lay the materials.

Installing Shingles or Shakes on Low Slopes

Generally, wood shingles and shakes shouldn't be installed on roofs with a slope of less than 4:12. However, sometimes a house may have a small roof area that has a low slope, and it would look odd to have a different roofing material on that section if the rest of the house is roofed in shingles or shakes. Although it's less than ideal, you can use the following installation procedures (which are really for a double roof) as a good compromise. Check first with your local building code to make sure this is acceptable in your area.

1. Install a built-up roof. With the final hot-mop, attach 2- × 4-inch red cedar spacers or preservative-treated lumber spacers in the bituminous coating. Place the spacers over the rafters at 24 inches, extending from eave to ridge.
2. Attach 1- × 4-inch or 1- × 6-inch nailing strips, spacing them so the boards are placed equal to the exposure for nailing. In other words, if you're setting 18-inch shakes with a $7^1/_2$-inch exposure, the spacers underneath should be set $7^1/_2$ inches on center.
3. Attach the starter shingles and proceed in the same way as for a steep roof.

Flashing Installation for New Roof Construction

Install flashing for shingles and shakes in the same manner. Use flashing at all valleys, where the roof meets another structure, or wherever rain or moisture will be channeled. The flashing provides a collecting point and is designed to move moisture quickly away from the roofing materials. If water is allowed to gather on or seep through the flashing at any point, eventually there'll be a leak in the roof.

Consequently, the most important thing to keep in mind when working with flashing is to avoid puncturing it, either when you place the flashing or overlay it with roofing material. In other words, *don't nail through the flashing*. Instead, nail through the side clips to secure it to the roof. If the flashing doesn't have side clips, drive a large-headed roofing nail on the outside of the fold with the nail head overlapping the fold to hold it in place. To lay shingles or shakes over this, fasten the outside edges of the shingles or shakes to the sheathing like you ordinarily would. For the inside edges, use shorter nails and drive them just to the point of contact with, but not into, the flashing. This will further help hold the flashing in place.

Refer to your local code for size specifications and metal selection to reflect local climate conditions. Galvanized steel is the most commonly used flashing material, but copper and even double layers of 90-pound felt are acceptable in some areas. When considering copper, remember that in addition to being the most expensive flashing material, it may corrode rapidly as a result of the acid released by red cedar when it rains. Likewise, 90-pound felt isn't generally as durable as galvanized steel.

Whichever type of flashing you use, it must have the same longevity as the shingles or shakes. Otherwise, you'll have to replace the flashing before the roofing material — hardly the sort of thing that makes a homeowner smile. If you use galvanized metal, it should be no less than 26 gauge. Also, you need to paint metal flashing on both sides with a good metal or bituminous paint. If you have to bend the material to a sharp angle, paint it after bending to maintain the integrity of the coating.

You can buy metal flashing prebent, have it custom made, or you can even make it yourself. When buying or making flashing, always think in terms of what you need to keep water from being trapped under the roofing material.

***Valleys* —** Lay 36-inch wide adhered bitumen membrane underlayment along the valley. It's fairly expensive but self-sealing when nailed through and almost guarantees a leak-free valley. Flashing should have a 1-inch center crimp, and the sides should have a $^1/_2$-inch fold. If necessary, overlap pieces by 6 inches and seal it with mastic or tar. Leave a $2^1/_2$- to 3-inch space on each side of the center of the valley. Some professionals recommend a gradual widening of the valley as it goes from top to bottom to prevent ice from damming up at the bottom, although visually a valley that stays equal in width the entire length is more attractive. Where two valleys meet, cover the joint with a lead saddle.

***Gambrel Roof* —** Flashing should have a 1-inch crimp, $^1/_2$-inch folds, and a minimum length of 5 inches on the upper side of the fold and 4 inches on the lower side. The edges should fold over $^1/_2$ inch, with the upper fold turned up and over and the lower fold turned down and under. If a single length won't cover the distance, use a 6-inch overlap and seal it with mastic or tar.

***Change in Roof Slope (Steep to Less Steep)* —** Flashing should be a minimum length of 18 inches on the upper portion and a minimum of 4 inches on the lower portion. Like flashing for a gambrel roof, the $^1/_2$-inch upper fold should be turned up and over, and the $^1/_2$-inch lower fold turned down and under. Overlap lengths by 6 inches and seal with mastic or tar.

Convex Juncture — The upper length, or roof portion, should be a minimum of 8 inches, and the lower length, or wall portion, should be at least 4 inches. Place the flashing before you fasten the final course to the top of the wall. With the last course in place, install a narrow band of shingles, shakes, or a strip of wood molding horizontally after you install the final wall course. As with all eaves, use a double or triple starter course, with a $1^1/2$-inch overhang.

Concave Juncture — Install the flashing to cover the top of the roof slope and the bottom 4 inches of the wall before placing the final course of shakes or shingles. Snugly fit the tips of the final course against the wall at the juncture. Use a double starter course on the wall.

Apex Juncture — The metal flashing should cover the top 8 inches of the roof and the top 4 inches of the wall before you apply the final course to the wall. For the best results, apply the shakes or shingles to the wall first and then to the roof. Trim any overhanging material flush with the wall. The ridge cap is slightly different for an apex juncture. Instead of alternating the overlap, the roof piece should always overlap the wall piece.

Vent Pipes — Leave a minimum 1-inch clearance around the pipe and at least 2 inches of clearance from the edge of the flashing flange to all shingle joints.

Dormers — Underlay dormer walls with building paper. The flashing should lie 3 inches up on the dormer and 6 inches on the roof. At the juncture where the angled roof meets the wall, use step flashing. Cut the flashing into 10-inch lengths and overlap the lengths by 5 inches so the exposed area is 5 inches. Along the level roof and wall juncture, seal the overlapped pieces with mastic. The corners themselves should be soldered.

Chimney — Use saddle flashing or cricket flashing on the upslope and apron flashing on the downslope. Solder the corners. Extend the apron flashing at least 3 inches up the vertical surface. It should also go at least $1^1/2$ times the shingle or shake exposure (6 inches minimum) over the roof slope. Carry the cricket flashing at least 10 inches under the shingles or shakes. Extend step flashing over the roof at least 3 inches and up the chimney. It should be covered by at least 4 inches of counterflashing. Lap each step flashing over the next piece by at least 3 inches. Install counterflashing so it extends down within 1 inch of the finished roof surface.

Replacing Wood Shingles and Shakes

You can temporarily repair shingles or shakes that are cracked but not completely split by slipping a galvanized metal patch under the damaged shingle or shake. The metal should be about 2 inches longer and

2 inches wider than the split. For various reasons wood shingles and shakes may curl up along the edges. When this happens, you can nail down the edges, but at best this is a short-term solution. For long-lasting repair, your best choice is to replace the damaged roofing material. The difficult part in doing this isn't in replacing the shingle or shake, but avoiding breaking the surrounding shingles or shakes.

Tools and Materials

- *Chisel or hacksaw*
- *Sharp knife or ax*
- *Hammer*
- *Small wood block*
- *Replacement shingle or shake*
- *Nails*

Replacement Procedures

Use the following instructions as a guideline for replacing broken shingles or shakes.

1. Remove the broken shingle or shake. If it doesn't pull out easily, carefully break it into narrow sections with a sharp knife, chisel, or ax. (Figures 28a and 28b show a broken shingle and the gap after the shingle is removed.)
2. After removing the shingle or shake, probe under the next course to find the fasteners that held the material in place. The nails or staples should be about 1/4 to 1 inch in from each edge and 1 to 2 inches above the bottom of the next course. Either cut the nails with a hacksaw, or place the blade of the chisel below the nail head and tap the chisel with a hammer to sever the old nail. Don't try to pull the old nails out through the top of the next course.
3. Cut a new shingle or shake to fit the gap, allowing a 1/8 -inch gap on each side of the replacement piece. Tap the new shingle or shake into place, using a block of wood to protect the butt. Pressure from the course lying above it should hold the new piece in place.
4. Another option is to tap the new piece in, leaving it about 3/4 of an inch below the butt line. Place the nails at the butt line of the course above and 1 inch from each edge as shown in Figure 28c. Drive in the nails by angling them upward. Tap the shingle or shake into place, using a block of wood against the butt (Figure 28d). As you push the replacement piece into place, the nail will be hidden.

Cleaning and Maintaining Wood Shingles and Shakes

The chemicals in Figure 29 should all be available through hardware stores, building supply centers, or lumberyards.

Summary Table

Figure 30 summarizes the roofing systems you'll commonly use, including their weight, relative cost, ease of installation and life span.

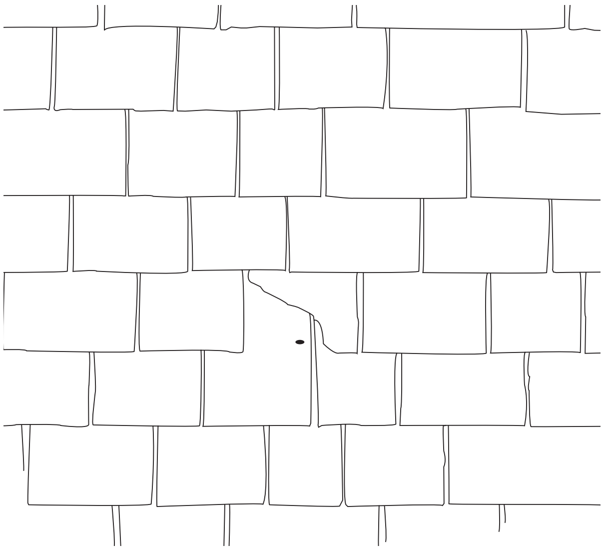


Figure 28a
Replacing damaged shingle

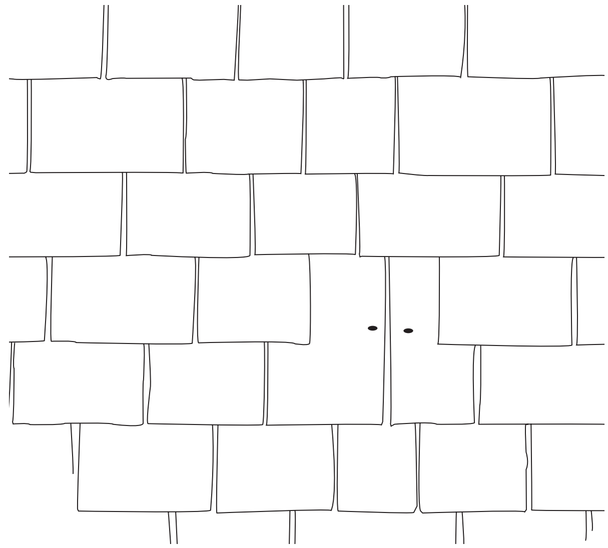


Figure 28b
Damaged shingle removal

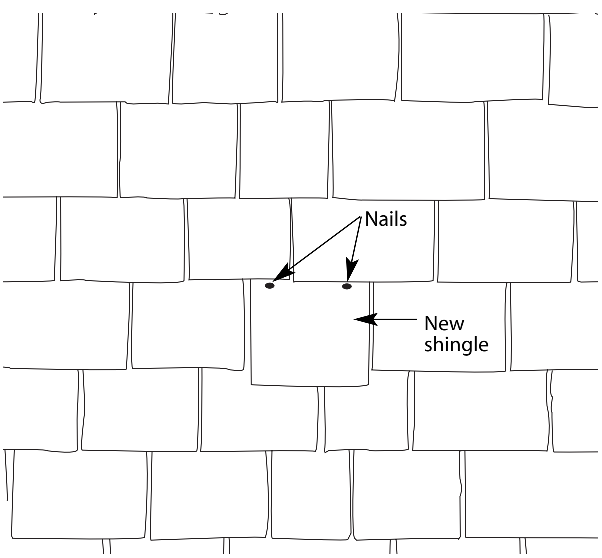


Figure 28c
Place nails at butt line of course above

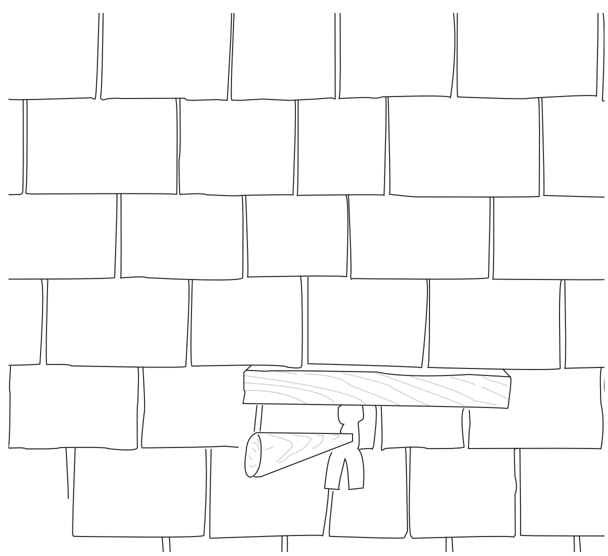


Figure 28d
Tap new shingle flush, hiding nails

Problem	Solution	Procedure	Comments
Light staining or irregular discoloration	3 oz. TSP 1 oz. laundry detergent (i.e. Tide or All) 1 qt. 5% liquid bleach (i.e. Clorox) 3 qt. warm water	Apply mixture; lightly scrub surface with soft brush or broom; rinse.	If mixture splashes on plants, rinse them thoroughly.
Persistent stains not removed by detergent solution	Use liquid bleach full strength; or 2 oz. granular chlorine (calcium hypochlorite) 1 gal. water	Apply with brush for small spots; spray large areas, using plastic or stainless steel sprayers; don't let solution stand more than $^{1}/_{2}$ hour; rinse.	Wear eye protection, rubber gloves, and apron. Apply out of direct sunlight. Better results are obtained with several lighter applications instead of one highly concentrated one.
Moss control	Light or small patches may be removed by simply sweeping.		
	Use the following solutions (listed in order of effectiveness):	Solutions are most effective when moss is growing rather than dormant; wet moss first, if necessary, to increase absorption; most effective when rain isn't likely for several days.	After you have killed moss using one of the solutions listed (which may take several days), sweep it off the roof.
	1. 3 lb. zinc sulfate (monohydrate) powder 5 to 10 gal. water	Spray on with watering can or pump sprayer; solution covers approximately 600 sq. ft.	Don't use with copper gutters, downspouts, or flashing because zinc sulfate corrodes copper. Thoroughly wash all exposed gutters, flashings, application equipment, and plants.
	2. $^{1}/_{4}$ to $^{1}/_{2}$ oz. copper sulfate (blue stone) 10 gal. water	Spray on.	This solution is safer on copper than #1, but is still corrosive to metals; flush all metal surfaces thoroughly after application.
	3. 1 pt. zinc chloride 3 gal. water	Soak moss thoroughly; solution covers about 100 sq. ft.	As with #1 and #2, flush metals and plants thoroughly after application.
	4. Potassium salts of fatty acids	Follow manufacturer's instructions. Rinse off overspray on plants.	These are noncorrosive and offer minimal hazards to people and plants.
	5. Weed-killing compounds	Follow manufacturer's instructions. Rinse overspray on plants.	Also noncorrosive and offers minimal hazards to people and plants.

Figure 29
Cleaning and preserving shingles and shakes

Problem	Solution	Procedure	Comments
Preservation treatment to retard growth of molds, mosses, and fungi	1. 2% copper naphthenate or copper octoate 1 gal. water	Apply at a rate of 100 sq. ft./gal. for shakes or 150 sq. ft./gal. for shingles. Better to use several uniform light coats rather than one heavy one. Apply with a brush, thick-napped roller, or spray equipment, taking special care to cover the butts as well as the exposed shingle or shake surface.	Should protect for up to 5 years. Can produce a greenish color that may be counteracted with a pigmented solution. Preservation treatments are more effective on new roofs than old ones.
	2. 4% zinc naphthenate 1 gal. water	Apply at the same rate as above; will leave gray/silver wood color intact. Again, use several uniform light coats rather than one heavy one. Apply with a brush, thick-napped roller, or spray equipment, taking special care to cover the butts as well as the exposed shingle or shake surface.	Weaker solution will protect up to 3 years; stronger up to 5 years. More effective on new roofs than old ones.
	3. Zinc and copper strips	Fasten 2-inch-wide strips to either side of ridges for the entire length of the roof. Rain will cause zinc to leach and run down roof, preventing moss, etc. from growing.	On very large roofs, you may need to add strips lower down on the roof as well.

Figure 29 (continued)
Cleaning and preserving shingles and shakes

Roofing System	Slope		Weight *	Underlayment	Fasteners	Cost **	Ease of Installation ***	Life span
	Minimum	Maximum						
Built-up roofing (BUR)	1/4 to 1/2:12		Ply Bitumen (asphalt) @ 20-30 Surfacing Bitumen @ 60-75	Fiberglass base or 43 lb felt, spot mopped	Some types, placed on slope of 1:12 or greater, require laying parallel to slope (strapping) and back nailing	Inexpensive	Requires experience and special equipment; generally subcontracted	10 to 20 years, depending on number of plies and surfacing
Modified bitumen roofing	1/4:12 — suitable for barrel roof		APP (torch) 108 lb/sq SBS (mop) 125 lb/sq	43 lb organic or 28 lb glass base	Sealed by torch or electrical heat or by cold process	Moderate	Easy to moderate (potential fire danger adds to difficulty)	10 to 20 years

Figure 30
Roof systems

Roofing System	Slope		Weight *	Underlayment	Fasteners	Cost **	Ease of Installation ***	Life span
	Minimum	Maximum						
EPDM (rubber roofing)	Flat or barrel roof		26 – 35 lb/sq	None	System mechanically attached by regular fasteners	Inexpensive to very expensive, depending on system used	Difficult	10 to 20 years
Asphalt roll roofing;				15 lb felt	Nails and cement	Very inexpensive	Easy	5 to 10 years
Smooth:	0:12	6:12	50 – 65 lb/sq					
Mineral surface:			90 lb/sq					
Double coverage fiberglass:	1/2:12	4:12	60 lb/sq					
Fiberglass reinforced:	1/8:12	4:12	75 lb/sq					
Asphalt shingles;				15 lb felt	Galvanized steel or aluminum roofing nails or zinc coated staples	Inexpensive	Easy	20 to 40 years
3 tab:	4:12	12:12	235 lb/sq					
2 tab:	4:12	12:12	300 lb/sq					
Dimensional:	4:12	12:12	345 lb/sq					
No cutout:	2:12	12:12	290 lb/sq					
Fiberglass shingles;				15 lb felt	Galvanized steel or aluminum roofing nails or zinc coated staples	Very inexpensive	Easy	20 to 40 years
3 tab:	4:12	12:12	210 – 225 lb/sq					
2 tab:	4:12	12:12	260 lb/sq					
Dimensional:	4:12	12:12	245 – 370 lb/sq					
No cutout:	4:12	12:12	225 lb/sq					
Wood shakes	4:12		Handsplit and resawn 200 – 450 lb/sq* Taper split 260 lb/sq*	Spaced or solid sheathing; 30 lb felt interlayment	Corrosion resistant nails	Moderately expensive	Moderate	15 to 40 years
Wood shingles	4:12		200 lb/sq*	Open or solid sheathing; 30 lb felt	Corrosion resistant nails	Moderately expensive	Moderate	20 to 50 years

Figure 30 (continued)
Roof systems

Roofing System	Slope		Weight *	Underlayment	Fasteners	Cost **	Ease of Installation ***	Life span
	Minimum	Maximum						
Clay tile; Shingle flat: Interlocking flat: French: Spanish:	 3:12 3:12 3:12 4:12		 800 – 1600 lb/sq 800 lb/sq 940 – 1000 lb/sq 850 lb/sq	30 or 45 lb felt over plywood	Noncorrosive copper nails	Expensive	Difficult	30 to 70 years
Concrete tiles	4:12		950 – 1200 lb/sq	30 lb felt over plywood	Corrosion resistant galvanized copper or stainless steel box nails	Expensive	Difficult	30 to 50 years
Slate	4:12		Commercial grade 700 – 800 lb/sq Quarry – run rough 825 – 3600 lb/sq	30 lb felt over plywood	Slaters hard copper wire nails, cut copper, cut brass, or cut yellow metal slate nails	Very expensive	Most difficult	100 years
Seamed metal roofing; Aluminum coated steel: Copper coated galvanized: Prepainted galvanized steel: Zinc-copper titanium alloy:	 1/4:12 3:12 3:12 3:12		 250 lb/sq 130 lb/sq 130 lb/sq 100 lb/sq	 None 30 lb felt 30 lb felt Roofing felt	 Clips and interlocking seams Anchor clips, galvanized nails, screws Anchor clips, galvanized nails, screws Galvanized U channel or L seam support spacer with screws or nails	Varies	Difficult to most difficult	Varies

Figure 30 (continued)
Roof systems

Roofing System	Slope		Weight *	Underlayment	Fasteners	Cost **	Ease of Installation ***	Life span
	Minimum	Maximum						
Seamed metal roofing (continued);						Varies	Difficult to most difficult	Varies
Terne coated stainless steel standing, batten seam:	3:12		89 lb/sq	Roofing felt and rosin paper	TCS cleats, stainless steel nails			
Terne coated stainless steel, flat locked seam:	1/2:12		89 lb/sq	Roofing felt and rosin paper	TCS cleats, stainless steel nails			
Terne plate, standing, batten seam:	3:12		62 lb/sq	Rosin paper	Tern cleats, roofing nails			
Terne plate, flat locked (wood deck):	1/2:12		62 lb/sq	Rosin paper	Tern cleats, roofing nails			
Painted aluminum:	1/2:12		70 – 90 lb/sq	None	Anchor clips			
Iron and steel or galvanized iron corrugated roofing	3:12		70 – 570 lb/sq, depending on gauge	None	Corrosion resistant self-tapping screws, bolts, welded studs, power driven fasteners or nails in wood; use neoprene washers	Very expensive	Easy	15 to 20 years
Protected steel corrugated roofing	4:12		150 – 275 lb/sq, depending on gauge	None	Corrosion resistant self-tapping screws, bolts, welded studs, power driven fasteners or nails in wood; use neoprene washers	Inexpensive	Easy	15 to 30 years
Aluminum corrugated roofing	3:12		40 – 110 lb/sq	None	Aluminum nails, sheet metal screws, clips	Inexpensive	Easy	15 to 30 years

Figure 30 (continued)
Roof systems

Roofing System	Slope		Weight *	Underlayment	Fasteners	Cost **	Ease of Installation ***	Life span
	Minimum	Maximum						
Corrugated fiberglass, wire-reinforced plastic	3:12		40 lb/sq	None	Self-tapping screws, drive screws and nails; use neoprene washers	Inexpensive	Easy	15 to 25 years
Corrugated glass or plastic, non-reinforced plastic	1:12		40 lb/sq	None	Self-tapping screws, drive screws and nails; use neoprene washers	Inexpensive	Easy	15 to 25 years

* Weight will vary with the humidity and moisture in the air.
** Costs will vary within a range according to grade selected, painted vs. galvanized, and local labor costs. These are meant to be a general guideline only: Very expensive – $500 to $2,000/sq; Expensive – $200 to $500/sq; Moderate – $150 to $200/sq; Inexpensive – $100 to $150/sp; Very inexpensive – under $100/sq.
*** Ease of installation: Easy – requires some special tools or training but is easily learned; Moderate – requires some special tools, training, and experience; Difficult – requires special tools or training and considerable experience; Most Difficult – should be subcontracted because of special tools or skills required for satisfactory work.

Figure 30 (continued)
Roof systems

Roofing Terms

Asphalt *— a dark, brown to black, cementitious material that is made up primarily of bitumens.*

Asphalt felt *— felt that is asphalt saturated or coated.*

Backnailing *— the process of blind-nailing roofing felts to a substrate, in addition to hot mopping, in order to prevent slippage.*

Base ply *— the first ply of roofing material in a roof membrane assembly.*

Bitumen *— 1. a class of amorphous, black or dark-colored, solid, semi-solid or viscous cementitious substances that occurs naturally, but can also be produced through manufacturing;*
2. a generic term that denotes any material composed principally of bitumen.

Blind nailing *— nailing the back portion of a roofing material so that the fasteners are not exposed to the weather.*

Bond *— the adhesive and cohesive forces that hold two roofing components together.*

Brooming *— to smooth out and embed a ply of roofing material into the ply beneath it using a broom.*

Butt *— the bottom edge of a shingle.*

Butt nailing *— to drive a nail perpendicular to the butt portion of the shingle.*

Cap sheet *— a granule-surfaced coated sheet used as the top ply of a built-up roof membrane or flashing.*

Course *— 1. a single row of shingles;*
2. each layer or application of material in a roofing system.

Cricket *— a small, built-up area designed to divert water around a chimney, curb, or other projection on a roof.*

Cut-out *— the manufacturer's slit or opening in a 2-tab, 3-tab, and T-lock shingle.*

Deck *— the structural surface to which the roofing system (including insulation) is applied.*

Double course *— two layers of shingles applied in a single row; usually done only on the first, or starter course, but may also be done in a ribbon course.*

Drip edge *— flashing material that extends beyond the fascia to prevent water from dripping onto the fascia.*

Ear *— the protruding piece of a shingle that locks into the slits on adjacent shingles.*

Eaves *— the horizontal lower edge of the roof.*

Embedment *— the process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive.*

Exposure or weather exposure *— the portion of the shingle that isn't covered by other shingles but is left exposed to the weather.*

Face nailing *— to drive a nail perpendicular to the face of the work.*

Flashing *— a system, made of either metal or asphalt felt, used to seal exposed roof areas where the roof is interrupted or stopped; there are several types of flashing used in roofing, such as:*

a. base flashing, which covers the edge of the membrane;

b. cap flashing or counterflashing, which covers the upper edges of base flashing or laps down over the wall or step flashing;

c. saddle flashing, which is placed on the upper side of a chimney or other projection to divert water;

d. step flashing, which is a series of flashing pieces that overlap each other as they stair-step up a slope.

Glass felt *— glass fibers bonded into a sheet with resin.*

Inorganic *— material that is not of plant or animal origin.*

Lace *— the process of weaving or interlaying felt between courses of wood shakes.*

Membrane *— a flexible or semi-flexible roof covering or waterproofing layer.*

Mopping *— the application of hot bitumen, using a mop or mechanical applicator, to the substrate or to the felts of a built-up roof membrane.*

Organic *— material that is composed of plants or animals or of hydrocarbons or their derivatives.*

Ply *— a layer of felt in a built-up roof membrane system.*

Rake *— the slope edge of a roof at the first or last rafter.*

Ribbon course *— a double course of shingles used to create a distinct visual effect.*

Ridge *— the horizontal upper edge of the roof.*

Saddle *— a small structure designed to channel water away from the upper side of a chimney or other roof projection.*

Saturated felt *— a felt that has been partially saturated with low-softening-point bitumen.*

Selvage *— a manufactured edge or edging that differs from the main part of the material.*

Single course *— a single layer of shingles in a course.*

Square *— a common unit of roofing measurement consisting of a 10-foot by 10-foot section, or 100 square feet.*

Starter course *— the first course of shingles or roll roofing placed at the eaves edge.*

Substrate *— the surface, such as the structural deck or insulation, upon which the roofing or waterproofing membrane is applied.*

Tab *— the individual exposed section of a shingle.*

Tail *— the tapered or thin end of a wood shake or shingle.*

Underlayment *— roofing felt that is laid over the substrate before the shingles or other roofing material is applied.*

Valley *— the point where two sloping roofs join; shingles or other roofing materials are applied with flashing in a manner which protects the valley and encourages proper roof drainage. There are two types of valley applications:*

a. a closed valley is a valley in which the shingles are run into each other across the valley and the flashing is not exposed;

b. an open valley is a valley in which the roofing materials are cut back from the valley center and the flashing is exposed.

Manhours

Manhours to Install Roofing		
Type	**Manhours**	**Suggested crew**
Asphalt roll roofing, 72 lb, 108 SF roll	1.03 per square	1 roofer, 1 laborer
Asphalt roll roofing, 72 lb, 96 SF roll	1.16 per square	1 roofer, 1 laborer
Asphalt shingles	2.05 per square	1 roofer, 1 laborer
Wood shakes (sawn), 1/2" to 3/4" x 24"	3.52 per square	1 roofer, 1 laborer
Wood shakes (sawn), 3/4" to 5/4" x 24"	4.16 per square	1 roofer, 1 laborer
Wood shakes (tapersplit), 1/2" x 24"	3.52 per square	1 roofer, 1 laborer
Wood shakes, hip and ridge units	1.00 per bundle	1 roofer, 1 laborer
Wood shingles	3.52 per square	1 roofer, 1 laborer
Wood shingles, hip and ridge units	.500 per bundle	1 roofer, 1 laborer

For information on related topics, see:

Asbestos, page 31

Framing Materials and Planning, page 363

Insulation, page 395

Porches and Decks, page 485

Roof Framing, page 513

Windows and Skylights, page 747

Siding

The exterior finish — whether it's brick, stucco, wood, aluminum, vinyl, or mineral fiber — is what gives a structure its character and distinction. Each type of finish has advantages and disadvantages. Brick and other masonry finishes, are the most durable. If correctly maintained, their solid beauty will last centuries. Stucco, which is a cement-lime material, requires little maintenance, but is more susceptible than some other finishes to changes in climate.

Although many people value the natural look of wood sidings they require a great deal of maintenance. Aluminum and vinyl are newer materials that require less upkeep than wood. Many customers feel that aluminum siding has a cheaper, less aesthetic look than other siding materials. As a result, it's being edged out of the market by vinyl. Even though vinyl doesn't have the natural beauty of wood, it offers many of the advantages of aluminum without its disadvantages, and it's more reasonably priced and easier to install than wood.

Of all the available siding materials, mineral-fiber shingles are the least desirable. Currently, they're made of portland cement and fiberglass, but in the past they were made of asbestos, which is no longer used in construction. Although mineral-fiber shingles tend to be fairly cheap and have high fire resistance, their brittle nature makes them tough to install and repair and their appearance over time is unappealing.

The chart in Figure 1 shows common siding materials and some of their advantages and disadvantages.

Surface Preparation

In new construction, you place siding over sheathing and either building paper or an air barrier. In remodeling, you can usually install new siding over existing wood or mineral-fiber siding, providing the old siding is still in good shape.

Type	Cost	Ease of Installation	Advantages	Disadvantages
Wood shingles and shakes	Very expensive	Most difficult and labor intensive	Natural beauty; easy repair	High initial cost; high maintenance (it must be restained or resealed at least every 5 years, more often in humid or sunny climates); poor fire resistance.
Wood lap boards	Expensive	Difficult and labor intensive	Natural beauty	High initial cost; high maintenance (it must be repainted every 7 years or restained or resealed every 5 years, more often in humid or sunny climates); poor fire resistance.
Board and batten	Moderately expensive	Easy	Easy installation; natural beauty	High maintenance (it must be repainted every 7 years or restained or resealed every 5 years, more often in humid or sunny climates); poor fire resistance.
Hardboard and plywood panels	Inexpensive	Easy	Inexpensive; easy to install	Very high maintenance; boards tend to warp and crack if not maintained properly; shorter life span than other wood sidings.
Aluminum	Moderately expensive	Moderately difficult	Good fire resistance; comes in a variety of colors and textures; easy to maintain; can be painted	Fades and dents more easily than wood; more difficult to repair; considered less aesthetic than wood by some; may need to be grounded.
Vinyl	Inexpensive	Moderately difficult	Long life span; easy maintenance (only needs occasional washing); doesn't fade or rust; good fire resistance	May crack in cold temperatures and sag in hot sun.
Mineral fiber	Inexpensive	Moderately difficult	Good fire resistance; low maintenance, although it may chalk as it ages	Breaks easily; very difficult to replace.

Figure 1
Common siding materials

If the old siding is deteriorating, you can do one of two things: remove the old siding down to the sheathing, or install furring strips over the existing siding and attach the new siding to the strips.

Of the two choices, furring strips are definitely easier. Stripping off old siding is labor intensive, and disposal of the trash can be a problem, particularly if the old siding was made of asbestos.

Dealing with Asbestos

When the asbestos scare was at its peak, some city health departments made contractors literally envelop the house in plastic while they removed asbestos shingles. The waste could then be removed only to certain sites, where the fees were outrageous.

You'll want to check with your local health department for specific regulations in your area now, but in most regions, the current wisdom is that as long as the asbestos shingles are in good shape, they can be removed by a certified asbestos abatement contractor, or they can be sided over.

To dispose of removed asbestos shingles, you must slightly dampen them, double bag them in 6-mil trash bags, and seal the bags with duct tape. In addition, you must label the bags with the name of the structure owner and the address of the building from which the shingles were removed, as well as the name and address of the person or company hauling them to the disposal cite. Each load requires a nonhazardous waste manifest form, and most dump sites will only accept the material on certain days because it requires special disposal at the dump sites. The cost per yard for disposal is still considerably higher than regular trash, ten times or more in most areas. Clearly, it's easier and certainly cheaper just to side over asbestos shingles whenever you can.

Installing New Siding Over Existing Siding

If the existing surface is even, in good repair, and nailable, you can install new siding right on top of the old. However, the new surface will only be as smooth and even as the layer it covers, so spend some time checking over the existing siding. Pay particular attention to the following:

- Nail down all loose existing siding, and replace anything that's broken or rotten.
- Remove the old caulking and recaulk around doors, windows, cracks, and other areas that need to be sealed from moisture penetration.
- Check all walls to make sure they're even, and shim where needed.

Once you have made these preparations, you can remove gutters, downspouts, light fixtures, and other obstacles. Tie back the shrubbery around the building to keep it out of your way and prevent it from being damaged during the siding installation. Then you can proceed with re-siding the structure.

Installing Siding Over Furring

If you're dealing with an existing surface that isn't in good shape or isn't nailable, the fastest and easiest way to provide an even, nailable surface is by installing weather-resistant sheathing over the old siding. If you choose not to use sheathing, you'll need to attach furring strips to the existing siding and attach your new siding to that. If the walls are uneven, shim the furring strips to create an even surface.

Depending on what the new siding will be, you can install the furring either vertically or horizontally. Place the strips at all corners and around windows and doors. The distance for the rest of the furring may be anywhere from 12 to 24 inches on center, depending on the replacement siding. Usually, 1- by 3-inch furring strips work well for this purpose.

Wood Shingles

Wood shingles and shakes are an attractive but expensive option for siding a house. The real beauty in using shingles and shakes is their durability. Although both will endure best if they're painted or treated, even unfinished they'll outlast other types of wood siding. Shakes are the rougher of the two; they're split from logs, which makes them thicker and less uniform than shingles. Shingles are cut to size, making them smoother and more uniform. Typically, builders prefer shingle siding over shake because of the coarse, irregular look of shakes. Figure 2 is an example of shingle siding.

Shakes come in standard lengths of 18 or 24 inches and range from $^1/_2$- to $^3/_4$-inch thick at the butt, or exposed end. Shingles come in bundles of 16, 18, and 24 inches and are $^3/_8$-inch thick at the butt. Both come in varied widths and are set with a $^1/_8$- to $^1/_4$-inch gap between each one to allow for expansion and contraction. The portion that's exposed must be slightly less than half of the total length, or $7^1/_2$, $8^1/_2$, and $11^1/_2$ inches for shingles, but more often the exposure is closer to only a third of the total length. The shorter the exposed area, the longer the shingle will last, and the more insulation value it will have. Of course, it also means you'll use more shingles or shakes because the wall will require more courses.

There are also cedar siding panels available that look like shingles but are installed like lap siding. They are attached to a plywood backing and come in 8-foot lengths with a height of one to three courses. They even come in fancy patterns, including fishscale, arrow, octagon, diamond and more.

Because shingle siding is more commonly used, we'll refer only to shingle application in the following section, although the information is accurate for both shingles and shakes.

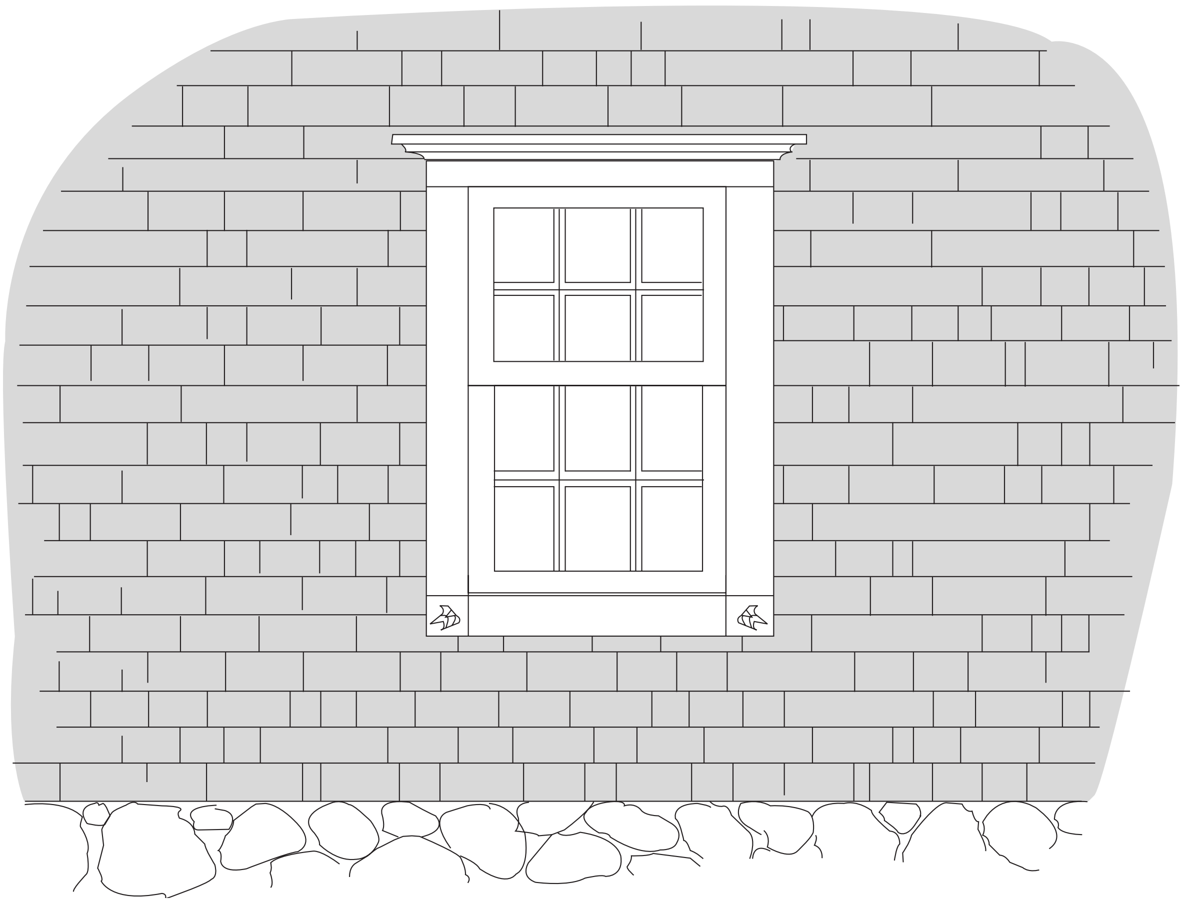


Figure 2
Shingle siding

Types of Shingles

Red cedar is the most common type of shingle produced. As it weathers, it changes from a yellow-gold to a brown hue. White cedar, which is available in some parts of the country, turns to silver-gray. It's used far less than the red cedar.

Shingles come in four grades, with Number 1, or Premium, being the best. Premium grade shingles are cut entirely from heartwood. They're 100 percent clear and edge-grain, which makes for a more uniform appearance and easier installation. Number 2 shingles can include flat grain and sapwood, or the outer wood, which has more knots. Although both Number 1 and Number 2 are considered acceptable for exterior siding, unless there's a significant price difference, Number 1 is the better buy in the long run. Only use Number 3 and Number 4 utility grades for undercoursing. They have more knots and a less regular grain pattern.

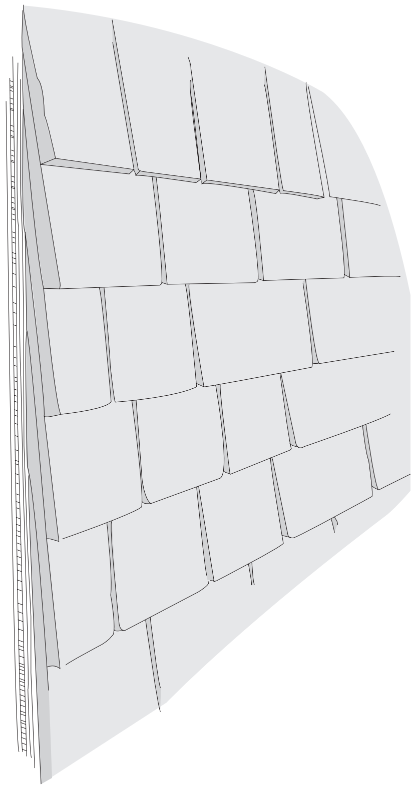


Figure 3
Single-course shingles

You can apply shingles in either a single layer (*single-coursing*), or in a double layer (*double-coursing*). For the most part, double-coursing is done for the visual effect rather than durability, although the added layer does add some durability. Because of the extra coverage, you can have a greater exposure for double-coursing than for single-coursing. Figure 3 shows an example of single-coursing, and Figure 4 shows a front and side view of double-coursing. Regardless of which method you use, always double the first row of shingles at the base of the house and the first row above windows and doors.

Estimating Wood Shingle Siding

Shingles are packaged in bundles, with four bundles equaling one square, or enough to cover a 10- by 10-foot area. But allowable exposure lengths can vary by several inches, which will throw off the actual coverage you can get per bundle.

The chart in Figure 5 will help you determine the number of bundles to buy. Using the chart, determine the number of bundles you'll need to cover a 1500 square foot house if you're using 18-inch shingles with a 6-inch exposure. According to the chart, one square of four bundles covers 109 square feet. Divide 109 into 1,500 to find out how many squares you need. In this case, it's 13.76 squares. Allowing 10 percent for waste, the total comes to 15.14 squares, or 60.56 bundles, which you round up to 61. Most suppliers will let you return unbroken bundles, so it's better to err on the generous side.

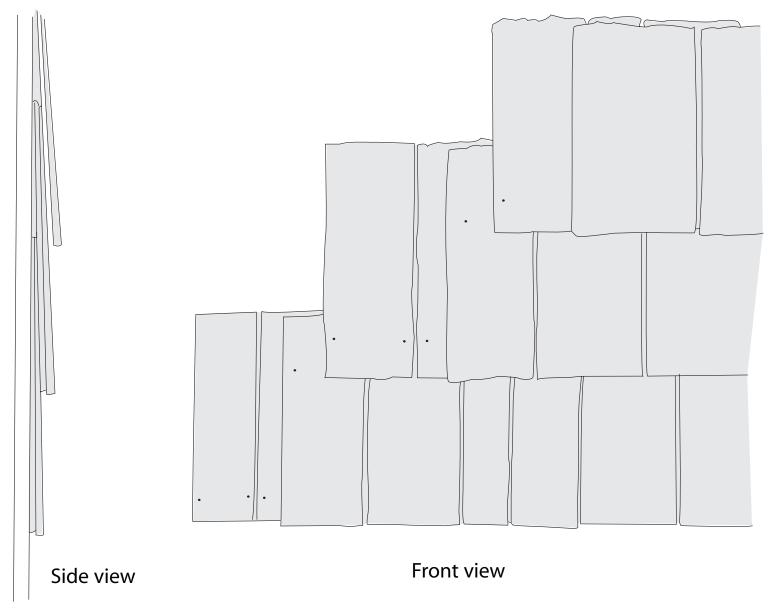


Figure 4
Double-course shingles

Approximate square foot coverage of 1 square (4 bundles) of shingles, based on the following exposures:								
	Exposure							
Shingle length	**5"**	**5 1/2"**	**6"**	**6 1/2"**	**7"**	**7 1/2"**	**8"**	**8 1/2"**
16"	100	110	120	130	140	150*	160	170
18"	90.5	100	109	118	127	136	145.5	154.5*
24"			80	86.5	93	100	106.5	113
	Exposure							
Shingle length	**9"**	**9 1/2"**	**10"**	**10 1/2"**	**11"**	**11 1/2"**	**12"**	**12 1/2"**
16"	180	190	200	210	220	230	240**	
18"	163.5	172.5	181.5	191	200	209	218	227
24"	120	126.5	133	140	146.5	153*	160	166.5
	Exposure							
Shingle length	**13"**	**13 1/2"**	**14"**	**14 1/2"**	**15"**	**15 1/2"**	**16"**	
18"	236	245.5	254.5**					
24"	173	180	186.5	193	200	206.5	213**	

* Maximum exposure recommended for single-coursing No. 1 and No. 2 grades.
** Maximum exposure recommended for double-coursing No. 1 grade.

Figure 5
Estimating shingle coverage

Surface Preparation

As long as the surface is smooth, in good shape, and it's a nailable surface, you can install shingles over existing siding. With composite shingles, masonry or stucco you'll need to attach horizontal furring strips, placed the width of the exposure apart, so that you have a solid surface to nail into.

Cover the entire structure with an air barrier rather than a vapor barrier. (See *Insulation*.) To protect corners, doors, and windows from moisture, install flashing.

If you're going to paint or stain the trim a different color than the shingles, do it before you apply the shingles. This includes window and door trim, corner boards, moldings, soffits, and so on.

Flashing

Moisture is always an enemy. With wood siding, it can creep up behind shingles at window and door casings. Or if water sits on the casing drip cap, it can freeze and damage the wood or paint. To prevent moisture penetration, install flashing. Vinyl and aluminum siding are designed with flashing as part of the system, so you don't need additional metal flashing. But with any kind of wood or composition siding, you'll need to install flashing. In addition, horizontal plywood or hardboard panels also require Z-flashing.

Tools and Materials

Metal flashing (may come with new windows, you can buy prebent, or make your own)

- *Tin snips*
- *Straightedge*
- *Hammer*
- *Building felt*
- *Air barrier*
- *Nails or staples*

Flashing Installation

1. Use window wrap to seal around openings. Window wrap is a paper-backed self-adhering bitumen membrane. Remove the paper and apply it directly to the plywood. If window wrap isn't available, use building felt cut into strips 6 to 8 inches wide. Staple the felt strips around corners and door and window openings before the doors and windows are set in new construction. For remodeling, tuck the felt in between the casings and the wall. Allow about 4 inches of felt to remain exposed.
2. To make your own flashing, cut a metal strip the length of the drip cap, about $^1/_8$ inch wider than the width of the drip cap plus 3 inches. Using a straightedge, bend the metal to fit over the drip cap and up the wall 3 inches.
3. Place the flashing on the drip cap. Nail it onto the wall using just enough shingle nails to keep the metal temporarily in place. The siding will hold it permanently.
4. Cut a strip of builder's felt 6 to 8 inches wide. Staple it to the wall so that it hangs over the metal strip.
5. Staple an air barrier over the entire structure. Then proceed with siding installation.
6. After you've installed the siding, press the straightedge against the $^1/_8$-inch flashing on the drip cap, and bend it down over the edge of the casing.

Shingle Layout

Ideally, you should try to line up the butt of the shingle course with the bottom edge of the windows. It'll mean less cutting and a cleaner visual line. Realistically, though, not all of the windows will be the same distance from the first course. So you'll have to choose which window or windows are the focal point, and use those as the point of alignment.

To figure the exposure, measure from the starting line to the bottom of the window, and divide by the intended number of courses. If it doesn't come out even, add $^1/_4$ or $^1/_2$ inch to each course to make it come out. For instance, if the distance between the bottom edge and the window is 33 inches, and you had planned to use a 6-inch exposure, add $^1/_2$ inch to each course. That way, you end up with five even courses without changing the overall look of the house.

If you're re-siding an old house, chances are it may have settled and the exterior walls will no longer be plumb. In this case, you may have to make incremental adjustments at the lower end in each course to finish with the same number of courses.

To make this all easier, most professionals use a story pole as a quick check to make sure that the courses stay even. Use a 1 × 2 that's several feet long, and mark the bottom of each course along the length of the pole. Another option is to use the gauge on your shingling hatchet as a measuring guide. This lends itself to error, though, unless you're fairly experienced. Also, if you have several people shingling, everyone's techniques vary slightly, and that may cause some variations in the courses.

Nailing Wood Shingle Siding

Always use rust-resistant, hot-dipped galvanized coated nails or aluminum nails with wood siding. Choose a nail that's long enough to penetrate the substrate by at least 3/4 inch or through the substrate thickness, whichever is less. In new construction, 3d nails should work with 16- and 18-inch material; 24-inch shingles will need a 4d nail. In re-siding and double-coursing, use 5d nails for 16- and 18-inch shingles and 6d nails for 24-inch shingles. Keep in mind that you may need a longer nail for shorter exposures.

Nailing Procedures

1. Use no more than two nails to attach each shingle.
2. Place nails 3/4 to 1 inch in from the sides and 1 to 2 inches above the shingle's exposure line. See Figure 6.

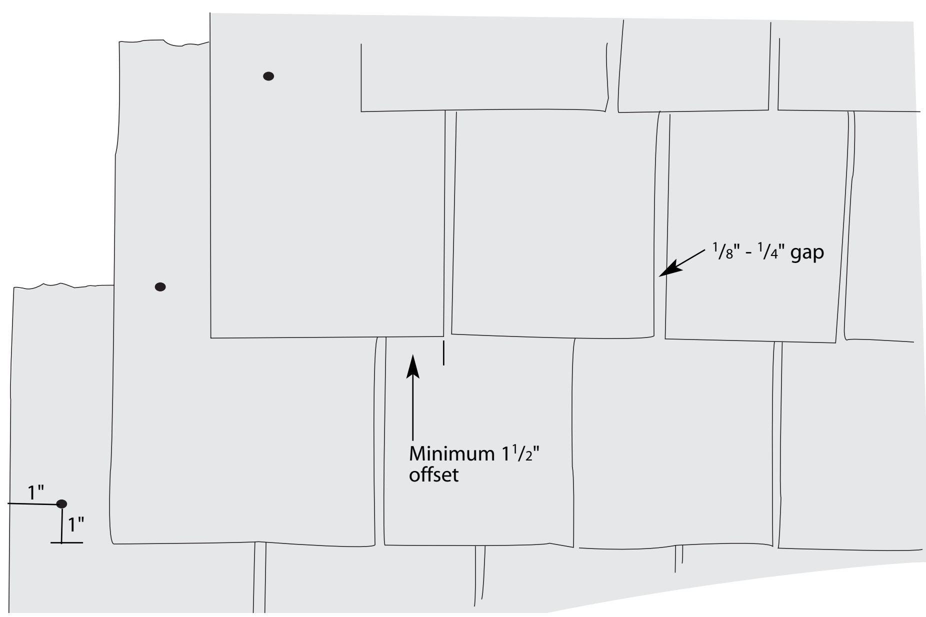


Figure 6
Nailing shingles

3. Drive the nail flush to the surface of the shingle, not into the fiber of the wood. If you nail the head too deep, you risk splitting the wood or making an indentation, which in turn will collect moisture.
4. Leave a $^1/_8$- to $^1/_4$-inch gap between each shingle in the course to allow for expansion.
5. Offset the gaps in adjoining courses by at least $1^1/_2$ inches.
6. Double-course the first row along the bottom, and above windows and doors.

Shingle Installation

One of the real benefits to using shingle siding is that you can do it with a minimum of equipment and without any help. Although it's a labor intensive job, it's not heavy work, and it doesn't require a lot of people to handle the material.

You'll do most of your cutting at the corners. Either use a sharp utility knife or a shingler's hatchet, and smooth the edges with a block plane.

Tools and Materials

- *Chalk line*
- *Guide board*
- *Tape measure*
- *Utility knife*
- *Metal straightedge*
- *Shingler's hatchet*
- *Block plane*
- *Level*
- *Story pole*
- *Hammer*
- *Keyhole saw*
- *Nails*

Single-Coursing

1. Snap a chalk line to determine where the first row of shingles should go. Attach a couple of shingles at each corner and in the middle along the line. Tack a small nail at the bottom of these shingles, and stretch a taut line between the nails as shown in Figure 7. Some professionals nail a furring strip as a guide board at the bottom edge of the wall instead of the line.
2. Lay the first course of shingles with their butts even with the line, nailing them as described above. Check with a level to make sure the line stays straight.
3. Lay another course of shingles directly over the first. Stagger the gaps so that they're offset by at least $1^1/_2$ inches.
4. Use the story pole to determine where the next row should go. Snap a chalk line where the shingle butts should be aligned. Some experienced siders use the gauge on their hatchets, and instead of snapping a line every course, they snap a line every five or six courses. Some also continue to nail a guide board for each course.
5. Align each succeeding course with the chalk line. See Figure 8.

Double-Coursing

Follow the steps above. The butt of the top course should be $^1/_4$ to $^1/_2$ inch lower than the butt of the under course. Offset the gaps of each layer by at least $1^1/_2$ inches.

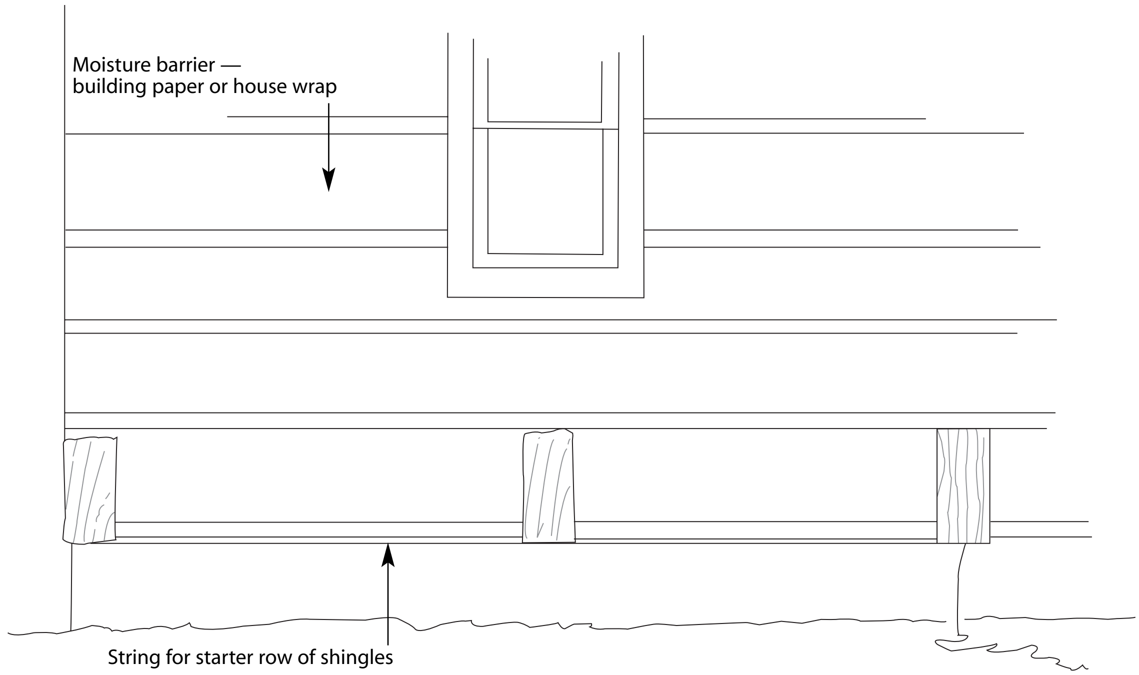


Figure 7
Use chalk line and string line to lay out first course

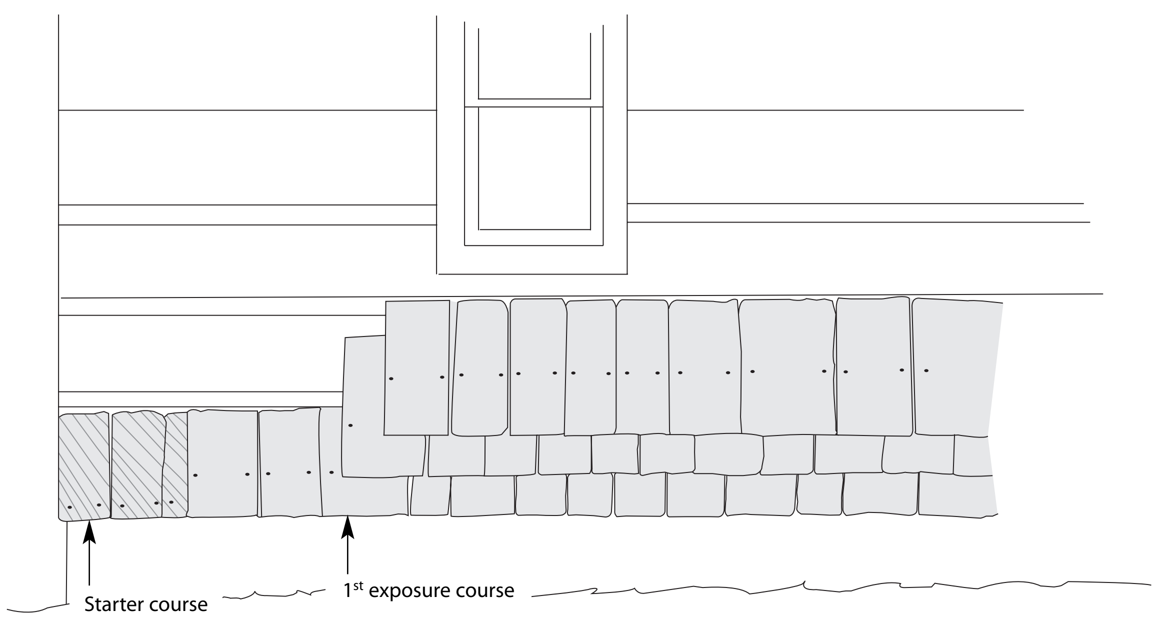


Figure 8
Line up courses

Corners

Three different methods can be used for inside and outside corners: mitered, woven, or butted to corner boards. Of these, mitered corners are the most work (each shingle has to be cut to fit) and provide the least protection. Unless the client specifically requests mitered corners, and you can't talk them out of it, avoid using this method.

Corner Boards — Corner boards, shown in Figure 9, give the most protection and are the easiest to install. You don't have to be quite so meticulous at the corners with corner boards, but they do clutter up the lines of the house.

For inside corners use 1 × 1 vertical boards and nail them in place. Outside corners should be 1 inch thick by at least 3 inches wide. Butt the shingles up against the boards for a clean fit. Cut to fit with either a shingler's hatchet or a keyhole saw.

Woven Corners — Woven corners, shown in Figure 10, take a little more time than corner boards, but they also keep the lines of the structure clean.

Alternate laps at the corner on each course. Butt the side of one to the face of the other for inside corners, and the side of one to the back of the other for outside corners.

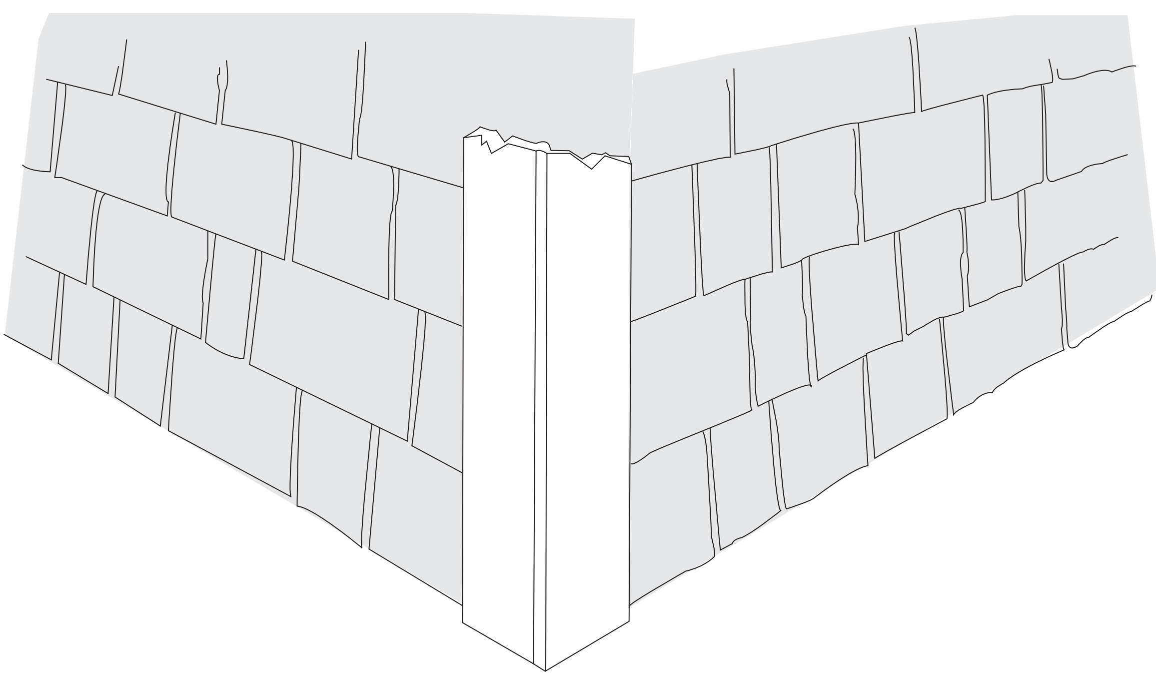


Figure 9
Corner boards

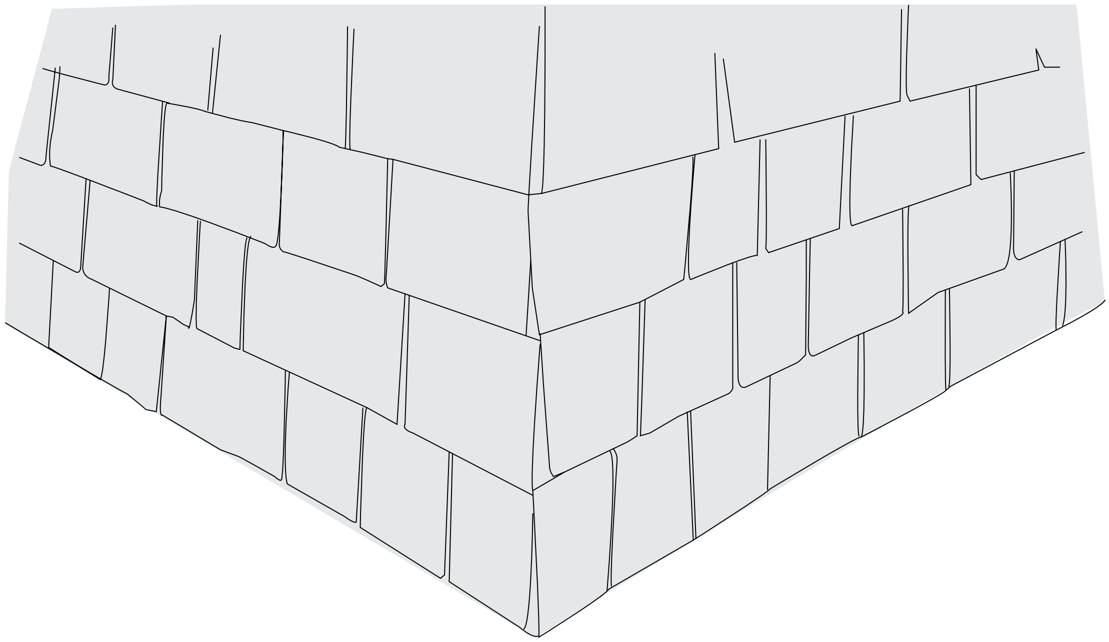


Figure 10
Woven corners

Windows

1. Cut a groove $^1/_2$ inch deep and $^5/_8$ inch wide on the underside of each sill. Tuck the shingle into this space to keep it from popping away from the wall.
2. For shingling around windows, notch the shingle so that the joint won't fall directly under the casing edge. See Figure 11.
3. To make a smooth line above a window, line up the tops of the shingles and cut the bottoms as needed rather than vice versa.

Preserving Wood Shingles and Shakes

All wood sidings should have some kind of protective coating to endure. Although shingles and shakes are sometimes installed uncoated, for increased durability you should protect them with some type of preservative. Sun, water, insects, and fungus are all enemies of wood. If the wood isn't protected, it will shorten the life span of the siding by years or even decades. Most coatings should be reapplied every two to five years, particularly in climates that have high humidity and intense sun exposure. Water-repellent preservatives need to be reapplied more often, usually every one to three years. The following sections briefly cover your options for preserving wood. See *Paint* for application instructions.

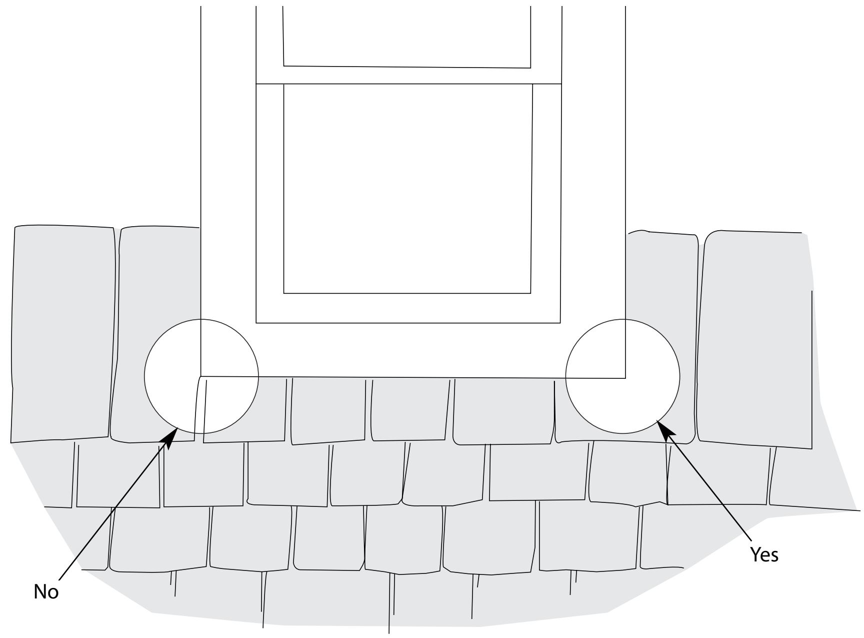


Figure 11
Shingling around windows

Water-Repellent Preservatives

Water-repellent preservatives may combine a mildewcide, or an insecticide with wax or silicone to provide a natural finish by itself. Two coats will cause the wood to lighten. A water-repellent coating is also a great base coat for paint or stain. Because wood preservatives need to penetrate the wood to be effective, use a wide brush and apply the preservative as generously as possible without causing runs. Don't spray it on because it won't soak into the wood enough.

Bleaching Oils

Bleaching oils contain mildewcides and are designed to speed up the natural graying process as well as protect the wood from damaging UV rays. Once the wood has reached the desired shade of gray, apply a coat of water-repellent preservative to further protect the finish.

Stains

Semitransparent stains tint the wood without hiding the grain, yet they have enough pigment to block UV rays. They also are, or can be, combined with water repellents to provide a low-maintenance finish. Semitransparent stains are absorbed into the wood and won't peel later. They're a good choice for rough-sawn wood.

Opaque or heavy-bodied stains cover the wood grain and color but highlight the wood texture. Use opaque stains over primer. They cover best if you apply them to a smooth surface. Eventually, they may peel just like paint.

Paint

You can use paint on any smooth wood siding. It's not recommended for rough-sawn wood because it will quickly weather off the surface and allow moisture to creep in. The moisture will cause the paint to buckle and peel. Paint will last longer if the surface is primed first. Use two coats of paint for good coverage.

Tools and Materials

- *Wood chisel*
- *Mallet*
- *Hacksaw*
- *Claw hammer*
- *Utility knife*
- *Replacement shingle/shake*
- *Nails*

Replacing Damaged Shakes and Shingles

Use the following guidelines to replace broken or damaged shingles or shakes:

1. Using a wood chisel and mallet, carefully break up the damaged shingle or shake by splitting it along the grain in several places.
2. Slip a hacksaw under the course above and saw off the nail that holds the shingle or shake in place.
3. Cut a new shingle to fit, and slip it up under the course above. To hide the new nails, align the shingle so it's about $^1/_2$ inch lower than it should be. Drive the nails in at an upward angle. Then, place a small block of wood under the base of the new shingle and tap on the block to gently push the new shingle even with the existing course. Tap the nail flat, using the block of wood as a buffer between the old shingle and the hammer.

Lap Siding

Depending on the part of the country you're in, lap siding may be called clapboard, drop siding, bevel siding, or one of its variations such as shiplap or tongue-and-groove. All of them are descriptions of the same thing: horizontal board siding, called lap siding because the boards are overlapped to provide a weathertight, solid wall. Figure 12 shows typical lap siding.

The board widths may vary from 4 to 12 inches and lengths from 3 to 20 feet, and the manner in which they're overlapped may vary as well. The narrower widths are usually called *clapboard*. Lap siding is generally beveled, or slightly wedge-shaped. But it also may have matched rabbet cuts on each end so the panels fit together, resulting in a flat surface. You can get lap siding in 10-piece bundles of individual strips or, less often, in panels for quicker installation.

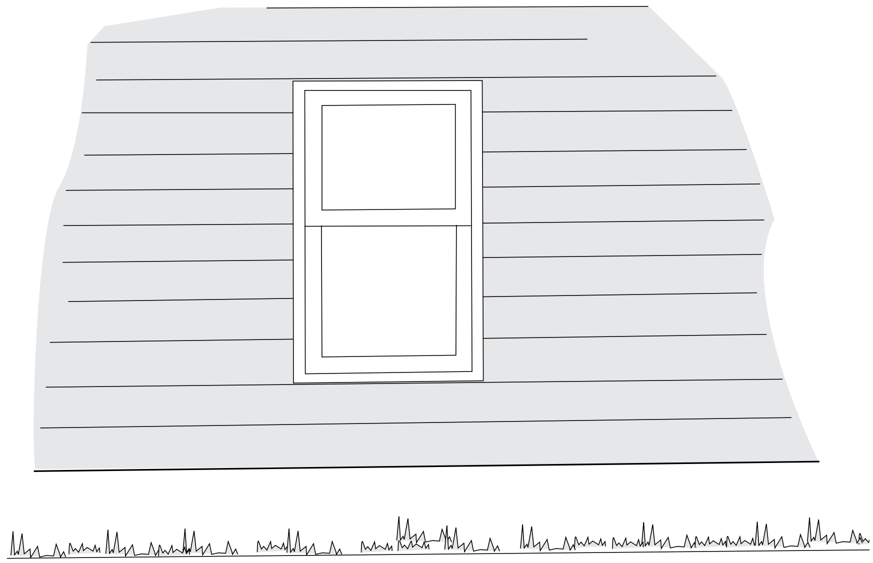


Figure 12
Horizontal or lap siding

The most common woods used for lap siding are pine, redwood, and cedar. Of these, pine is the cheapest, but it's used the least. Because the natural oils in redwood and cedar make them more resistant to rot and insects, they're usually preferred. Edge-grain siding is less likely to warp or check than other cuts; it's preferred for siding that's to be painted.

Estimating Lap Siding

There are two factors which affect the amount of siding a structure will require. Like other wood products in construction, lap siding has a nominal size and an actual size. The actual size is the dressed, or finished, dimension and runs about $^1/_2$ inch smaller than the nominal, or stated, size. This is one of the factors. The other is that lap siding should be overlapped a minimum of 1 inch.

To figure the amount the amount of siding you'll need, first find the square footage to be covered, subtracting for windows and doors. Determine what the actual exposure will be, and divide that amount into the nominal size of the siding. Use that figure to multiply the amount of square feet to cover. Add an additional 5 to 10 percent for waste, and you have the amount of siding material you'll need to cover the building.

For example, you're covering 1,000 square feet of a house with lap board. You plan to use 1 × 6 inch lap siding (actual width $5^1/_2$ inches) with a 1 inch lap, so the actual exposure is $4^1/_2$ inches.

6 (nominal size) divided by $4^1/_2$ (actual exposure) = 1.33

1,000 × 1.33 = 1,333

1,333 × .10 (for waste) = 133

1,333 + 133 = 1,466 square feet of material

Surface Preparation

Install lap siding over sheathing that has been covered with an air barrier. Corners and doors and windows need further protection because these are the areas most likely to be damaged by moisture penetration. Cover them with window wrap or builder's felt and install flashing as explained earlier.

Some siding comes pretreated to resist moisture. If it hasn't been pretreated, paint or seal the back of it before you install it. If you don't and the wood is exposed to moisture from behind, the boards will start cupping because the moisture has no place to go. The wider the board, the worse the problem. Some professionals rig up a trough and soak each board for several minutes before they install them. It's easier and faster to brush a sealer on. Just don't forget to seal the ends as well, particularly if you have to trim pieces to fit after you've applied the paint or sealer.

Layout

You should try to install siding so that the bottoms and tops of windows and the tops of doors line up with the bottom of a siding course. Again, this is more easily said than done because windows and doors will often vary in height. But if you can do it, you'll have fewer boards to notch and cleaner lines visually. If you have to choose between aligning with the windows or the doors, opt for the windows because there are more of them.

To figure out how wide to make the courses, measure from the starting line at the bottom to the bottom of the window and divide by the width of the exposure you intend to use. If it doesn't come out perfectly even, adjust the exposure by a quarter or half an inch until it does. For instance, if you're using 6-inch siding, you'll have a maximum actual exposure of $4^1/_2$ inches. If the distance to the bottom of the window is 33 inches, divide 33 by 4.5. It comes out to 7.3 inches. Rather than have one third of a course under the window, adjust the exposure to $4^1/_8$ inches, which will give you eight even courses. If the top of the window is 34 inches up from the bottom, adjust the following courses to $4^1/_4$ inches so that your courses come out even at the top as well. The extra $^1/_8$ inch won't be at all noticeable and it will save you extra work and provide a clean line at the top of the window.

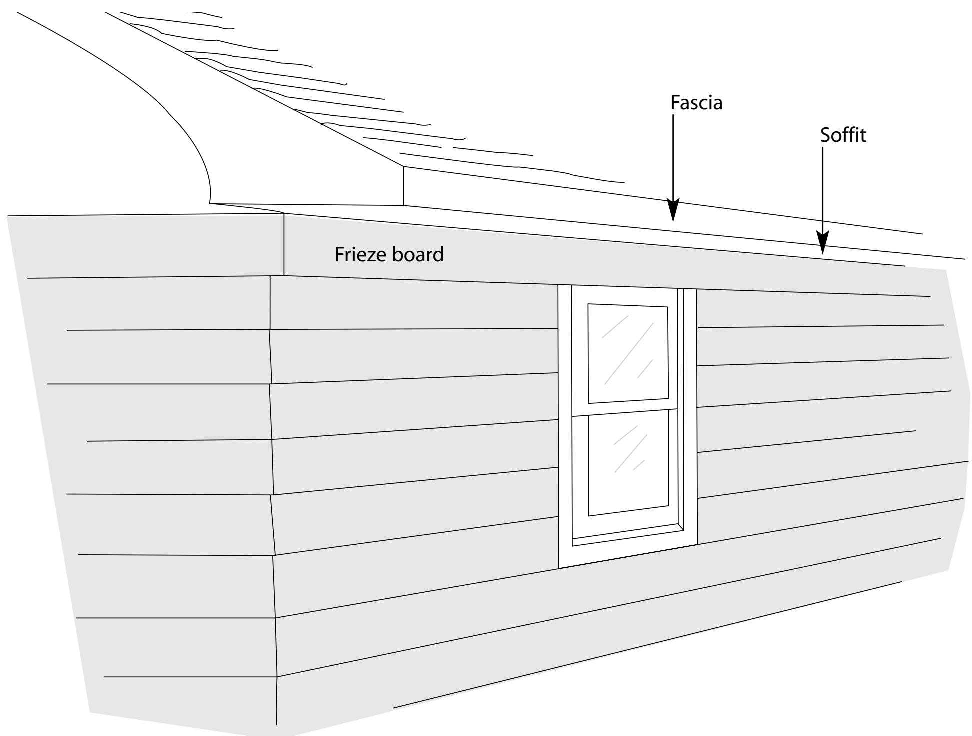


Figure 13
Frieze board above a window instead of siding

In one-story houses, a frieze board is often used instead of siding above a window (see Figure 13).

If you're re-siding an old house that's no longer level, do the same kind of gradual adjusting so the siding is straight at the roof line.

Marking a story pole before you begin to even nail the first board will speed things along, particularly if you have to make small adjustments from course to course. Use a stick that reaches as high as the frieze board, and pencil in the bottom of each course as well as the height of door casings and windows. Some installers also use a story pole to mark the corners all around the house. Others use it as a check as they hang each course.

Nailing Lap Siding

Use only hot-dipped galvanized or aluminum nails to attach siding. If you use steel nails, they'll rust and leave an ugly stain. Flathead siding nails are the most commonly-used type of nail. Drive the heads flush with the surface and then paint over them. Another option is to use a finishing nail, which you can then set with a nail punch $^{1}/_{16}$ inch below the surface and putty smooth after the siding is primed. Avoid overdriving the nails, which creates unsightly dimples and can split the siding.

For narrow bevel siding, nail through the siding at both the top and about $^1/_2$ inch from the bottom of the board. The bottom nails will also go through both the exposed siding and the board lapped under it, as well as through the sheathing and studs. (See Figure 14.) Refer to the manufacturer's specifications for this step because some don't recommend nailing through both courses. Wider boards expand more. Nail them about 2 inches from the bottom and only through the exposed course, not the course under it.

You can nail panels installed flush in several different ways depending on the specific style. Follow the manufacturer's recommendations.

For either bevel or panel lap siding, choose a nail that will penetrate the stud by at least $1^1/_2$ inches as shown in Figure 15.

Installation

As much as possible, avoid butting two siding pieces over doors or in high traffic areas. Always place the butt joint over a stud, and stagger the joints from course to course.

Originally, lap siding was installed from the top course down because the bottom and top edges weren't always parallel. The only way to keep the courses even was to align them with the bottom of the previous course. Today, most installers begin with the bottom course and work up.

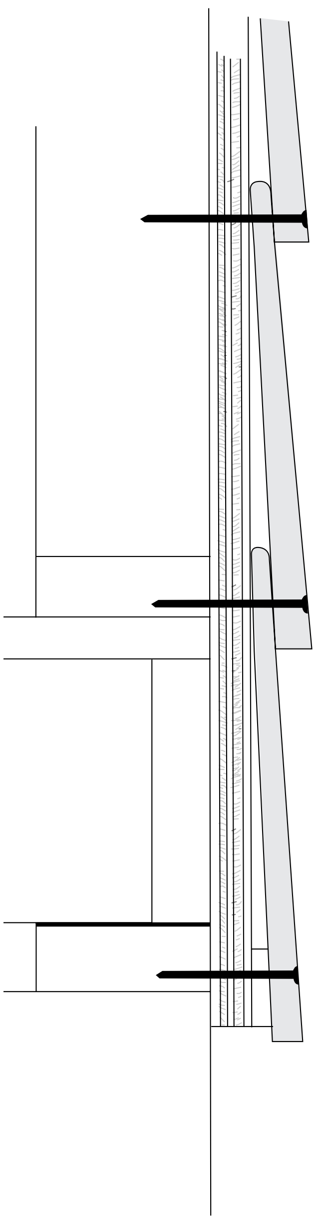


Figure 14
Nailing board siding

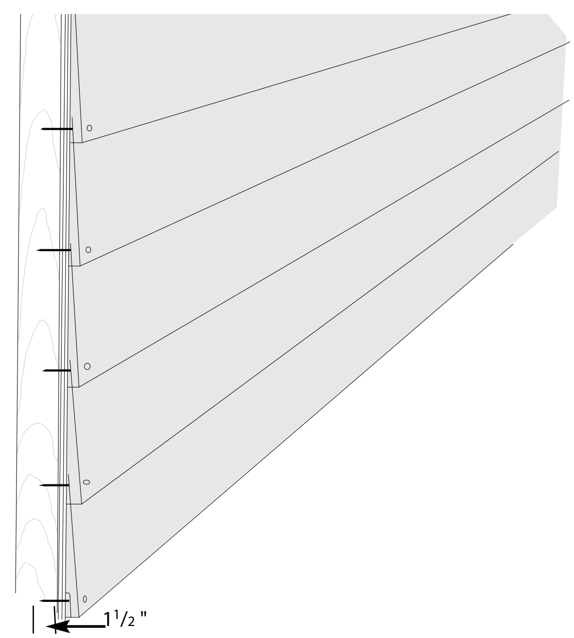


Figure 15
Nail should penetrate stud by at least $1^1/_2$ inches

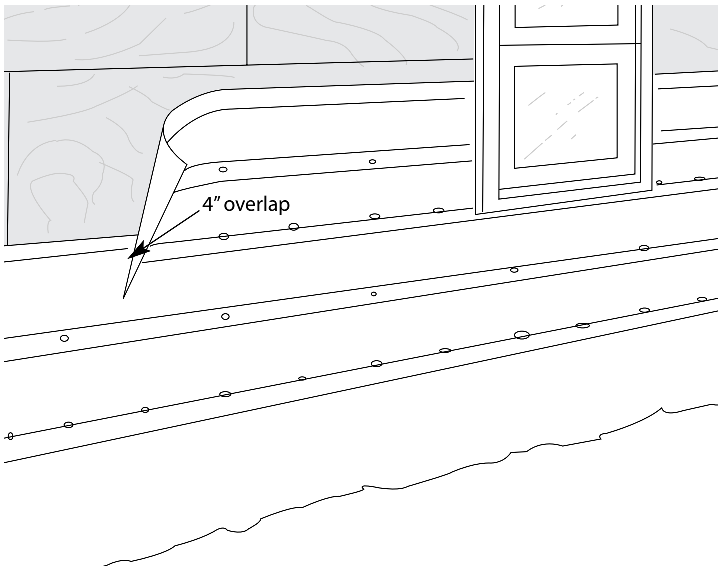


Figure 16
Each layer of felt overlaps the one below it

Figure 17
Mitered inside corner

Tools and Materials

- *16 oz. hammer*
- *Hand saw*
- *Utility knife*
- *Story pole*
- *Chalk line*
- *Radial-arm saw*
- *Siding gauge (slip siding into the gauge for cutting)*
- *Square*
- *Level*
- *Block plane*
- *Corner boards*
  Inside: $^3/_4 \times {}^3/_4$ inch
  Outside: at least 3 inches wide, depending on thickness of siding
- *Beveled starter strip (2 inches wide and as thick as the siding butt)*
- *Builder's felt*
- *Nails*
- *Staples*

Installing Bevel Siding

1. After protecting doors and windows with window wrap or builder's felt, staple a width of felt the length of the first wall. Attach new widths of felt as you work up the wall, rather than covering the entire wall from the start. Overlap widths by about 4 inches, with the top layer draped over the bottom layer as shown in Figure 16. Staple every 6 inches along the edges and every 12 inches in the field.

2. Install inside and outside corners. (Refer back to Wood Shingle Corners.) If you plan to miter the outside corners, install only the inside corner. Miter the outside corners as you work up the wall. Nail through the corners with 4d galvanized finish nails. Another option is to install metal corners for outside corners after the siding is completed. Figures 17 and 18 show inside and outside mitered corners. Figure 19 shows outside metal corners installed.

3. Nail the starter strip so the bottom edge is even with where you want the bottom edge of the first course. Let the starter strip hang about $^1/_2$ inch over the top of the foundation but at least 6 inches up from the ground.

4. Snap a chalk line at the top edge of the first course. True up the end of the first board, seal it, and align it over the starter strip. Nail it in place, 16 inches on center.

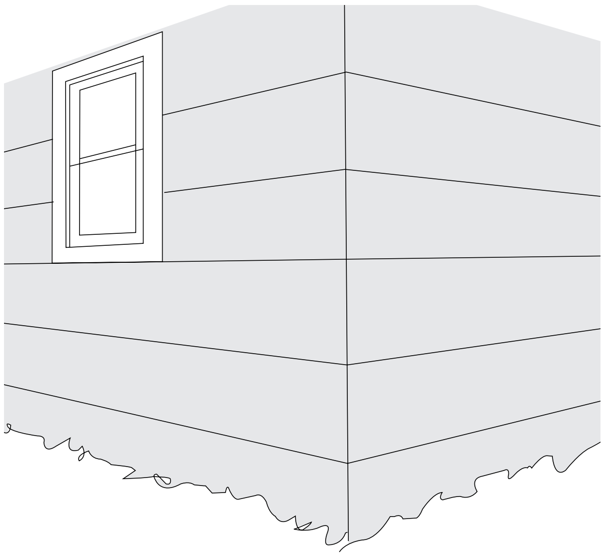


Figure 18
Mitered outside corner

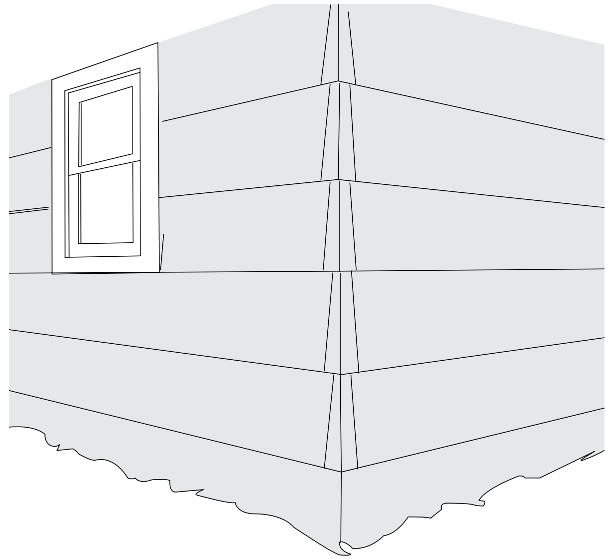


Figure 19
Outside corner with metal corner

5. Snap a line for the top of the next course. As long as it's within the manufacturer's guidelines, nail narrow siding through both the underneath and outer course. Nail wider siding only through the outer course. Allow about $^1/_8$ inch between the nail and the upper edge of the underneath course. This space allows the wood to expand and contract. For rabbeted bevel siding, leave a $^1/_8$-inch gap between the top of one course and the bottom of the rabbet on the next course.

6. Continue nailing up courses. Wherever you butt joints, put another short strip of builder's felt behind the joint. Make sure the joint falls over a stud. Some manufacturers recommend leaving a gap the width of a nickel between boards for expansion and contraction. Generally, if you just fit the boards loosely against each other the space is sufficient.

7. Under windows, cut a groove $^1/_2$ inch deep on the underside of the sill to hook siding pieces into (see Figure 20). If you use a frieze board, groove the bottom edge of this as well to tuck the boards under as shown in Figure 21.

8. When you reach the rake, you can butt the siding up against it, or run the siding under the rake. To do this, you'll need to shim the upper edge of the rake the thickness of the installed siding (the butt edge plus the overlap).

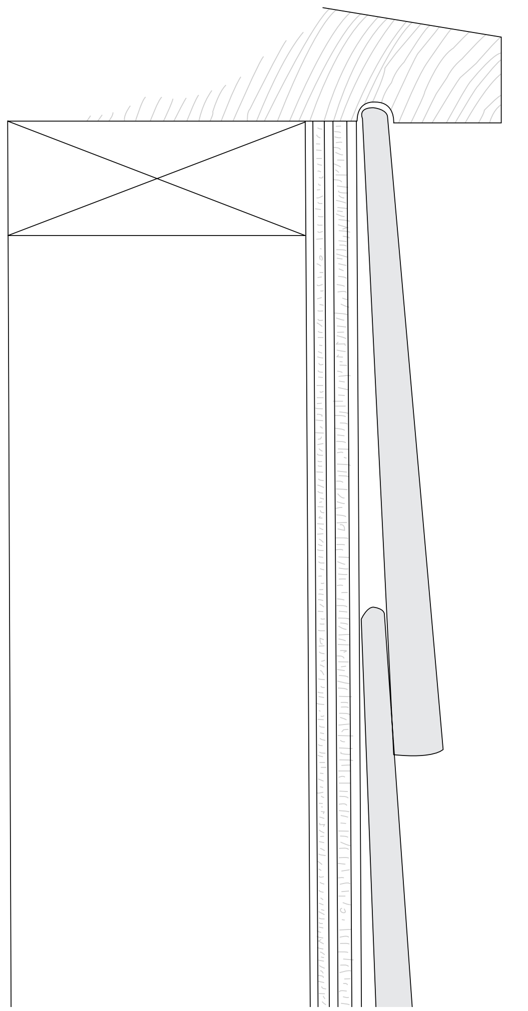


Figure 20
Cut groove on underside of window sill

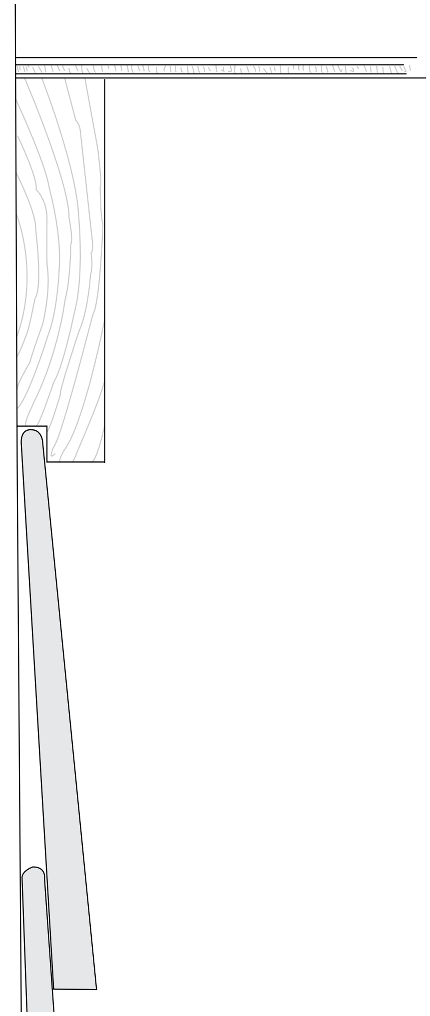


Figure 21
Cut groove in bottom edge of frieze board

Installing Panel Siding

Panel siding is sometimes installed as a less expensive option because sheathing isn't necessary. Of the panel sidings, tongue-and-groove tends to be more weather resistant to wind-driven rain than shiplap since the groove has an extra turn to it. Use two nails for widths greater than 6 inches.

1. Follow Step 1 under Installing Bevel Siding. Snap a chalk line for the first course. Cut the first length so that the joint will fall over a stud. Nail it in place, tongue up, using two nails on each stud as illustrated.
2. Install corner boards over the siding.

Repairing and Replacing Lap Siding

Wood siding will last for decades if it's properly maintained with a good sealer or paint. If siding bows out, use a screw that's long enough to attach to the substrate to pull it back in. For holes or cracks, clean out the damaged area, and patch it with wood filler to match the stain. Remove dry rot promptly, coat the wood with a dry rot inhibitor, and then finish it as you would for holes or cracks.

Tools and Materials

- *Crowbar*
- *Hammer*
- *Shims*
- *Hot-dipped galvanized nails*
- *Waterproof glue*
- *Wood putty*
- *Sandpaper*

Repairing Split Boards

1. Remove the nails from the damaged area. Pry up the split siding piece with a crowbar. Shim the split section away from the wall.
2. Spread glue along the exposed edge. Follow the glue manufacturer's directions for the proper waiting time, and then press the siding back in place, wiping up any excess glue.
3. Nail both parts of the damaged board into place, using a nail that's long enough to go through the sheathing and the stud. Putty the holes; sand when dry as needed; prime and paint.

Replacing Siding Boards

1. Remove the nails, or if they're finish nails, drive them into the undercourse with a nail punch. Or cut the nails by slipping a hacksaw under the siding. Make the cuts for the damaged area over studs. Wedge shims under the boards to make it easier to cut them.
2. Cut a replacement board to fit. Seal the ends of the replacement board and the exposed existing siding. Press it into place using a scrap piece of wood as a buffer between the hammer and siding. Nail the siding in place over the studs in the same way as you would if you were installing new siding.

Vertical Siding

You can install some types of siding, such as tongue-and-groove or shiplap, either horizontally or vertically. Regardless of the direction, the installation method is similar.

Siding that uses a combination of boards and battens is always done in a vertical pattern. A batten is a narrow strip of wood that covers the space between boards. Board-and-batten siding may be done with boards over battens, battens over boards (as shown in Figure 22), or boards over boards.

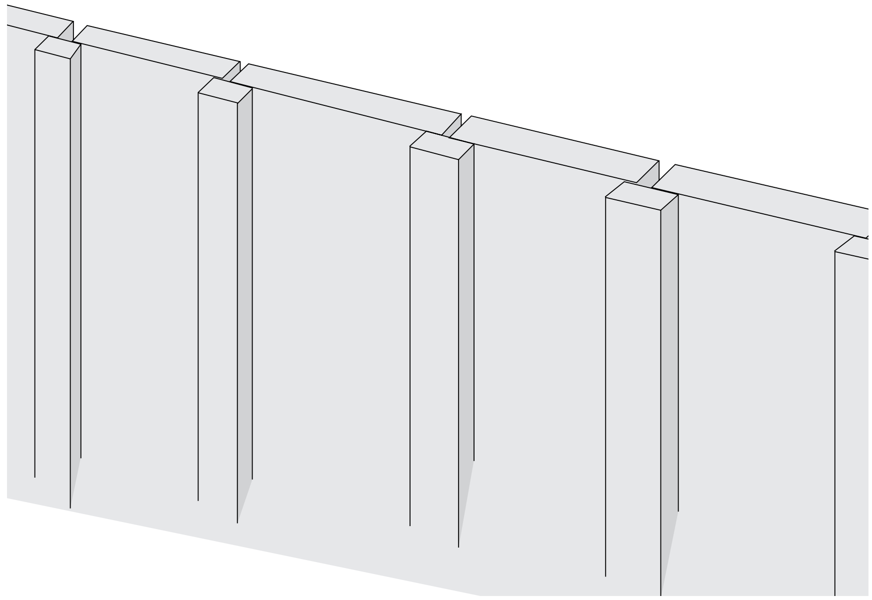


Figure 22
Board-and-batten siding

Surface Preparation

Generally, you install vertical siding over sheathing. Add horizontal blocking between studs to reinforce the sheathing, placing it 16 to 24 inches on center depending on the manufacturer's specifications (see Figure 23). Never attach siding to just sheathing because it doesn't provide enough support. Some local building codes allow vertical siding to be installed without the sheathing for structures such as garages or outbuildings.

Flash around windows and doors with window wrap or builder's felt and metal flashing. Install drip caps over windows and doors. Cover the sheathing with an air barrier and builder's felt as recommended by the manufacturer.

As with other wood siding, vertical siding will last longest if it's treated to resist moisture. Either brush the back of the siding or soak the wood in a preservative before installation. Remember to seal the cut ends as well.

Nailing Vertical Siding

Again, use only hot-dipped galvanized or aluminum nails to attach siding. You may drive them flush or countersink them. If countersunk, cover the nails with putty. Nails should penetrate the substrate at least $1^1/_2$ inches. So for board-and-batten siding, you'll need two different lengths in order to reach into the substrate.

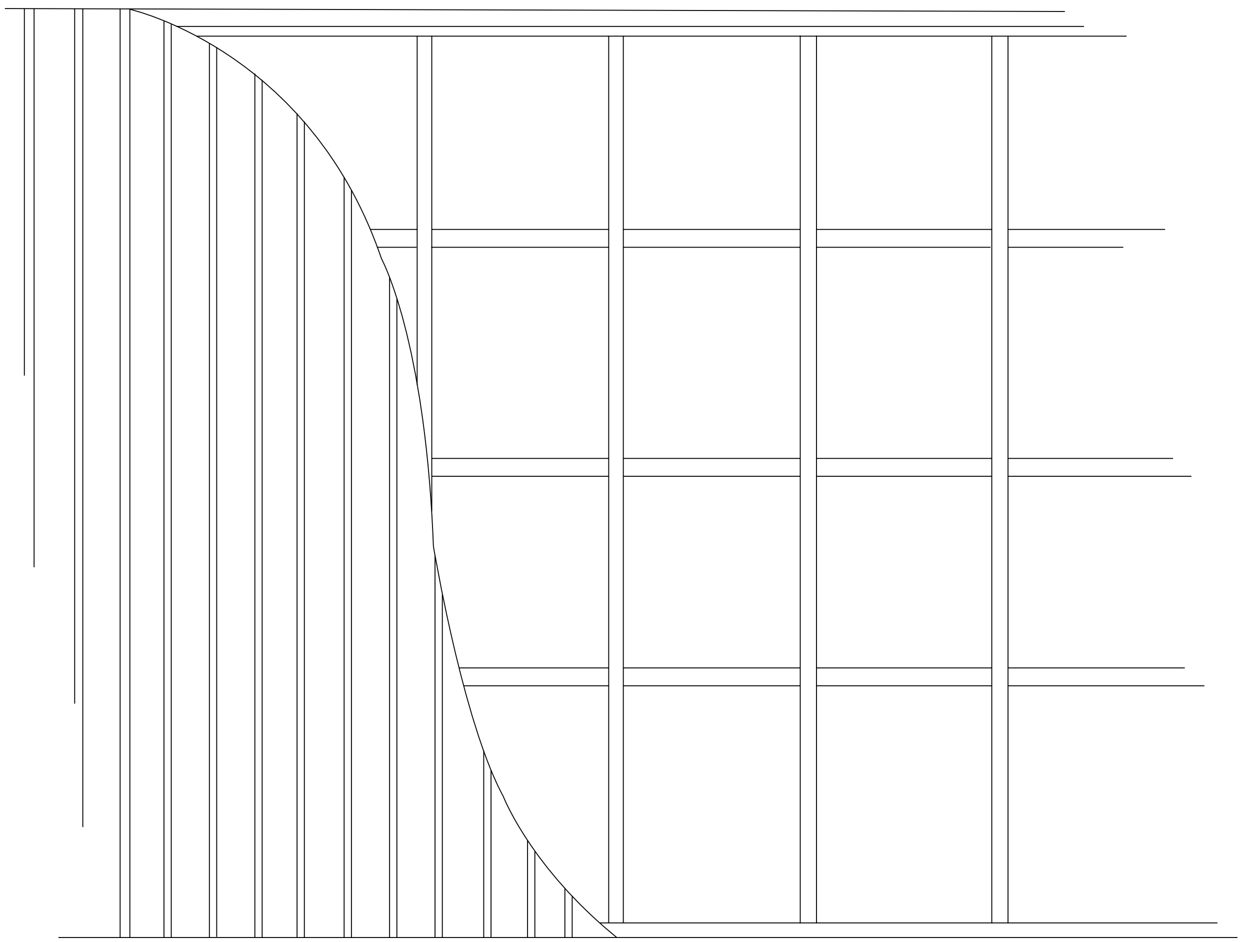


Figure 23
Place horizontal blocking between studs for vertical siding installation

Board-and-Batten Siding

There's some debate as to the best nailing pattern for board-and-batten siding. Keep in mind that both the board and the batten will expand and contract as the humidity changes. A good nailing pattern secures the wood but still allows it to move unhindered.

The first board or batten should be nailed with one 8d nail at center or, for wide boards, two nails spaced 1 inch each side of center. Close spacing is important to prevent splitting if the boards shrink. The top board or batten is then nailed with 12d nails through the space between the boards beneath (see Figure 24). Use only corrosion-resistant nails. Galvanized nails are *not* recommended for some materials so be sure to check the siding manufacturer's instructions. Figure 25 shows nailing patterns for variations on board-and-batten siding.

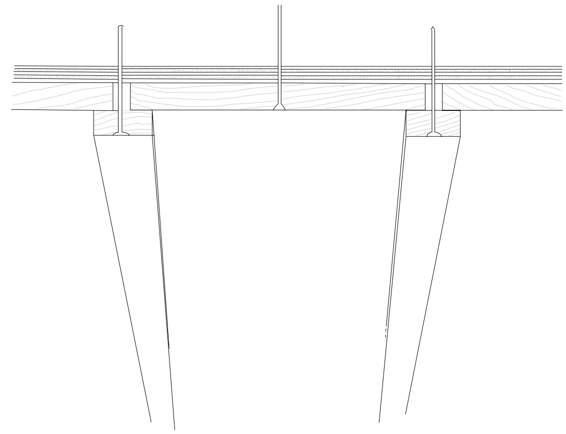


Figure 24
Nailing board-and-batten siding

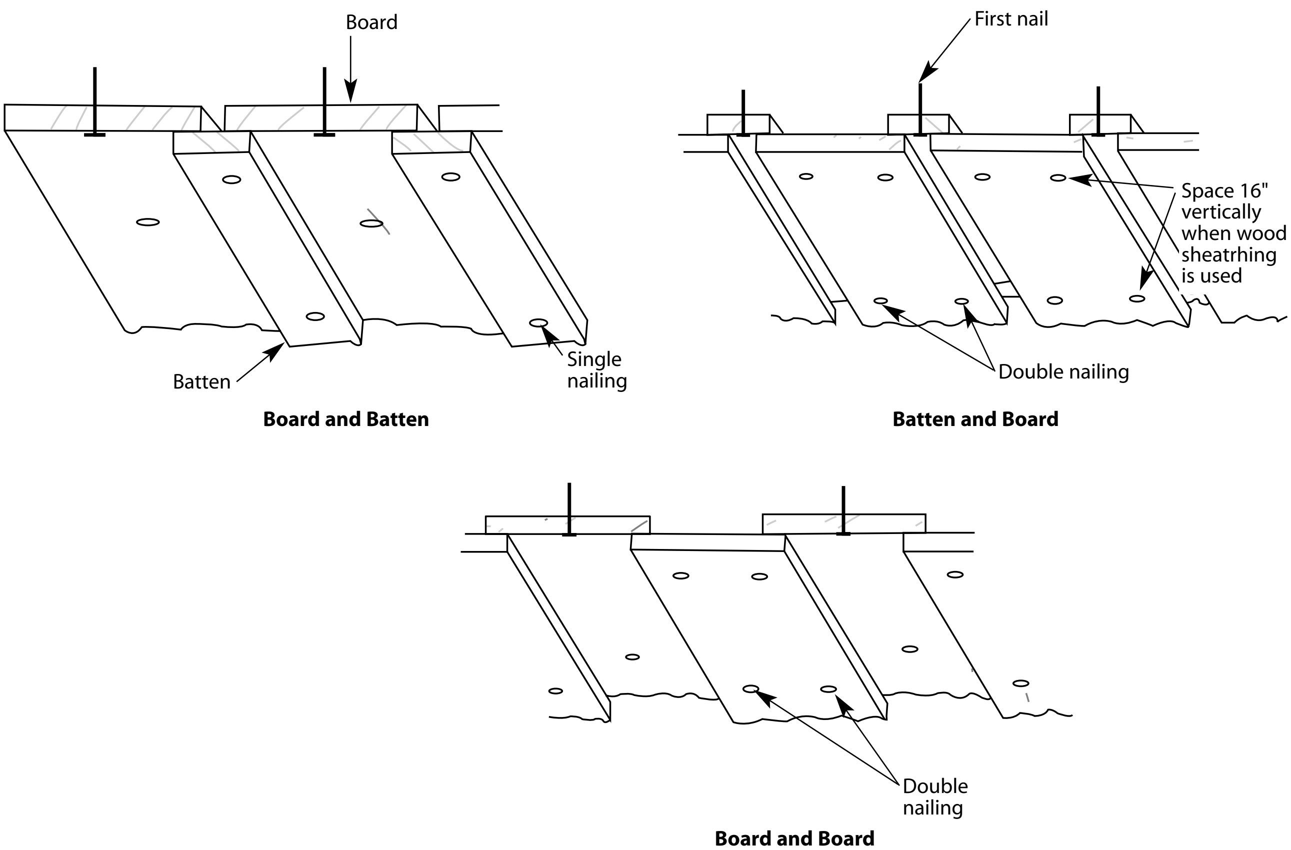


Figure 25
Nailing applications for vertical wood siding

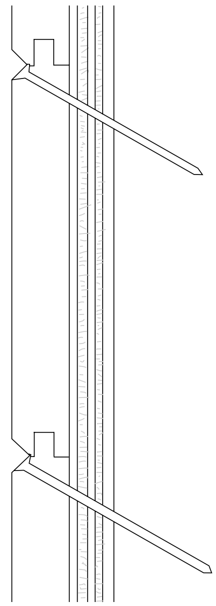


Figure 26
Nailing tongue-and-groove siding

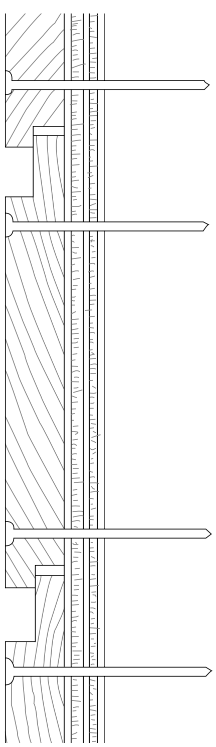


Figure 27
Nailing channel siding

Tongue-and-Groove Siding

Blind nail tongue-and-groove siding, using one nail for boards that are 6 inches or less and two nails for wider boards (see Figure 26).

Channel Siding

Face nail boards using two nails per board as shown in Figure 27. Allow $^1/_8$ inch between boards for expansion.

Installing Vertical Siding

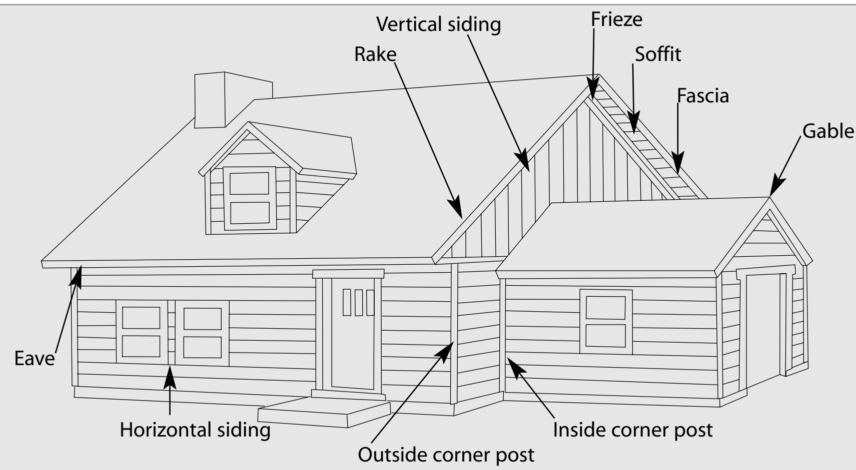
You need the same materials that you would use to install lap siding.

1. Install flashing and builder's paper as explained under Lap Siding. If you're using corner boards, install them at this point. Snap a vertical chalk line every 4 feet to use as a guideline.
2. If you're installing tongue-and-groove siding, cut a groove in the corner board for the tongue of the first piece. Begin board-and-batten with a wide board against the corner board.
3. Cut the first number of lengths that you'll be installing. Seal the edges. Every 3 to 4 feet, leave one board 4 to 6 inches longer than the others. When the wall is completed, nail a piece of strapping to these uncut ends. Snap a chalk line above the strapping the width of your saw's baseplate to its blade. Use the strapping as a cutting guide to even up the bottom edge.
4. Install the first board tight against the corner board and nail at points of vertical blocking. Continue nailing up the siding. Check every few boards to make sure they're plumb.

Vinyl Siding

Vinyl siding is a popular choice for a low maintenance, durable exterior. Unlike wood, it resists insects, moisture, and fire. In addition, it doesn't peel, blister, or dent. And if it should get scratched, the scratches won't easily show because the color goes all the way through the vinyl. Vinyl siding is available in a growing number of colors, and in textures ranging from smooth to deeply embossed wood grain patterns. Figure 28 shows typical vinyl siding.

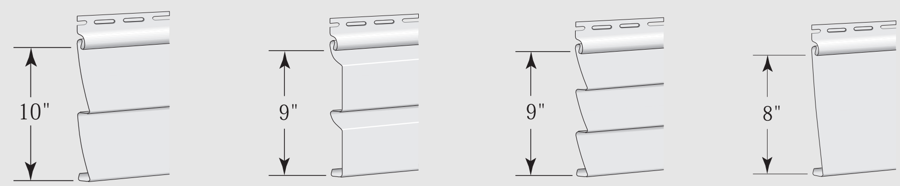
You should install vinyl siding over a minimum of $^1/_4$-inch weather-resistant sheathing. Sheathing is preferable to drop-in backerboard. In fact, some manufacturers specifically recommend that you not use backerboard. If you do use backerboard, make sure that the bottom of the board rests on top of the nail rail of the preceding course. Place the top of the backerboard even with the top of the siding panel so that the nails or staples pass through the backer. Don't force the backer down into the butt of the siding panel.



Horizontal siding

Horizontal siding is typically available in 12 1/2-foot long panels. The narrower configurations are often used on single-story houses because the added number of shadow-lines tend to make the house look taller and larger. Available widths are:

- *Double 4 inch*
- *Single 8 inch*
- *Double 5 inch*
- *Triple 3 inch*
- *Dutch lap*

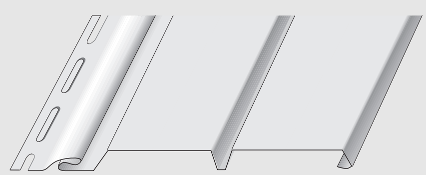


Double 5" clapboard **Double 4.5" Dutchlap** **Triple 3" clapboard** **Single 8"**

Vertical siding

Vertical siding is generally used on gables or as accent pieces or in combination with horizontal siding. It's available in:

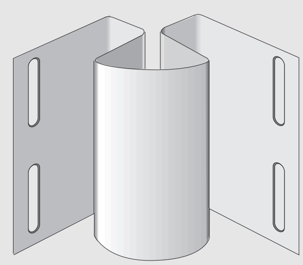
- *Double 5 inch*
- *Triple 3 inch*
- *Quad 4 inch*



Double 5" solid

Inside corner posts

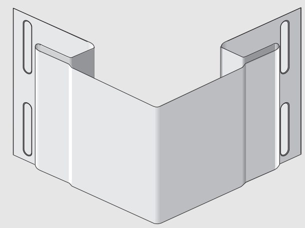
These provide a weather-resistant corner joint. They're available in a variety of widths to fit various configurations. You can also install two J-channels with their corners together as an inside corner post.



Inside corner post

Outside corner posts

These provide a weather-resistant joint for outside corners. The siding fits into the channels, which are available in widths to match the various configurations.

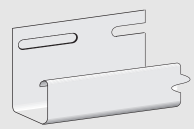


Outside corner post

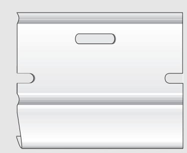
Accessories

J-channels are used for vertical siding trim and soffit trim and for horizontal siding. Openings for vertical siding range from $^3/_8$ to $^1/_2$ inch; horizontal siding openings range from $^3/_4$ to 1 inch. Be careful to match accessory piece sizes to the siding panels for a snug, weatherproof fit. Other accessories include:

- *Starter strip*
- *Frieze molding*
- *Undersill finish trim*
- *Drip cap vertical edge*
- *Inserts*
- *Trim*



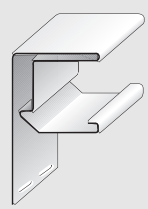
J-channel



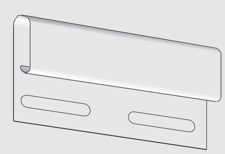
Starter strip

Soffit and fascia

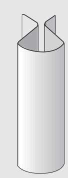
- *Quarter round*
- *Drip cap*
- *J-channel soffit/vertical*
- *J-channel — non-insulated*
- *F-channel*



Soffit receiver



Utility trim



Quarter-round insert

Courtesy: Wolverine Siding Systems

Figure 28
Typical vinyl siding

Specialty Tools for Vinyl Siding Installation

You'll need standard siding installation tools, and in addition, you'll also need some inexpensive specialty tools:

Snaplock punch — to punch ears or lugs in the cut edges of the siding for the top, or finishing, course. This punched edge will engage and lock into your already installed undersill or finish trim (Figure 29A).

> ***Tools***
>
> *Standard siding installation tools:*
>
> - *Hammer*
> - *Fine-tooth saw*
> - *Square*
> - *Chalk line*
> - *Level*
> - *Tape measure*

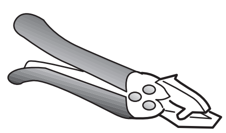
Nail hole punch — to punch holes in the panels if there isn't a hole where you need one. It makes a hole that's elongated to allow for expansion and contraction (Figure 29B).

Unlocking tool — to remove or replace siding panels. You insert the curved end of the tool under the end of the panel and hook it onto the back lip of the butt lock. To disengage the lock, pull downward and slide the tool along the length of the panel. Use it in the same manner to install a new panel. (Figure 29C).

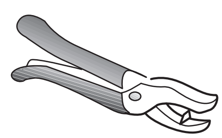
Tin snips — for making neat, clean cuts. Avoid closing the blades completely at the end of a stroke (Figure 29D).

Utility knife — for cutting vinyl. This may not seem like a specialty tool, but it's important that you have one. Use a metal straightedge as a guide, and score the vinyl from the face side using medium pressure (you don't have to cut all the way through). Snap the vinyl in two for a clean cut.

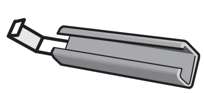
Power saw — to speed up cutting. You'll find that a circular, bench, or radial arm power saw will come in handy for cutting. Use a fine-tooth blade (12 to 16 teeth per inch), and install it in the reverse direction. In extremely cold weather, move the saw through the material slowly.



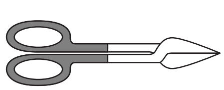
a Snaplock punch



b Nail hole punch



c Zip tool



d Tin snips

Courtesy: Wolverine Siding Systems

Figure 29
Specialty tools for vinyl siding

Fasteners

Use aluminum, galvanized steel, or other corrosion-resistant nails or staples. Nail or staple in approximately the center of the slot at this maximum spacing between fasteners:

- Horizontal siding: 16 inches
- Vertical siding: 12 inches
- Accessories: 6 to 12 inches

If studs are 24 inches on center, check with the siding manufacturer for installation instructions.

Select only corrosion-resistant nails that are long enough to allow for a $^3/_4$ inch penetration into a solid, nailable surface. Nail heads should be a minimum of $^5/_{16}$ inch in diameter. Shanks should be $^1/_8$ inch in diameter. Lengths should be:

- Siding and backerboard: $2^1/_2$ inches (minimum)
- General use: $1^1/_2$ inches
- Re-siding: 2 inches
- Trim: 1 to $1^1/_2$ inches

Power Nailers

You can use power nailers to fasten siding using a special vinyl siding guide attachment on the power equipment. Follow the siding manufacturer's recommendations for specifics. Staples should be at least 16 gauge and long enough to penetrate into a solid substrate at least $^3/_4$ inch. Use a staple with a minimum $^7/_{16}$-inch crown.

When nailing, take care to leave a clearance space of $^1/_{32}$ inch between the fastener's crown and the siding panel. Also, center the fastener leg in the nail slot to allow for the expansion and contraction of the vinyl.

Nailing Procedures

As temperatures change, vinyl siding can expand and contract as much as $^1/_4$ inch over its $12^1/_2$-foot length. For this reason, it's important that you make sure the panels remain loose enough to move freely in a lateral direction. Whether you hand or power nail, make sure you observe the following guidelines:

1. Do not face nail. Not only is it unsightly, but it will cause the vinyl to buckle with changes in temperature.
2. Do not nail any siding parts too tight. Leave at least $^1/_{32}$ to $^1/_4$ inch (about the thickness of a paper match) between the nail head and the vinyl. Manufacturer's recommendations vary on the exact amount of space you should leave. Follow their instructions.
3. Center the nails in slots to permit expansion and contraction of the siding.
4. Drive nails straight and level to prevent distortion and buckling of the panel.
5. Start nailing vertical siding and trim pieces in the top of the uppermost slots to hold them in position. Place all other nails in the center of the slots.
6. Space nails according to the guidelines above.
7. Make sure the panels are locked at the bottom, but don't pull them tight when nailing. Panels must be able move freely from side to side.

CAUTION: Always wear safety goggles when you're nailing or cutting.

Vinyl Siding Installation

Follow the general preparation guidelines for siding at the beginning of the siding section.

Installing the Accessories

Inside and Outside Corner Posts —

1. Install the inside and outside corner posts before the siding. It's essential that they're perfectly plumb and square.

2. Position the corner post so that $^1/_4$ inch is left at the top. Place the first nail at the top of the upper slot. Center the rest of the nails in the slots. This allows for the expansion and contraction to occur at the bottom. Fasten the post every 6 to 12 inches on center. When you install the siding, maintain a $^1/_4$-inch space in the channel section of the corner post.

Window and Door Trim —

1. Use J-channel around windows and doors that will receive siding. Cut side J-channel members longer than the height of the window or door, and notch them at the top. Miter cut the free flange at a 45-degree angle and bend the tab to provide flashing over side members. Caulk around windows and doors before you install the trim pieces.
2. To further prevent water from getting behind the siding, cut a flashing piece from coil stock, and slip it under the base of the side J-channel members. Position it to lap over the top lock of the panel below.

Gable End Trim —

1. Remove all old paint build-up before you install the J-channels.
2. Before placing the siding, you need to install J-channel to receive the siding at the gable ends. Where the left and right sections meet at the gable peak, let one of the sections butt into the peak with the other section overlapping. Make a miter cut on the face flange of this piece for a better appearance. Fasten the J-channel every 6 to 12 inches.

Installing Horizontal Siding

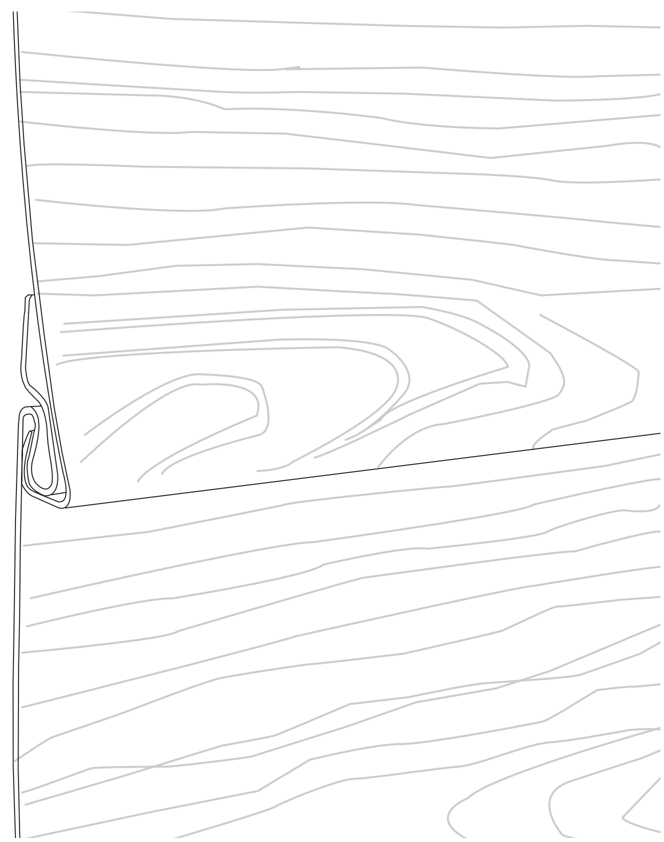
Here are some general guidelines to use along with the specific manufacturer's instructions:

1. Snap a chalk line for the horizontal starter strip. Make it parallel to the foundation at the lowest point of the house, about $1^3/_4$ inches up from the foundation base. Make your measurements from the eaves or the top and bottom of the windows rather than from the foundation. If the siding is uneven at the foundation, you can camouflage it; if it's uneven at the eaves, it will be embarrassingly obvious.

   If you must trim the lower portion of a horizontal panel to install it over steps or a porch, you'll need to fur the panel for proper cant (angle) and rigidity. Use undersill trim to seal the cut edge of the panel and then secure it to the wall.

2. Using the chalk line as a guide, install the starter strip along the bottom of the building. Allow space for corner posts, J-channels, and so on. Keep ends of starter strips at least $^{1}/_{4}$ inch apart to allow for expansion. Align the panels with windows and eaves, then nail in the center of the nailing slots. If you're using insulation or backerboard, shim as necessary to accommodate its thickness.

3. Place the first panel in the starter strip and securely lock it (see Figure 30). Nail the panel in the center of the nailing slot, 16 inches on center. Allow a $^{1}/_{4}$ inch gap at all corner posts and channels for normal expansion and contraction. When installing in temperatures below 32 degrees Fahrenheit, increase minimum clearance to $^{3}/_{8}$ inch. Follow the manufacturer's recommendations for lapping the panel ends so that they can move freely in a lateral direction. Use a level and tape measure to check that each course is correctly aligned with windows, eaves, and adjacent walls.



Courtesy: Wolverine Siding Systems

Figure 30
Wolverine's GripLock™ panels firmly lock into place

4. Install the next course in the same way. Stagger end laps so they aren't directly above one another unless they're separated by three courses. For the best overall appearance, never overlap joints around entrances or at the points of greatest traffic. Check every fifth or sixth course for alignment. Do not force the panels up or down when nailing in position — allow them to hang without strain. Panels should never be under vertical tension or compression when nailed.
5. Don't caulk panels where they meet the receiver of inside corners, outside corners or J-trim, and don't caulk overlap joints.

Fitting under Windows —

1. Mark the section to be cut out. Cut the sides with snips and score lengthwise with a utility knife. Bend the section back and forth along the scored line to separate it from the main panel.
2. Install the cut panel under the window, furring if necessary. Place undersill trim along the horizontal cut edge to hide the cut.
3. Install the drip cap at the window top.

Eaves Treatment —

1. Before installing the last course, nail the finishing trim in place along the top of the wall. (You may need furring to maintain the face of the panel at the desired angle.)
2. Check the manufacturer's application instructions for exact cutting tolerances to ensure you have a proper fit for the top of the finishing course. Cut the siding panel so it covers the remaining open section. If you're installing siding over existing siding, you may need to fur to set the last panel.
3. Using a snaplock punch, punch the vinyl siding along the cut edge every 6 to 12 inches so that the raised ear or lug is on the outside face.
4. Push the siding into the finish or undersill trim. The raised ears will catch and hold the siding firmly in place.

Installing Vertical Siding

1. Install vinyl soffit and fascia first.
2. Snap a chalk line around the base of the sidewalls. Make it parallel to the foundation at the lowest point of the house, about 1 inch up (consult specific manufacturer's instructions). Measure from the eaves or the top and bottom of the windows rather than from the foundation. Again, if the siding is uneven at the foundation, you can camouflage it; if it's uneven at the eaves, it will be obvious.

3. Install outside and inside corner posts. Leave a $^1/_4$ inch gap at the top of these trim pieces. (Corner posts should extend $^1/_4$ to $^1/_2$ inch lower than the horizontally installed vertical base, or head flashing.) Place the first nails in the uppermost ends of the top nail slots to hold them in position. Place all other nails in the center of the slots. Space nails 6 to 12 inches on center.
4. Position the top edge of the vertical base (head flashing) along the previously snapped chalk line. Fasten every 6 to 12 inches in the center of the nail slots. Fasten it securely, but not tightly; don't restrict lateral movement. Leave $^1/_4$-inch gaps at the corner posts. Where lengths adjoin, back trim the nailing flanges 1 inch and overlap $^1/_2$ inch to create a neat joint.
5. Install $^1/_2$-inch J-channel at the tops of sidewalls. At gable ends, snap a level chalk line along the base of the gable and install J-channel. Lap where necessary and allow for expansion.
6. Trim around all windows and doors using $^1/_2$-inch J-channel. (Head flashing is optional.) We suggest following this sequence:
   a. Cut a $^1/_2$-inch J-channel for the bottom of the window as wide as the frame and install it.
   b. Cut side J-channels the length of the frame *plus* the width of the bottom J-channel. Cut and bend tabs into the bottom channel. Install the side channels.
   c. Cut the top J-channel (and head flashing if you use it) the width of the frame plus the width of the side J-channels. (If you use head flashing, cut out the ends to match the side J-channels and install it.) Notch the top J-channel on each end, and bend the tabs into the side J-channel. Fasten the top J-channel.
7. Don't caulk panels where they meet the receiver of inside corners, outside corners or J-trim, and don't caulk overlap joints.

Sidewalls for Gable End Sidewalls (Center Start) — Find the center of each sidewall and use your level or plumb line. Install the vertical starter strip at this point, using the nailing procedure for vertical pieces. Leave a $^1/_4$-inch gap at the top and bottom. Working from the starter strip to the corners, lock each panel and fasten every 6 to 12 inches. Terminate panels in the J-channel already installed at the top.

Sidewalls for Non-Gable End Sidewalls —

1. Slit a vertical siding starter strip in half lengthwise. Fasten it inside the receiver channel of the corner post, making sure the starter strip is plumb. Leave enough clearance between the inside web of the corner post receiver, and lock on the starter strip to allow you to attach the siding panel.

2. Install vertical siding panels by locking the first siding panel into the starter. Fasten this panel 12 inches on center. Leave a $^1/_4$ inch clearance at the top and bottom. Place the first nails in the top ends of the top nail slots to hold them in position. Place all other nails in the center of the slots. Terminate the top of the panel into a $^1/_2$-inch J-channel.

3. If it will take more than one course to span the height of the house, you'll have to terminate the first course into an inverted J-channel, allowing $^1/_4$ inch for expansion. Install head flashing on top of the J-channel, and begin the second course, leaving a $^1/_4$-inch gap at the head flashing. Where you anticipate severe water runoff, flash 4 to 6 inches behind the upper vertical panel onto the head flashing.

Window and Doors —

At windows and doors, cut the panels (if necessary) to fit the opening, allowing $^1/_4$ inch for expansion. If the panel is uncut or cut down in the V-groove, simply insert it into the $^1/_2$-inch J-channel, locking the other side onto the previously applied panel. If the panel is cut on the flat surface, install undersill trim, backed by furring, into the $^1/_2$-inch J-channel. Fit the flat surface of the vertical siding into the undersill trim. Further secure the panel above and below the windows and above the door once you have the panel fastened in place.

Corners —

At corners, insert $^1/_2$-inch J-channel into the receiver of the corner post. If the panel is cut in the bottom of the V-groove, insert it into the J-channel. Add a furring strip before you insert the panel. This will prevent the panel from detaching. If you cut the panel on the flat surface, place a piece of undersill trim, backed by furring, into the receiver of the corner post. Punch snap locks along the cut edge of the panel at 6-inch intervals, and snap it into the undersill trim.

Make sure the fasteners you use to attach the furring and undersill trim *don't penetrate the fastening leg of the outside corner post*. In addition, you shouldn't position the furring too far into the outside corner post where it may restrict the channeling of runoff water.

Gable Ends —

1. Begin by fastening $^1/_2$-inch J-channel along the rake edge of the roof. Install vertical base (head flashing) on top of the previously installed J-channel at the base of the gable. Attach either a vertical siding starter strip or two back-to-back regular starter strips, centered with the peak of the gable.

2. Make a pattern for end-cuts along the gables, using two pieces of scrap siding. Lock one piece onto the starter strip just under the eaves. Hold the edge of the other piece against, and in line

with, the roof line. Mark and cut the vertical piece. Use it as a pattern to mark and cut the ends of all other panels required for this side of the gable end. Make another pattern for the other side of the gable.

Installing Soffit and Fascia

Before installing soffit and fascia panels, nail down any loose panels, boards or shingles. Check surfaces for straightness and fur where necessary. You should have surfaces that are uniform and straight from every viewing angle. For open rafters, construct the soffit parallel to the ground. For enclosed rafters, apply the vinyl components over the existing unit. Refer to the manufacturer's guidelines for the specific installation method, and follow these general guidelines for soffit and fascia coverage.

Open Rafters —

1. Place the F-channel pieces parallel to each other, one on the house and one on the opposite side of the fascia. This will allow you to insert the soffit panels.
2. Fasten the F-channel directly to the wall. Fasten it every 6 to 12 inches, centering the fasteners in the nail slot.
3. Install an F-channel or J-channel on the outer bottom edge of the fascia board to provide support for the outer edge of the panel.
4. Cut the soffit panel to length, subtracting $^1/_4$ inch from each panel for expansion. Place the soffit panel in the channel slots. The panels hook or slip together. On panel sections over 24 inches wide, use intermediate nail supports. Where two soffit surfaces meet, use a T-channel or two $^1/_2$-inch J-channels, properly supported and nailed back to back, to provide support for the soffit panel.
5. At the ends, install pieces of vinyl F-channel or $^1/_2$-inch J-channel, as appropriate, to finish the job. Either miter or butt the corners.

Enclosed Rafters —

1. Nail the appropriate molding to the wooden soffit, making sure that it's level and aligned with the F-channel on the bottom of the fascia. Install the F-channel on the outer bottom edge of the fascia board.
2. Cover boxed ends with field-formed trim sheet or fascia.

Fascia —

You can use vinyl fascia cover with or without soffit panels. Install the finish trim and F-channel. Measure the cover required and, if necessary, cut the fascia cover to proper width. Punch snaplock "ears" every 6 to 12 inches along the top of the fascia using the snaplock punch.

Corner Cap —

1. Use prefabricated corner cap or cut a piece of fascia cover $5\,^1/_2$ inches long. Mark a vertical centerline on the back. Cut out a 90-degree section of bottom flange from the center, leaving 45 degrees on each side. Using a hand seamer, fold along the vertical centerline to form a right angle.

2. Trim the fascia cover ends at the corners. Punch the top edge of the corner cap with a snaplock punch. Hook the corner onto the bottom ends of the fascia cover and snap the top into place under the undersill trim lock.

Vertical Soffit Panels in Porch Ceilings —

1. Frame the edge of the porch ceiling with quarter-round vinyl wall molding or other suitable vinyl accessory. Install finishing trim in left or right quarter-round receiving slots.

2. Cut vertical panels to proper length, allowing $^1/_4$ inch for expansion. Fit the first panel in the molding and trim the last panel to size and secure the cut edge in the finish trim. Fasten it at a maximum of every 16 inches in the center of the slots. *Don't nail it too tightly!*

Repairing and Replacing Vinyl Siding

Depending on how severe the damage is and what siding scraps you have for repair, you have the option to repair or replace damaged panels.

Tools and Materials

- *Zip tool*
- *Hammer*
- *Fasteners*
- *Siding panel*

Replacing a Damaged Panel

1. To remove a panel for any reason, slip the zip tool behind the bottom of the panel above the one to be replaced. Pull down on the tool as you slide, or "unzip" the lock on the damaged panel.

2. Gently bend out the upper panel. Take the nails out of the damaged panel and remove it.

3. Lock on the new panel, and nail it as explained under Nailing Procedures.

4. To lock the upper panel over the lock on the new panel, pull down the bottom edge of the upper panel with the zip tool. Press the upper panel's edge over the lower panel with your hand.

Materials

In addition to the materials already listed, you will need:

- *PVC cleaner*
- *PVC cement*

Repairing a Damaged Panel

1. Follow steps 1 and 2 above. Clean the back side of the damaged area with PVC cleaner. Apply PVC cement to the damaged area. Cover the area with scrap siding placed finished side down.

2. Follow steps 3 and 4 above to replace panel.

Tools and Materials

- *Utility knife*
- *Pliers*
- *Long-nose riveter*
- *Caulk*
- *Blind rivets*

Replacing a Damaged Corner Section

1. Score the sides of the corner section where the sides meet the flanges. Use the pliers to work the post free by bending the vinyl back and forth.
2. On the replacement post, cut off the nailer strips (as described in step 1, above), but leave the flanges.
3. Apply a bead of caulk to the flanges on both the replacement post and the post still attached to the house.
4. Press the two pieces together, and secure them with blind rivets.

Cleaning and Maintenance

Vinyl siding comes closer to being totally maintenance-free than any other siding on the market today. Although vinyl siding will eventually become dirty, the same as a freshly painted house or anything else that's exposed to exterior weather conditions, you can keep vinyl siding clean with very little effort. A heavy rain will do wonders, or you can just wash it down with an ordinary garden hose. If neither rain nor hosing does a satisfactory job, use the simple instructions in the following section to clean vinyl siding.

Normal Maintenance

Get an ordinary, long-handled car washing brush at an auto supply store. The brush has soft bristles, and the handle fastens onto the end of a hose and allows you to wash the siding just like you would wash your car. If the dirt is hard to remove, such as the soot and grime found in industrial areas, wipe down the siding with the cleaning solution below. Start at the bottom of the house and work up to the top to prevent streaking.

Cleaning Solution —

$^1/_3$ cup powdered laundry detergent

$^2/_3$ cup household cleaner (Spic & Span, Soilax or equivalent)

1 gallon water*

*For mildew problems, use the same solution, but substitute 1 quart of liquid laundry bleach for 1 quart of the water.

Stain Removal

If stubborn stains persist, use the stain removal chart in Figure 31. Follow any precautionary instructions on the cleaning agent label. Protect shrubbery from direct contact with cleaning agents. Protect your skin and eyes from direct contact with all cleaning solutions.

CAUTION: Before using any cleaning agents on siding, test-clean a small, inconspicuous area. Always follow the manufacturer recommendations.

Staining agents	Cleaning agents	Preparation	Special cleaning procedures
Light oils and greases, heavy grease, caulking compound, wax, crayon, asphalt, tars, etc.	Solvents — mineral spirits, V.M.P. naphtha auto tar remover	Remove excess with plastic or wood scraper.	Use soft cloth to apply mineral spirits. Avoid polishing stained area by using too much pressure. After removing stain, rinse area with water.
Inks (marking), nail polish, paint, lipstick, gum	Cleaning fluid	Remove excess with plastic or wood scraper. Chill gum to remove excess.	Use soft cloth to apply cleaning fluid. Avoid polishing stained area by using too much pressure. After removing stain, rinse area with water.
Rust stains	Oxalic acid — auto radiator cleaner	Make a solution of one tablespoon of oxalic acid crystals to one cup warm water.	Apply oxalic acid solution with soft bristle brush, wipe with damp cloth, and then flush with rust-free water. (Use rubber gloves and protect eyes and face.)
Stubborn stains	Xylene — lacquer thinner	First try the procedures listed above in the order given. If they fail to remove spots, then use lacquer thinner in this procedure.	Dampen small section of cloth, rub vigorously. Do not remove any more material than necessary. Rinse area with water.

Figure 31
Stain removal chart

Using Vinyl Siding on Historic Restorations

Use the following guidelines provided by The Vinyl Siding Institute if you're considering vinyl siding for use on a historic building or a building in an area of historic restoration. Figure 32 shows how you can use vinyl siding products to restore Victorian accents.

1. If a building is in a historic area and/or has been designated a historic building, be certain that approval for the use of vinyl siding has been obtained from the local historic society before you decide to use it. This applies to building additions as well.
2. Before you begin re-siding a historic building, make sure to have the building examined for moisture, insect infestation, structural defects, and other problems that may be present. These problems should be addressed and the building pronounced "healthy" before you re-side with any material.
3. Don't damage or remove the original siding. If at all possible, don't alter the original structure. That way your application of vinyl siding is reversible. (The original would remain intact so

Courtesy: Wolverine Siding Systems

Figure 32
Vinyl siding products reproduce Victorian style

that at some time in the future, if desired, the vinyl siding could be removed and the original siding restored.) There's one exception: "In cases where a non-historic artificial siding has been applied to a building, the removal of such a siding before the application of vinyl siding would, in most cases, be acceptable." (Preservation Briefs, Number 8 - U.S. Dept. of the Interior - 1984)

4. Exercise every care to retain architectural details wherever possible. Don't remove, cover, or add details until you have the building owner's written approval. Determine that the owner has consulted with the local historic society regarding any changes.
5. Use siding which closely approximates the appearance of the original siding in color, size, and style.

Aluminum Siding

Like vinyl siding, aluminum siding is very durable as well as being easier to maintain than wood siding. It's also fire-resistant, rot-proof, and insect-proof. However, unlike vinyl and wood, it dents easily, fades, rusts, and scratches. Also, because metal conducts electricity, many building codes require that aluminum siding be grounded.

Another problem that you find with aluminum is that unless it has an insulated backing, the siding expands and contracts noisily with temperature changes. In spite of these disadvantages, it's still commonly used as a siding material.

Installation

Installation for aluminum siding is similar to vinyl, with a few minor differences. Review the installation procedures for vinyl siding. In addition to those guidelines, follow these additional rules:

1. Install aluminum siding with aluminum nails.
2. Cut aluminum siding with tin snips or a power saw. If the siding is insulated, cut away the insulation first. When using tin snips, score the siding with a utility knife first. Carefully cut in the groove. If you use a power saw, rub the saw's teeth with either a bar of soap or candle wax to reduce burring. Cut away from you.
3. Install outside corners as you would with vinyl siding. Or you can use corner caps, which you attach after hanging the siding:

    a. Make sure that the panels are perfectly level on each side wall, otherwise the cap won't hold securely.

    b. Gently squeeze the corner cap before installing. Hook the bottom lip of the cap under the siding pieces.

    c. Nail the siding in place using 2- or $2^1/_2$ -inch aluminum nails.

Tools and Materials
- *Utility knife*
- *Tin snips*
- *Work gloves*
- *Caulk*
- *Roofing cement*
- *Replacement siding*

Repairing Aluminum Siding

Aluminum siding is fairly durable, but if it gets damaged, it can be difficult to repair. Because it dents and creases so easily, it's more practical to cut out the damaged section and cement a new piece in its place rather than trying to replace the entire panel.

Replacing Siding Pieces

1. With a utility knife, score the area to be removed. Don't cut the upper part of the siding where it's attached to the house. Follow the scored lines with the tin snips.
2. Cut a new length of siding, allowing an extra 3 inches at each end to overlap the old siding. Trim off the nailer strip on the upper part of the siding.

3. Caulk the edges of the replacement piece and the area to be patched. Spread roofing cement to the upper portion of the old siding.

4. Snugly fit the replacement so that the trimmed area is hidden under the lap of the existing siding. With your hand, hook the bottom edge onto the 3-inch overlaps on each end.

Tools and Materials

- *Drill*
- *Pliers*
- *Sheet-metal screws*
- *Two-part auto-body filler*
- *Sandpaper*
- *Metal primer*
- *Aluminum siding paint*

Repairing Dents

Small dents can often be repaired by using auto-body filler as explained below. Larger dents are more difficult. If you can't fill it in smoothly, its better to cut the dent out and replace the piece as explained above.

1. Drill a series of $^{1}/_{8}$-inch holes in the deepest part of the dent. Screw in sheet-metal screws with flat washers. With pliers, carefully pull on the screws, lifting out the dent as you work.

2. When you have made the surface as even as possible, remove the screws. Spread auto-body filler over the screw holes and remaining depression. Level it with the rest of the panel as much as possible.

3. When the filler has hardened, sand it smooth and prime with a metal primer. Paint with matching aluminum siding paint, using two coats if necessary.

Manhours

Manhours to Install Siding			
Component	**Unit**	**Manhours**	**Suggested Crew**
Cedar shingles/shakes, 16" with 7 1/2" exposure	Sq	3.86	1 laborer, 1 carpenter
Cedar shingles/shakes, 18" with 8 1/2" exposure	Sq	3.75	1 laborer, 1 carpenter
Panelized shingles on plywood backing, 8' lengths	Sq	.028	1 laborer, 1 carpenter
Board siding, lap, 3/8"	Sq	2.18	1 laborer, 1 carpenter
Board siding, lap, 5/8"	Sq	2.45	1 laborer, 1 carpenter
Board and batten	Sq	2.45	1 laborer, 1 carpenter
Vinyl siding, 10" or double 5" panels	Sq	3.34	1 laborer, 1 carpenter
Vinyl siding accessories	LF	.033	1 laborer, 1 carpenter
Aluminum siding, 8", double 4" or 12" widths	Sq	2.77	1 laborer, 1 carpenter
Aluminum siding accessories	LF	.033	1 laborer, 1 carpenter

For information on related topics, see:

Asbestos, page 31

Brick Masonry, page 51

Doors, page 223

Framing Materials and Planning, page 363

Glass Block, page 375

Insulation, page 395

Painting, page 427

Porches and Decks, page 485

Stone Masonry, page 655

Stucco, page 665

Trim, page 673

Wall Framing, page 709

Windows and Skylights, page 747

Stone Masonry

If brick is the granddaddy of all construction materials, stone is the great-granddaddy. Stone is a marvelous building material — durable, attractive and solid. For these obvious reasons, most of the finest man-made structures that have lasted through the millennia have been constructed of stone. Today, stone isn't used as commonly as other masonry materials because of the initial cost of the stone itself and the labor to lay it. Once in place, however, it requires little or no maintenance, making it more cost effective over the long run than far cheaper materials.

Stone Used in Construction

The varieties of stone most commonly used in the construction industry are granite, sandstone, slate, marble, and limestone. These stones come in an almost limitless choice of sizes, colors, and finishes to suit any purpose. Our descriptions are very broad ones, just to give you an idea of what's available. Remember, too, that costs and availability of the various options vary widely across the country. For instance, you can often get river rock, a common fieldstone in some parts of the country, free for the hauling. Quarried stone, on the other hand, can range from $20 to $200 a cubic yard depending on quality and availability.

Granite

Granite is extremely hard and durable. It's surface texture ranges from a coarse, almost granular texture to a highly polished, smooth-as-glass surface. The color ranges from white to deep bronze or black. Because of its excellent durability, you can use granite structurally or as a decorative or protective veneer.

Sandstone

Sandstone is really what its name says it is: tiny grains of sand held together by a natural cementitious material. Of the more commonly-used stones, it has the reputation of being the softest, although some types, such as Ohio sandstone, are actually very hard and durable. Generally, sandstone is in red to brown hues, depending on the amount of iron oxide in it. But you can also get bluish-gray sandstone; the color depends on the area where it's quarried. Sandstone is most commonly used for paving or flagstones.

Slate

Slate is actually silt from ancient sea bottoms. It has the unique quality of being able to be split into thin sheets — as thin as $^1/_4$ inch — and still hold together. The thinner dimensions are used as a long-lasting roofing material; the thicker ones, up to 2 inches, can be used for exterior and interior veneers, countertops, or even paving. The color of slate varies depending on the amount of iron, carbon, and chlorite it contains. Some of its colors are nonfading while others change from weathering.

Marble

Technically, marble is crystalline limestone. But in the marketplace, any crystalline rock with mosaic grains that will take a polish is considered marble. Because of this expanded definition of marble, the range of colors and weather tolerances is extremely wide. American marble ranges from white to pinks, greens and black, but imported marble comes in hundreds of colors and patterns. Some marble holds up well when exposed to weathering, while some crumbles from exposure to water, freezing, or pollutants and can only be used for interiors.

Limestone

Limestone has the unique quality of being relatively soft and easy to work with when it's first quarried, but develops a hard, durable surface after being exposed to air. Limestone commonly ranges in color from white to gray and often has some variegated coloring. It's used for both interior and exterior purposes.

Other Stone Classifications

Stone is further classified by how it's found, its shape and its surface finish.

Fieldstone

Fieldstone is stone that's been collected, like river rock, rather than being quarried. Flagstone, which is mostly used for paving, is split into flat slabs but generally isn't dressed further.

Stone

Quarried stone, in contrast to fieldstone, is drilled or blasted. It may be sold in this rough state, or it may be milled, or dressed, further. Quarried stone is further classified into the following types:

- *Rubble:* Quarry stone that hasn't yet been milled or dressed. It's uncut and unsized, which means it's relatively inexpensive, but it's also difficult to lay. Because of its uneven size, rubble is laid in a random pattern rather than in courses. Figure 1a shows a rubble stone wall.
- *Semidressed stone:* Quarry stone that's in between the rubble state and ashlar (Figure 1b). It's rough cut and sorted by size, but may need further trimming for individual applications.
- *Ashlar stone:* Also called *dimensioned stone*, it's the most expensive quarried stone because it's hewn or squared and trimmed to certain specifications. Because of its uniform shape, it's easily laid in courses like brick (Figure 1c) but can also be laid in random patterns (Figure 1d).

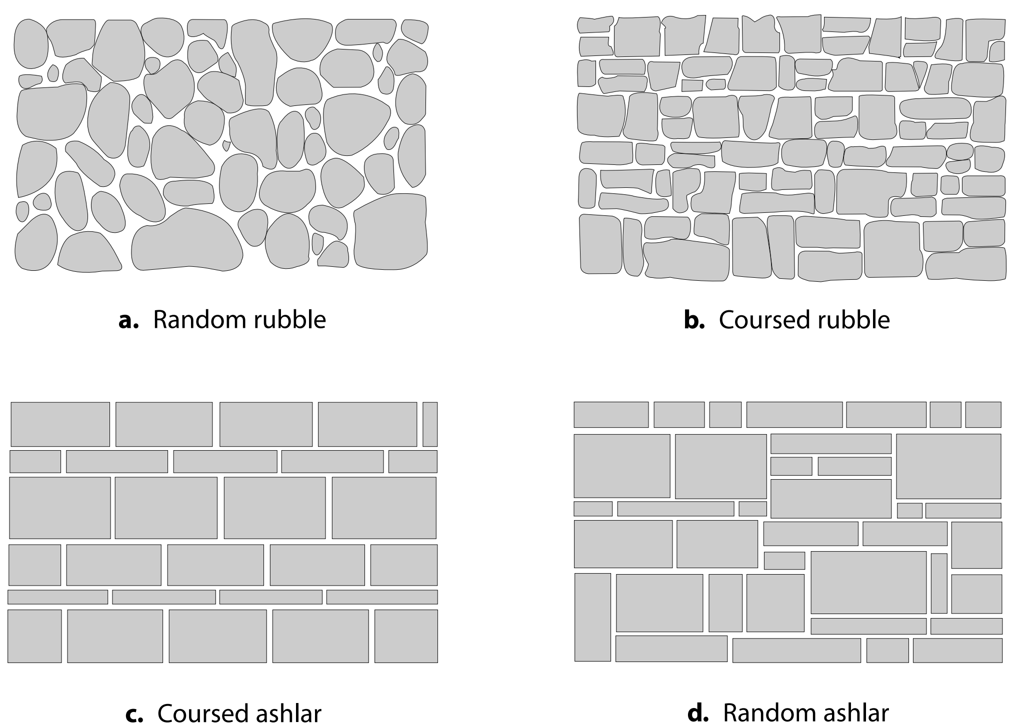


Figure 1
Stone wall patterns

Estimating Stone Quantities

Stone is sold a variety of ways, depending on the type and cut. As a general rule, you buy dressed stone primarily by the square foot, but you may also be able to buy it by the cubic foot, cubic yard or by weight. Edge detail for dressed stone is sold by the lineal foot. You buy fieldstone and rubble stone either by volume or by weight.

To determine how much you need for a project, measure the length, width, and where necessary, the height, converting your figures into the appropriate measurement. Because stone varies considerably in weight, if you're using a stone that's sold by weight, you'll have to get help from the supplier to convert your measurement into tonnage. In any project you'll have some waste, either in breakage or wrong sizing. For fieldstone or rubble stone, figure an extra 10 to 25 percent. For ashlar, allow for 5 to 10 percent waste.

Mortar is also part of the total volume. Allow 15 to 35 percent of the volume for mortar when building with fieldstone or rubble stone, 5 to 10 percent for ashlar masonry. Semidressed stone can vary so widely that it's difficult to estimate how much mortar you'll need, but somewhere in the range of 5 to 10 percent should be adequate.

Stone Mortar

For the most part, the mortar for stone is similar to mortar used for other masonry, although you generally mix it to a stiffer consistency. The two common mortar mixes used in stone masonry are lime-cement mortar and cement mortar.

- Lime-cement mortar is a 1:$^1/_2$:4$^1/_4$ mixture (1 part cement, $^1/_2$ part lime and 4$^1/_4$ parts sand), similar to a standard mortar mix. Hydrated lime stains porous stones such as limestone, so if you're working with one of these stones, choose a cement mortar without lime.
- Cement mortar mixed at 1 part cement to 3 or 4 parts sand gives a sturdy mortar. To improve the workability of the mortar, you can add $^1/_2$ part fireclay, which won't stain stone like lime does. For either mortar mix, use white or stainless portland cement. Refer to Mixing Brick Mortar on page 63.

Laying Stone

Laying stone is similar to laying brick. You must provide a solid foundation, mix the mortar correctly, and work constantly to keep the wall straight and plumb. But a few important distinctions exist. You keep

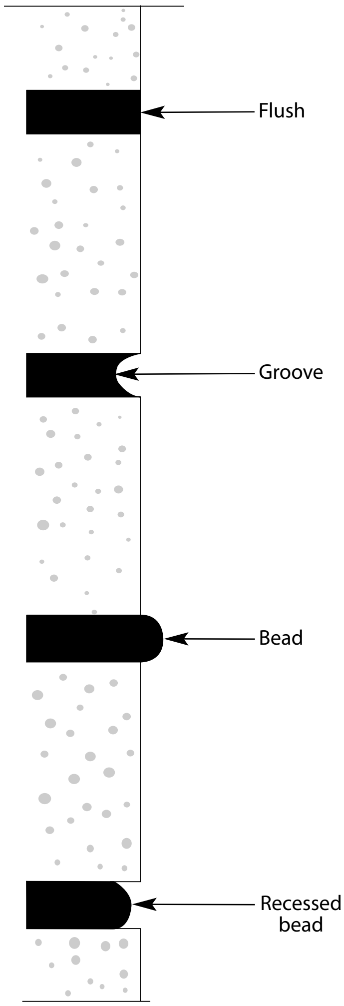


Figure 2
Types of stone joints

bricks wet to prevent them from drawing the water out of the mortar too quickly, but you should lay stone dry. The other major difference is in the way you finish the joints. As you lay the stones, clean or rake the mortar out of the joints to a depth of $^3/_4$ inch. Follow with a pointing mortar that's thicker than regular mortar. Finish the joint with a finishing tool, making a flush, groove, bead, or recessed bead joint. See Figure 2.

Laying rubble or fieldstone is a little more complicated. Again, there are many similarities to laying a brick wall. But because you need to fit odd-shaped pieces tightly together to make a structurally sound, attractive wall, it becomes almost an art form. Stone walls may be either dry stack or wet stack. A *dry stack* wall is a low rise wall (under 3 feet) that's held together by gravity and the friction of the stones, not by mortar. (Rounded stones such as river rock won't work well in a dry stack wall.) In a *wet stack* wall, you use mortar to hold the stones in place.

Stone Wall Batterboards

Both a dry stack and a wet stack wall should be battered, or gradually sloped toward the center, as it rises. A dry wall should slope inward 2 inches for each 1 foot rise. Batter a wet wall 1 inch for each 1 foot rise. To keep the batter even, make four batterboards.

Wet Wall Batterboards

1. For a 3-foot wall, cut four 1 × 6 boards into 42-inch lengths. See Figure 3.
2. On the bottom end, measure up 1 foot and then in 3 inches. Mark this point with an X. From this point, draw a diagonal line to a top corner.
3. Cut a straight line from the bottom up to the X. Then cut along the diagonal line to the top. Cut the bottom end into a point.
4. Repeat with the other three boards.

Dry Wall Batterboards

Follow steps 1 through 4 above except you'll need to use a wider board to account for the greater angle of the dry stack wall. For a 3-foot wall, for example, you could use a 1 × 12.

Building a Stone Wall

You'll need to use bonding stones as anchor points along both dry and wet stack stone walls. A bonding stone is a long, flat stone which is as long (or wide) as the width of the wall. Gauge the size and shapes of

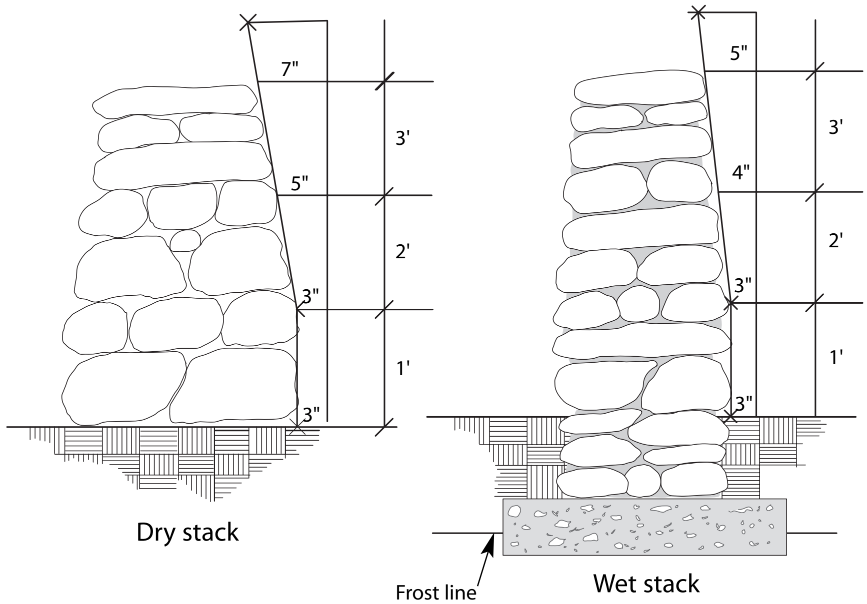


Figure 3
Stone wall batterboards

the rocks you're working with to end the top course with one wide stone for a dry stack wall or one or two stones for a wet stack wall.

For instance, if you're building a 3-foot dry stack wall, your first course will be 2 feet wide ($^2/_3$ of the wall height). At 1 foot up, you batter in the wall to 1 foot 8 inches. At 2 feet, you narrow the wall to 1 foot 4 inches. Then you taper the top in another 4 inches so that it's an even 1 foot wide. The top course should consist of one stone, roughly 12 inches across.

Wet Stack Walls

Since the mortar provides strength and stability to a wet stack wall, the base doesn't have to be as wide. Generally, you should make the width half the height. You'll only need to batter in 6 inches for a 3-foot wet stack wall. The top stone should be 12 inches across, or you can use two stones which are slightly less than 6 inches each to allow for mortar.

Because a wet stack wall depends on mortar rather than friction to hold the stones permanently in place, you may have trouble keeping the stones locked into place until the mortar sets. Try using wedges of wood in between joints to hold rocks, removing the wood when the mortar has set up some and pointing with mortar in the gaps. Or, use a 2×4 to brace big stones until the mortar has set sufficiently to hold them. Also, don't try to build up more than 2 feet of wall a day.

Guidelines for building a wet stack wall:

1. Because of its rigidity and weight, you need a solid foundation design for a wet stack wall. Begin by digging below the frost line and filling the trench with gravel. Pour a footer that's 6 inches deep and at least 6 inches wider than the base of the wall. Or build a rock and mortar foundation up from the frost line (with a minimum depth of 6 inches).
2. Stake two batterboards at each end of the wall; tie strings from one end to the other to use as a guide for keeping the stones relatively even. Snap chalk lines on the footer to use as an additional guide.
3. Do a dry run of the first course. Lay bonding stones at each end and every 4 feet in between. Then remove the stones and spread a 2-inch layer of mortar on the footer. Set the stones back into the mortar, filling the center and small cracks with stones and mortar as needed. Fill in the joints between the larger stones with a pointing trowel.
4. Build up the courses, overlapping vertical joints. Try to fit pieces together as much as possible. Fill all gaps with mortar; use mortar and small stones to fill in large spaces. Lay the last course using two flat rocks to span the width of the wall as shown in Figure 4.
5. Use a wet sponge to keep the stones as free from mortar smears as possible. Let the mortar set until it's thumbprint hard; rake back $^3/_4$ inch and point. When the mortar is fairly dry, clean off the remaining mortar with a stiff-bristled brush.

Tools and Materials

- *Batterboards (four)*
- *Level*
- *String*
- *Crowbar*
- *Mortar*
- *Hawk to hold mortar*
- *Pointing trowel*
- *Shimming material*
- *Stiff brush*
- *Sponge*

Although it's not as durable, you might want to consider using synthetic stone instead of real stone. It's cheaper, lighter, easier to use, and looks surprisingly realistic. Some suppliers will even number the pieces so that assembling the wall is just like putting together a big jigsaw puzzle.

Cutting Masonry

You need the same materials and use just about the same methods to cut brick, concrete block or stone.

Tools

- *Safety goggles*
- *Leather gloves*
- *Pencil*
- *Straightedge*
- *Brick or stone chisel*
- *Small sledgehammer*

1. Draw a line where you want to cut the brick, block, or stone. For stone, try to find the stone's natural grain. Place the stone on dirt or sand.
2. Wearing goggles and gloves, gently score along the lines by tapping the chisel with a sledgehammer.
3. After scoring all four sides, put the chisel into the etched line, blade facing toward the waste end. Hit the chisel with the sledgehammer in one hard, clean move. The unit should break neatly in two. For fieldstone, after scoring on both sides, place a 2 × 4 under the stone about an inch before the line. Use a sledgehammer to knock off the waste.

You can also cut masonry with a power saw and a masonry blade. Use either a diamond-tipped or carbide masonry blade. Wearing goggles and gloves, make several cuts. Start with a shallow one, and make each successive pass deeper than the last until the cut is complete.

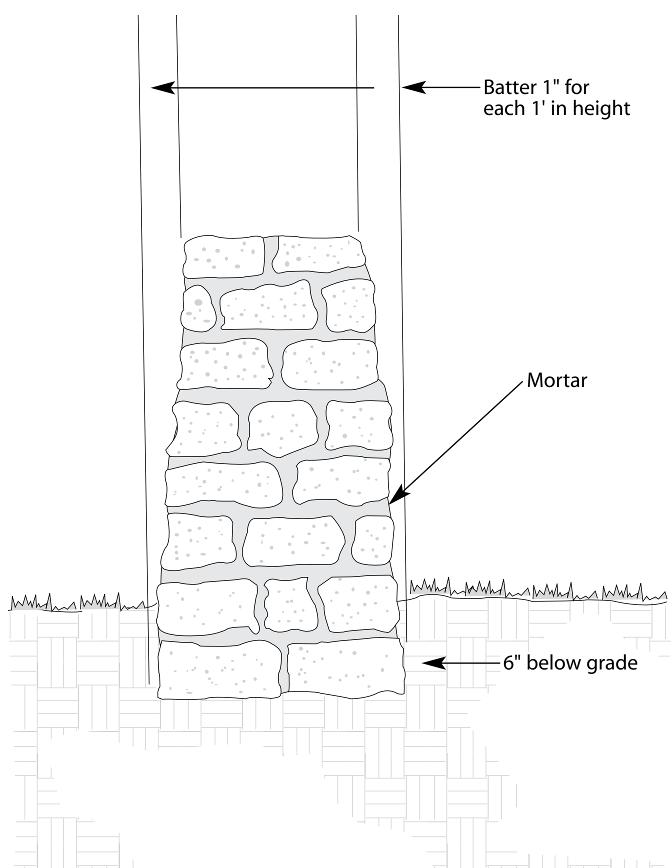


Figure 4
Wet stack freestanding rock wall with rock and mortar foundation

Cleaning Stone Masonry

Stone is more difficult to clean than brick or concrete. It's particularly important not to use acid cleaners on stone because the acid may cause a more difficult stain than the original one. Here are some general guidelines for cleaning stone:

- *Granite:* Wash with mild laundry detergent; rinse and wipe dry; polish with a chamois.
- *Limestone:* Scrub with a stiff, nonmetallic brush and water. Don't use detergent.
- *Marble:* For general cleaning, use a damp sponge to wipe clean; buff dry.

  For dirt, use dry borax on a damp cloth; rinse and buff.

  For grease or oil stains, make a poultice of talc and nail polish remover; dry overnight and sponge off; buff.

  Food stains can be removed with a poultice of hydrogen peroxide, a few drops of household ammonia, and talc; allow to dry overnight, sponge, and buff.
- Sandstone*:* Same as limestone
- Slate*:* Use a mild laundry detergent; rinse, then polish with pumice powder on a damp felt pad.
- Synthetic stone*:* Try washing with a mild laundry detergent first. If the stain remains, use a medium fine pumice powder; flush with water.

Manhours

Manhours to Install Stone Walls			
Stone	**Unit**	**Manhours**	**Suggested Crew**
Fieldstone rubble wall dry set mortar set	 CF CF	 .48 .52	 1 mason, 1 helper, 1 laborer
Limestone ashlar wall, natural finish	CF	.47	1 mason, 1 helper, 1 laborer
Sandstone ashlar wall, natural finish	CF	.47	1 mason, 1 helper, 1 laborer
Random stone retaining wall dry set mortar set	 SF SF	 .39 .33	 1 mason 1 mason
Ashlar stone retaining wall dry set mortar set	 SF SF	 .33 .32	 1 mason 1 mason
Cut stone wall, to 6" thick	LF	.17	1 mason, 1 helper
Hand clean stone wall	SF	.05	1 hod carrier

For information on related topics, see:

Brick Masonry, page 51

Ceramic Tile, page 125

Concrete Block, page 189

Countertops, page 209

Fireplaces and Chimneys, page 291

Floor Framing, page 299

Flooring, page 359

Framing Materials and Planning, page 363

Stucco

Exterior siding preferences vary considerably from one part of the country to another. In many parts of the Northeast and Midwest, a stucco house is the exception, and it may be difficult to find someone who is skilled in stucco application. In the Southwest, stucco is a common exterior, lending itself well to Spanish, adobe, and Mediterranean architectural styles. In these areas you'll find there's a lot of competition in stucco work.

A stucco exterior is actually very similar to interior plaster work. In fact, they involve the same materials and application processes. In some areas, the term stucco may refer to just the final coat, while in others it means the entire exterior process from scratch to finish coats.

Materials and Mixes

Like plaster, stucco is a mixture of sand, water, portland or masonry cement, and lime. You can also include additives in the mix to increase its workability or change the color. It's placed in a two- or three-step process to a $^{3}/_{4}$- to 1-inch depth.

Apply stucco over a solid surface such as masonry or concrete (Figure 1) or over an installed surface like stucco mesh or expanded metal lath (Figure 2). If you stucco directly over concrete or masonry, you need to apply a bonding agent to the surface first. Or you can apply a portland cement dash bond coat of $1^{1}/_{2}$ cubic feet of sand to 1 cubic foot of portland cement. You need to let the dash bond coat moist cure (spray it with water periodically) for 24 hours before you stucco. Generally, stucco mesh is used for most surfaces. Use expanded metal lath to trim around windows and doors where you can't bend the stucco mesh as easily.

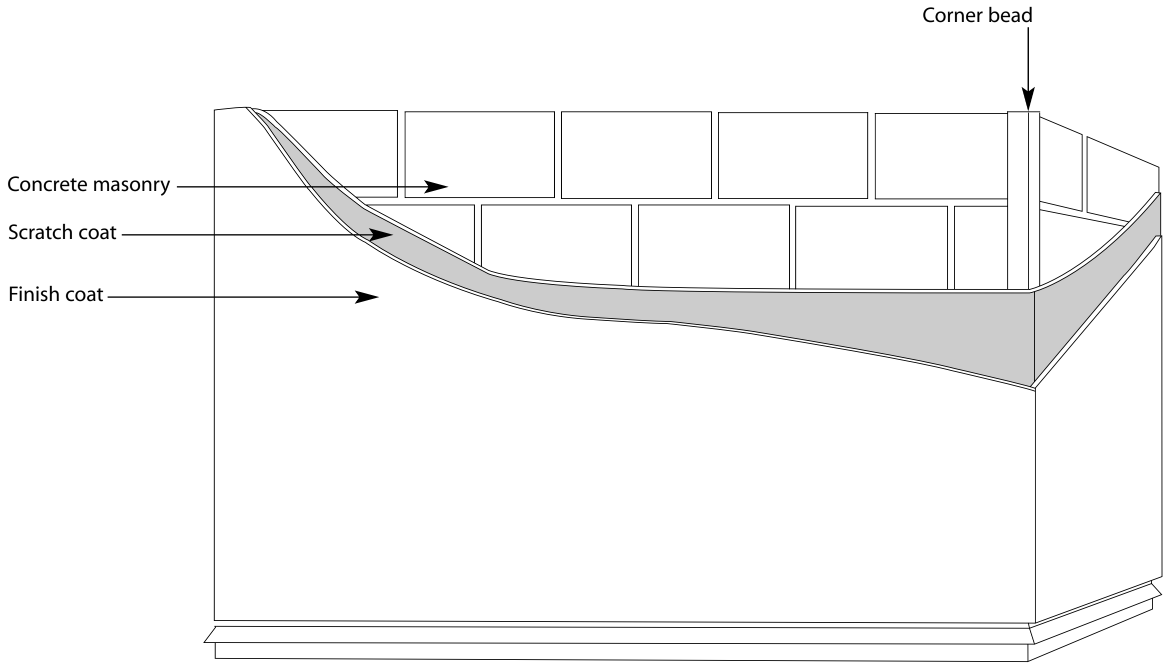


Figure 1
Stucco over masonry

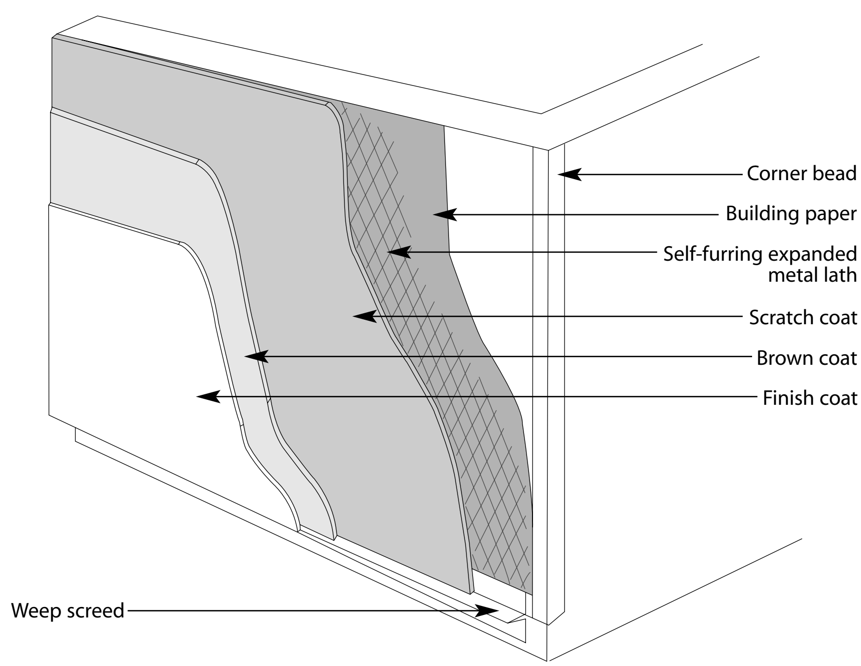


Figure 2
Stucco over wood

As with plaster, the first layer is a scratch coat, the second a brown coat, and the third a finish coat (see *Plaster*). If the base is masonry or concrete, you can skip the scratch coat and just wire-brush the surface to rough it up before applying the brown coat. In residential applications, the first two coats are sometimes combined in a two-step process.

Mix Preferences

For small repair jobs, you can buy premixed stucco from a lumberyard. For larger jobs, it's considerably cheaper to mix your own. The scratch and brown coats consist of different proportions of cement, sand and lime then the finish coat.

People who work with stucco usually have personal preferences on mixes. Here's one simple mix for the scratch and brown coats:

1 bag of portland cement

1 bag of masonry cement

50 shovelfuls of masonry sand

Mix the dry components thoroughly with a hoe, and then add enough water so that the mixture holds it shape and isn't crumbly.

Try this for the finish coat:

1 bag of portland cement

2 bags of lime

4 bags of silica sand

Again, mix it completely before adding water. Mix in just enough water to give it the consistency of soft butter.

Matching Stucco Colors

Matching colors for stucco repair is extremely difficult because of the wide variations possible in color mixes. Even when you know what color was used with the original batch, it's not always easy to figure out how much pigment you should add. Furthermore, even the whites in cement vary from one company to another.

To get the best match between a repair patch and the existing stucco, spray down the existing stucco and then match the wet color to your wet finish mixture. Weigh the amount of color you add on a gram scale to keep the mixture exact.

Expansion Joints

Stucco is very durable and resistant to the effects of weather if you apply it properly. It does, however, tend to shrink as it dries. To prevent cracks, you need to add control or expansion joints to any area larger than 12 feet wide. You should also place expansion joints on the sides of windows and doors where most cracks occur. The best prevention is to run the expansion joints up to the roof and down to the foundation because that's where the structure will crack. Usually a structure has enough doors and windows that you don't need additional expansion joints. Code requirements for expansion joints vary from region to region, so check local codes for expansion joint requirements in your area.

Temperature

Ideally, you should only apply stucco when the temperature is between 50 and 85 degrees Fahrenheit. If the weather is too cold, the water in the mixture can freeze and reduce the overall durability of stucco. At the very least, you need to prevent new stucco coats from freezing for at least 24 hours after they're applied. Never apply stucco to a frozen surface or a surface that still has frost in it.

If you stucco on a very hot day, the moisture may evaporate too quickly, and again, the stucco's durability will be affected. In warm weather, spray water frequently on new stucco to keep it from drying out too fast.

Tools and Materials

- *Chisel*
- *Hammer*
- *Utility knife*
- *Trowel*
- *Hawk*
- *Scarifier*
- *Darby or straightedge*
- *Furring nails*
- *Expanded metal lath*
- *Stucco wire*
- *Tar paper*
- *Staples*
- *Staple gun*
- *Metal shears (to cut lath and wire)*
- *Wood float or sponge trowel*
- *Hoe*
- *Shovel*
- *Wheelbarrow or mortar box*
- *Stucco mix (sand, cement, and lime)*
- *Water for mixing and spraying*

Applying Stucco

Whether you're doing a new stucco job or repairing an old one, the procedure is basically the same. For repair jobs, make sure that you clean the damaged section back to an area that's completely solid. Undercut the edge with a utility knife. Self-furring wire mesh lath works well for repair work. The back side has $^{1}/_{4}$-inch dips to hold the mesh away from the surface. Be sure to wear safety goggles for protection.

Follow these guidelines for your application:

1. Staple tar paper over the wood sheathing (where applicable). Nail expansion joints along the sides of windows and doors and on extended open areas.
2. Nail metal lath around doors and windows, etc. Use furring nails (which hold the lath $^{3}/_{8}$ inch away from the surface) to attach stucco mesh to the rest of the surfaces, or use self-furring metal lath.
3. Spray tar paper with water. Apply the scratch coat to the mesh with a trowel to a depth of at least $^{3}/_{8}$ inch. Make sure all of the openings are completely filled. After the coating starts to set slightly, in about 30 minutes, horizontally score the surface about $^{1}/_{8}$ inch deep with a scarifier.

4. Allow the scratch coat to set for 24 to 48 hours; moist cure it by spraying it with water every four to six hours. Spray again before you apply the brown coat. Apply the second (brown) coat so that the total depth (first and second coats together) is $^3/_4$ inch thick.

   If you stucco directly over gypsum backing or onto masonry, you can apply the brown coat over the scratch coat as soon as the first coat starts to set up. You don't need to wait 24 hours.
5. Level the surface with a darby so that there's no more than $^1/_4$ inch variation in a 5-foot area. Further smooth the surface with a sponge trowel or wood float.
6. Moist cure the surface for 48 hours, spraying it twice a day. Allow it to continue to dry for another seven days.
7. Spray the surface again with water. Trowel or brush on a $^1/_8$-inch finish coat, for a total depth of $^7/_8$ inch. If a texture is called for, use a brush or trowel to texture the surface within the first 30 minutes of application.

Synthetic Stucco

Synthetic stucco, called EIFS, for Exterior Insulation and Finish System, is marketed by corporations like Dryvit Systems, Inc. and Sto Corp. It isn't just stucco but a system of exterior insulation and wall coating. Although the initial cost of the system is several times higher than traditional stucco, synthetic stucco's advantages can make it an attractive alternative to other finishes. But it's recommended for installation only by factory-trained installers, because of the possibility of damaging moisture problems if it's not installed correctly. The newer versions are drainable, so any problem moisture can drain away before it does structural damage.

The system generally consists of four layers that can be placed over most rigid substrate surfaces, including concrete, masonry, cement plaster, and exterior-grade gypsum sheathing. It's installed by bonding insulated foam board, with a per-inch value of about R4, to the substrate, and then applying a thin, cement-modified primer coat that should form a protective, waterproof coating. Next, a layer of fiberglass mesh is embedded in the primer coat to increase surface strength and impact resistance. When the primer coat dries, a final acrylic copolymer finish coat is applied and textured.

When all the layers are in place, the insulation value is at least twice as high as traditional building materials. In addition, the system is highly resilient, which adds to its durability. If you press your finger against it, the surface gives slightly, without chipping or cracking, almost like a firm rubber. The extra insulation reduces thermal shock caused by temperature differences between the summer and winter months. The reduced thermal shock translates into lower energy costs and less structural stress. It also resists fading, and holds up well under weathering, even when subjected to such atmospheric corrosives as acid rain and salt spray.

A synthetic stucco system has the added advantage of working equally well for new construction applications and for retrofitting existing structures. The material itself is lightweight, about 1 pound per square foot when using 1-inch foam board. Because of this, you don't need to redesign the structure to provide any extra support or add footers to carry the weight.

Installation

The installation of EIFS may vary from manufacturer to manufacturer. As a rule, store all materials in a dry area at or above 50 degrees Fahrenheit. The primer and finish coats should always be applied when it's 50 degrees or higher. Ideally, the temperature should remain above 50 degrees for at least 72 hours after installation.

The following are general guidelines that you can apply to most EIFS. Check with the manufacturer of the system you're using for the specific installation instructions — then make sure the installers are following the instructions *exactly*. They should pay special attention to sealing all joints, especially where the insulation boards meet another material. Make sure the installers:

1. Inspect the substrate, and use a moisture meter to see if it's dry enough. Clean the surface with water and detergent to remove any dirt or grease. If the surface is flaking, apply a sealing primer. There should be expansion joints wherever dissimilar materials meet.
2. Spread the adhesive paste around the edges of the insulated foam board and daub it in a half-dozen spots in the middle of the board. Press the board firmly in place against the wall. Allow it to set for 48 hours.
3. Mix the primer cement coat and spread it evenly over the foam board.
4. Before the primer cement coat has set, embed the fiberglass mesh into it. Overlap the mesh seams by at least 4 inches.
5. Allow the primer coat to dry for five days; then apply the finish coat.

Combining Stucco Systems

The moisture problem experienced by some EIFS system installations has prompted a number of installers to combine stucco systems rather than installing a complete EIFS system. These installers use a traditional masonry system of base coats, followed by an EIFS system topcoat, utilizing what they see as the benefits of both systems. They get the traditional soundness of the masonry system with the color consistency, texture and overall finish features offered by the EIFS products.

Manhours

Manhours to Install Stucco, Float Finish

Component	Unit	Manhours	Suggested Crew
Stucco netting	SY	.20	1 lather
Stucco over masonry			
1 coat	SY	.32	2 plasterers, 1 laborer
2 coats	SY	.62	2 plasterers, 1 laborer
Stucco over metal netting			
2 coats	SY	.75	3 plasterers, 2 laborers
3 coats	SY	.95	3 plasterers, 2 laborers

For information on related topics, see:

Brick Masonry, page 51

Concrete Block, page 189

Framing Materials and Planning, page 363

Insulation, page 395

Plaster, page 465

Siding, page 611

Wall Framing, page 709

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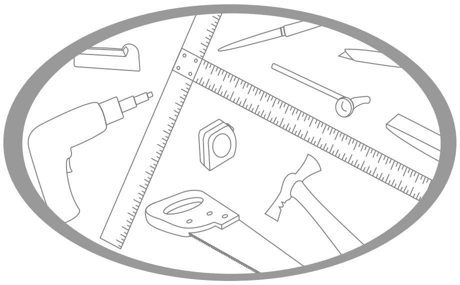


Trim

Trim consists of the wood and moldings that finish off a building. Interior trim includes finish work on interior walls, ceilings, stairs, doors, windows and cabinetry. Exterior trim includes trimwork at the cornice, as well as window and door casings and decorative moldings and millwork on the outside of the structure.

Interior Trim

On a tract house the interior trim can be as simple as baseboard, casing and closet shelves. More expensive homes may have ornate multiple-piece moldings for ceilings, baseboards and casings as well as built-up paneling and other specialty work. See *Cabinets* for information on kitchen cabinets and built-in cabinetry. Also see *Doors* and *Windows and Skylights*.

Trim and Molding Materials

The three most widely-used woods for moldings are pine, lauan and oak. Many other woods are available to provide a more “custom” look for your applications. You can narrow down your choices by determining whether the final finish will be paint or stain.

Without regard to species, the Wood Molding & Millwork Producers Association has two grades for moldings:

- P-GRADE, or paint grade, indicates moldings that are intended to be painted. P-GRADE moldings may have finger joints or be filled at the mill, both resulting in a smooth, paintable surface.
- N-GRADE, or natural grade, indicates moldings that are suitable for natural stain as well as paint.

Paint-Grade Woods

The most desirable characteristic of a paint-grade wood is a tight grain. Of the three standard molding species (lauan, oak and pine), pine is the most satisfactory choice for paint. Because they have a more open grain, you need a filler for oak and lauan.

When you need a wide paint-grade trim, poplar is another excellent species. It has a tight grain and excellent working characteristics. Companies that supply specialty items, such as the rosette corner pieces used in detailed door and window casings, often use poplar.

Natural-Grade Woods

There are several natural-grade woods suitable for a stain or clear finish. We most often think of clear woods from one of the hardwood species as being natural-grade woods. However, natural-grade woods can include anything from knotty pine to cherry and walnut. The distinguishing factor is that no finger jointing, plugs, or fillers are used on a natural-grade wood.

Alternative Trim Materials

In addition to the paint-grade and natural-grade moldings, there are also alternative moldings available. These alternatives are either derived from wood or are synthetic products designed to look like wood.

Those derived from wood usually consist of a particleboard base covered with a wood veneer. Once installed, an oak veneer molding is practically indistinguishable from a solid oak molding. For light usage, veneers are attractive and acceptable products that you can offer your customers at a lower cost than solid oak.

There are also prefinished synthetic products on the market. These products are often plastic-based materials with wood grains stamped or molded into the finish. They are usually sold as a system, complete with matching doors, doorjambs, baseboard, and casing.

Glue and Fasteners

You should glue as well as nail mitered corners on trim work. There is a yellow carpenter's glue available from several manufacturers that we recommend for this type of bonding. (See *Adhesives*.)

With few exceptions, professional trim carpenters use air-powered nailers to drive fasteners for trim work. These are quicker and produce better results for the average carpenter. There's a wide range of finish nails available for installing interior trim, from "pins" to 8d. In some cases, 10d to 16d nails are used for finish work.

Interior Trim Tools

There are two groups of tools for trim work; each can be used at various skill levels. The first group includes tools that someone with a little knowledge and skill can use to complete a trim job. These are the basic tools that any homeowner might have if they're handy at

Basic Tools

- *Hand miter box*
- *Coping saw*
- *Hammer*
- *Nail set*
- *Wood file*
- *Sanding equipment (belt and palm sanders)*

Professional Tools

- *Power miter box*
- *Trim saw*
- *Pneumatic nailers*
- *Table saw*
- *Router*
- *Jointer*
- *Sanding equipment (belt, palm and random orbital sanders)*

working on small projects around the house. The second group of tools, which includes some from the first group, is used by professional crews for trimming out jobs on site.

Cuts and Joints Used for Trim and Moldings

Narrow baseboard and casing moldings are, in some cases, the same product. However, because of the difference in their placement, the cuts and joints you use will vary. You install casing flat against the window or doorjamb and wall, and place baseboard and ceiling moldings at the apex of the floor and wall or wall and ceiling.

Butt Joints

Use butt joints in trim work when the joints aren't exposed. You can butt baseboard to the door casing or a corner when starting out, but you should *never* use a butt joint on an outside corner. You can also use butt joints when you use wide boards for casing. In most cases you'll be covering the end grain with an additional band of trim or you can conceal it with a corner block.

Miters

Miters cuts are not only preferred, they're expected for most trim work. Miters don't expose the end grain of the material, so they provide a smooth, uninterrupted, consistent surface. To make a miter, split the angle of the corner between the two joining pieces. To join two pieces at a 90-degree corner, you make a 45-degree cut on each piece. Joining two pieces at a 45-degree angled corner requires you to make two $22^1/_2$-degree cuts.

When you install baseboard outside corners, always fit them with miters as shown in Figure 1a. However, you cope baseboard inside corners. It's considered poor craftsmanship to miter an inside corner because you can never make the fit as tight as you can with a coped corner. Even if you can make an acceptable miter fit to begin with, it's more likely than a coped corner to spread or open up over time.

Flat Miter — Casing work is a good example for the use of flat miter cuts. You make a flat miter on a miter box or with a powered trim saw. Place the trim piece flat, and make the miter with an angle cut across the face. Figure 1b shows an example of a flat miter on a door or window casing.

Vertical Miter — You make a vertical miter cut at an angle through the width of the board. Place the trim piece vertically against the back of the miter box. With the saw set at the desired angle, make a cut through the piece. Use vertical miter cuts for outside baseboard corners.

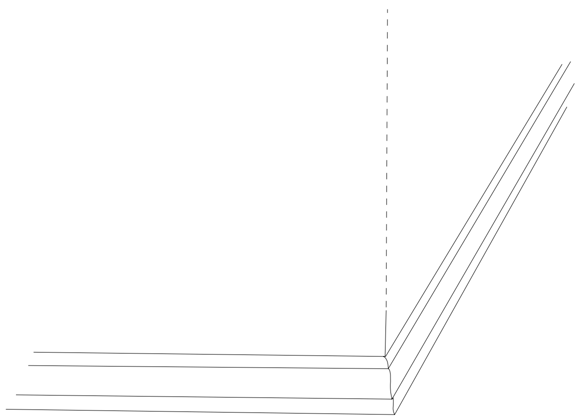


Figure 1a
Baseboard with mitered corner

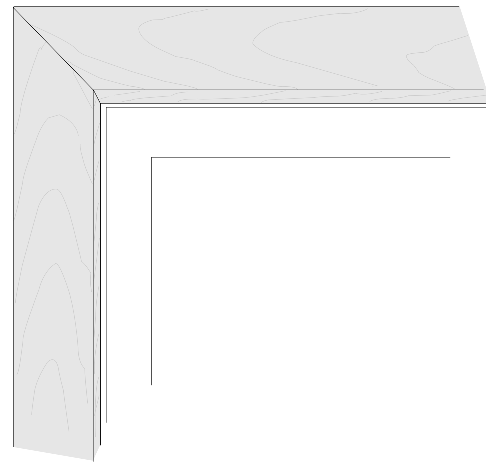


Figure 1b
Flat miter for door or window casing

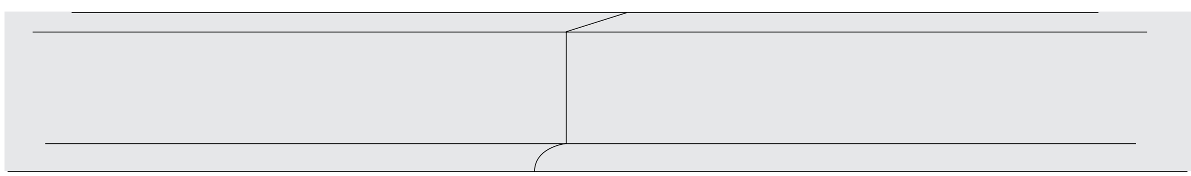


Figure 2
Use scarf joint to join two pieces on a straight run

Scarf Joints

Use scarf joints to join together two pieces of trim when you need additional length. You make a scarf joint using a 45-degree miter on each piece so that one laps over the other. (See Figure 2.) Scarf joints offer better concealment and a better finish surface than butt joints for this purpose. Bond scarf joints with glue.

Coped Corners

You make coped corner cuts using a coping saw — thus the name. Use coped corners for inside corners. To make a coped corner, butt the first trim piece into the corner. Then cope the second trim piece to fit the profile of the first trim piece. While this may sound difficult, it's really quite easy. Follow these guidelines to install a coped corner:

1. Install the first piece by butting it into the corner.
2. Cut a 45-degree vertical miter on the second piece (Figure 3a).

3. The edge where the miter meets the face of the trim piece is the profile of the face of the first piece. This same edge is also the cut line you use with the coping saw.
4. With a coping saw, cut along the profile line made with the miter cut. Angle the coping saw slightly so that the profile will be the leading edge of the finished cut. Cut slightly off of the profile, making certain not to cut into the face of the trim piece. See Figure 3b.
5. Using a wood file, remove any remaining material up to the profile line. With a good clean edge, check the fit (Figure 3c). If the fit is slightly off due to an irregular wall surface, a little file work will quickly produce a good fit. Figure 3d shows a coped inside corner.

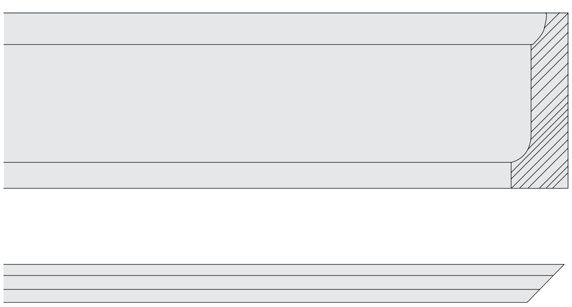


Figure 3a
Make a 45° cut to reveal line for a coped fit

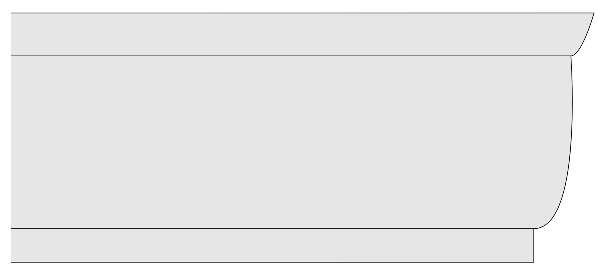


Figure 3b
Trim piece with material removed

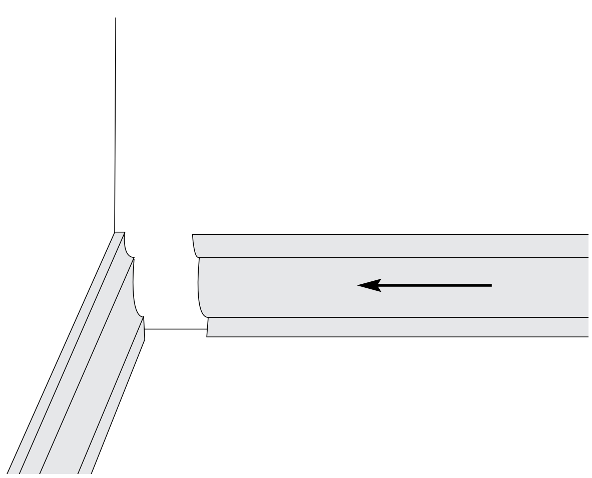


Figure 3c
Cut inside corners to fit with a coping saw

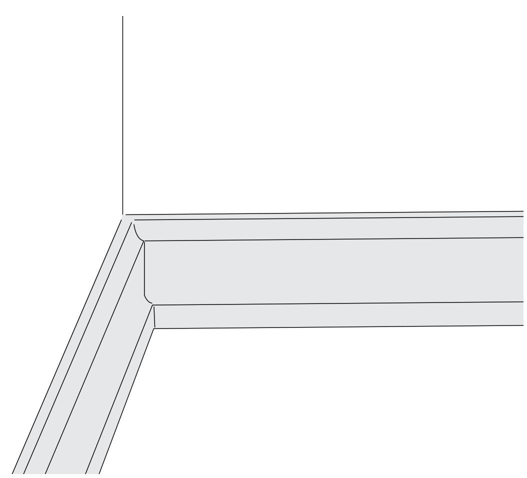


Figure 3d
Inside "coped" corner trim

Casing

The trim around openings, such as doors and windows, is called *casing*. Most modern casing is made of a shaped molding. Using combinations of moldings or boards and molding, you can assemble more elaborate trim.

Because the baseboard butts into the bottom of door casing, doors are the first items that you need to trim. Windows don't affect any other work, so you can trim them at any time. We'll cover step-by-step instructions for installing window trim. You'll use the same methods for doors, but of course there's no bottom piece.

Installing Casing Using Mitered Corners

1. Using a gauge for consistency, mark the reveal of the trim on the window or doorjamb.
2. Cut the head piece first by measuring the distance between the two side reveal marks. Cut 45-degree miter cuts on each end.
3. Install the piece by placing it in position on the reveal marks. Place fasteners into both the window jamb and the rough framing. Depending on the thickness and taper of the casing, you can shoot a small nail through the inside of the casing and directly into the jamb. Because the outer edge is thicker, and the nail must penetrate both the drywall and the rough framing, use an 8d nail for fastening the outer edge.
4. Cut a miter for the top of the first side piece. Flip the piece over and place the inside corner of the miter at the intersection of the side and bottom reveal. With the piece running long over the top of the head piece, mark the length at the intersection of the side piece and the top outside corner of the top piece. Make the second miter cut off of this long point mark.
5. Install the side piece using the reveal marks for placement.
6. To finish the window trim, repeat Steps 4 and 5 on the second piece, followed by the bottom piece in the same manner. Figure 4 shows a mitered window casing using shaped trim.

Installing Casing Using Butted Corners

1. Using a gauge for consistency, mark the reveal of the trim on the window jamb.
2. Place a board the width of the trim on the side reveal marks and mark the outside edge. This will be the overall length of the head piece.
3. Cut a head piece using the measurement from Step 2. Install the piece using the markings from Step 2 and the top reveal marks from Step 1 to determine the placement. Because you don't

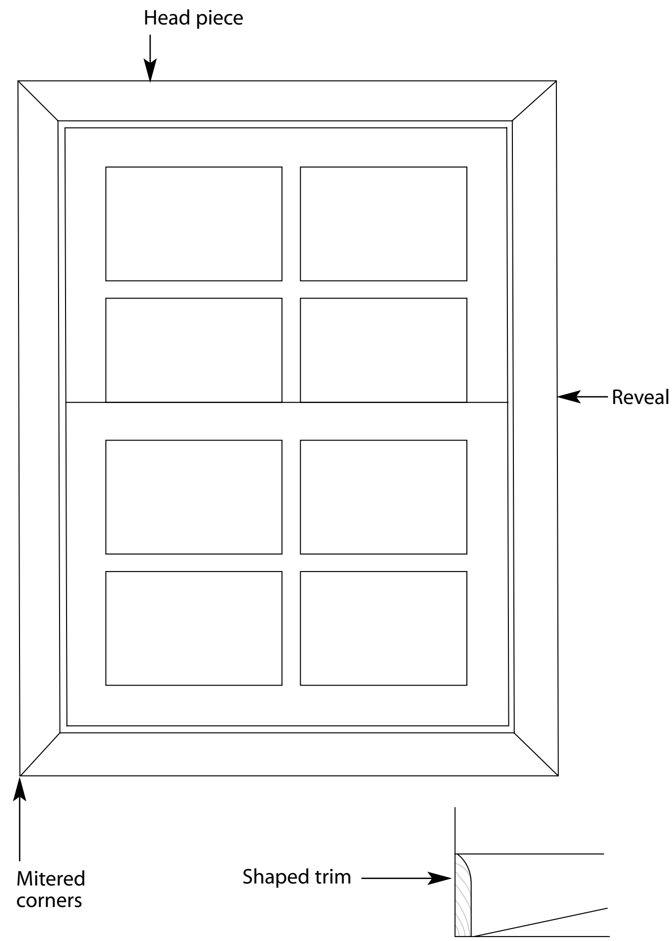


Figure 4
Mitered window casing

usually use tapered trim for this type of casing, you'll need 6d nails to fasten it through the inside edge of the casing and into the jamb. Use 8d nails to fasten the outer edge of the casing through the drywall and into the rough framing.

4. Find the length of the side pieces by measuring from the bottom of the head piece to the reveal marks for the bottom piece.
5. Cut the side pieces and fasten them into place.
6. Measure across the bottom from the outside to outside of the side pieces to find the length of the bottom piece.
7. Cut and install the bottom piece.

Variations Using Butted Corners —

If you install wider trim using butted corners, you can combine it with other trim to vary the style of the casing.

To dress up a casing with butted corners, you can add a trim piece to the bottom and place a band around the outside as shown in Figure 5. You can make up the band from $^{3}/_{4}$-inch material and rip it to the desired width. Round the edges using a shaper or router. This type of decorative trim should have mitered corners.

You can also use corner blocks or rosettes to dress up the casing. At one point, these were difficult to find and you had to make them up on the job site to match older styles if you were repairing windows or adding windows to an older home. But as they've regained popularity in many areas of the country, you can now special order them from most millwork suppliers.

To add corner blocks to a window casing:

1. Mark reveal and the locations of the corner blocks.
2. Measure the headpiece; cut, and install.
3. Install the top corner blocks at both ends of the headpiece.
4. Measure, cut, and install the two side pieces.
5. Install the bottom two corner blocks.
6. Measure, cut, and install the bottom piece.

Baseboard

Baseboard is the molding or combination of moldings placed at the base of the wall. The actual function of baseboard is to protect the plaster or wallboard. While it has a functional purpose, most people are more interested in the decorative qualities of baseboard.

Baseboard can be a single molding piece or, like casing, you can build it up using multiple pieces of boards and moldings. Figure 6 shows examples of single and built-up baseboard profiles.

Because baseboard butts into the door casing, the doors must be trimmed before you can install the baseboard. The type of flooring being used also influences when and how you install the baseboard.

Baseboard Installed Before Flooring

Install the baseboard before you lay stretched carpets. Place the baseboard approximately $^{3}/_{8}$ inch off the floor to allow space for the carpet to be stretched over the tack strip and tucked. You can use a carpenter's pencil as a spacer.

We recommend installing both ceramic tile and glue-down carpet after the baseboard is in place. However, you can install them before, if necessary. You might want to check with both the homeowner and your installer for their preferences.

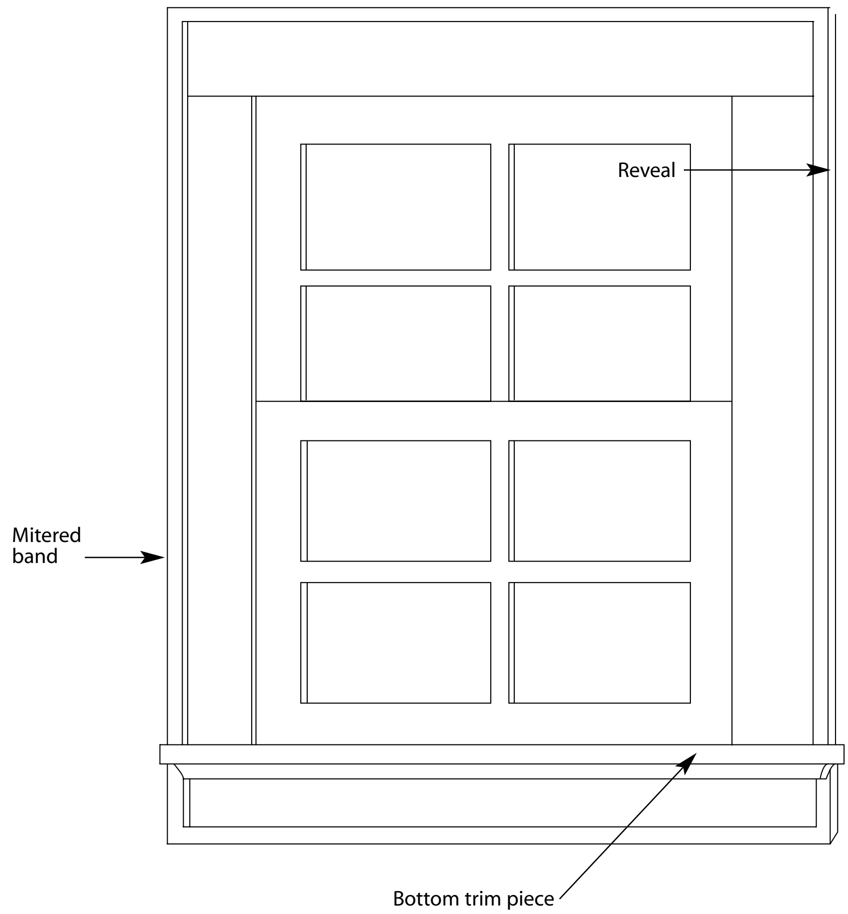


Figure 5
Butted casing with additional trim pieces

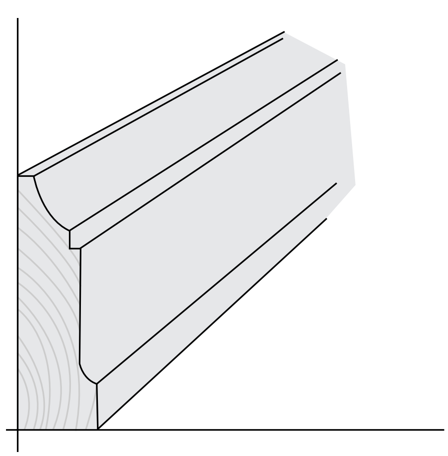


Figure 6a
Single-piece baseboard

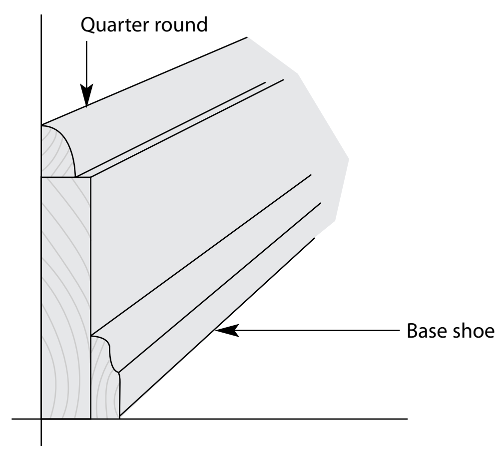


Figure 6b
Built-up baseboard

Baseboard Installed After Flooring

Install the baseboard after you install hardwood floors. Use a base shoe to cover slight irregularities. Base shoe is more flexible than baseboard and so it conforms better to irregular contours than baseboard, providing a nice finished look at the floor line.

We like to install vinyl flooring before the baseboard. The baseboard helps to secure the edges of the vinyl and provides a nice finished look to the flooring. But you can install it after the baseboard. Check with your vinyl installer for their preference.

Fastening Baseboard

Fasten baseboard using either hand-driven or air-driven nails. Use two nails every 16 inches. Place one nail at the top of the baseboard and one at the bottom. Two nails ensure a tight fit against the wall at the top and bottom. It's not a good idea to place a nail in the center, as some people seem tempted to do. You can cut corners by using only one nail in the middle, but you'll be cutting your reputation as well.

Installing One-Piece Baseboard

One-piece baseboard comes in a variety of shapes. You use the same installation process for all molding-type baseboards. Use miters, coped corners, and scarf joints to make the cuts and joints.

The first step in installing baseboard is to look over the area and plan out your installation. With experience, you can complete this step in seconds rather than minutes. Look at the layout in Figure 7 to determine the order of placement.

The easiest method is to place the longest piece with a butt into the wall at each end. In the illustration, A is the longest continuous piece, so we'd install it first. Then we'd install pieces B and C on the longest wall, coping the corner of B and using a scarf joint to joint the two pieces. You can follow along with pieces D through H.

Installation Steps —

1. Measure the first wall, then cut piece A slightly long, so when you place it against the wall, the center bows out slightly. When snapped in place against the wall, both ends will be a tight fit. Nail in place.

2. Cope piece B to fit against A. Check the fit of the cope.

3. With the coped end placed against piece A, mark the scarf cut where it will splice on a framing member. Cut with a 45-degree miter.

4. Place piece C in position against piece B with enough pressure for B to bow out slightly. Nail the scarf end of C. As you nail the remainder of C, place pressure against B, which straightens out the bow for a tight fit.

5. Cope piece D to fit against A, leaving the end to be mitered long. Place pieces D and E in position, letting E butt against the wall. Mark the miter cut and install both pieces.
6. Piece F butts against the front wall, with a cope joint against piece E.
7. Pieces G and H both have cope joints on one end and square cuts where they butt against the door casing.

Installing Two-Piece Baseboards

Install two-piece baseboard in the same manner as single-piece baseboard. After you install the first piece, simply repeat the steps on the second piece. The main baseboard is made of 1 × 6 boards. It's installed using butted inside corners and mitered outside corners. After the main baseboard is in place, install the base shoe and top quarter round with coped inside corners and mitered outside corners. Refer back to Figure 6b.

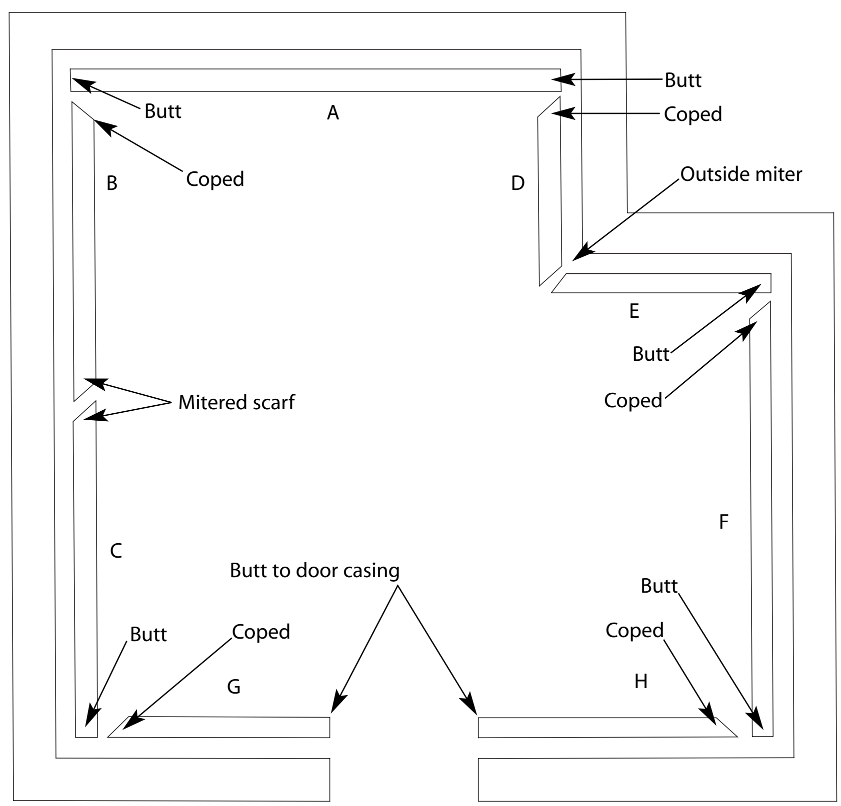


Figure 7
Baseboard layout

Moldings

You can use moldings for numerous applications. While moldings are more commonly used for the interior, you can also use them on the exterior to add character and interest. Interior moldings have both decorative and functional purposes. Baseboard, casing and chair rails serve to protect wall surfaces from damage. Ceiling moldings, our emphasis in this section, add decorative detail to a room.

Molding Installation

Depending on the application and the type of molding, you can use a flat installation or you may need to angle the molding against the surface or surfaces that you're placing it against. You can make standard cuts on a power miter box or trim saw for flat molding installations. Making cuts for an angled installation is more complicated. The first step in setting up a cut for an angled installation is visualizing its placement.

Making the Cut

First visualize the way you'll install the piece. It may help to make a mark on the top outside corner — or some other relevant position — to prevent confusion when you're setting up the cut.

If you're using a power miter box to cut the piece, the fence represents the flat vertical surface where the molding will be attached. If you're installing a piece flat, you can place it against the fence for the cut. Use more care when making a cut for a molding that's angled away from a vertical surface, such as crown molding.

You can achieve a straight cut in several basic ways, all of which are simple and relatively safe. You need a compound cut with a mitered corner for angle installation. Making the cut on a power miter box requires holding the piece at an angle, as if the fence were the vertical surface where it will be attached. This is a difficult cut to make due to the small area of trim which can be in contact with the fence and table. It's also a dangerous cut to hold and make. You can make a safer and more accurate cut on a trim saw capable of a compound miter, although this also becomes difficult with long pieces. With the table and fence stationary, secure the piece being cut for a more accurate cut.

Fastening the Molding

Fasten the moldings in place with hand-driven or air-driven nails. If you have the equipment, you'll find that air-driven fasteners simplify the installation. You'll probably need to install many of the pieces for ceiling molding from ladders or scaffolding. With air equipment, you can hold the molding in place with one hand and fasten it quickly with a single shot. This eliminates the need to hold the piece and the nail with one hand while swinging a hammer in the other.

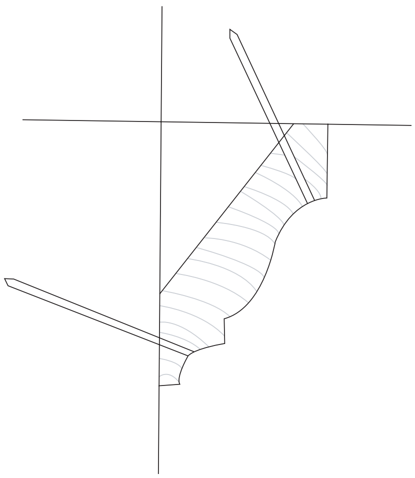


Figure 8
Nailing crown molding

Install angled pieces with fasteners driven into both surfaces, as shown in Figure 8. Place the fasteners at 16 inches on center. You can secure narrow moldings, positioned flat, with a single fastener at 16 inches on center. You need to countersink the nails in the molding. When using air-powered nailers, set the air to countersink the fastener.

Installing Molding

Refer back to the steps and installation instructions for installing one-piece baseboard. These steps provide details for using coped inside corners, mitered outside corners, and scarfed splices. Use the same joints and cuts for your molding installations.

Assembling multiple-piece moldings simply involves repeating the installation steps for each set of pieces. A profile of a multiple-piece crown molding is shown in Figure 9.

Exterior Trim

Exterior trim includes door and window casings, decorative moldings, millwork and trim on porches and gables, as well as trim at the cornice, which includes the frieze boards, fascia, and soffits.

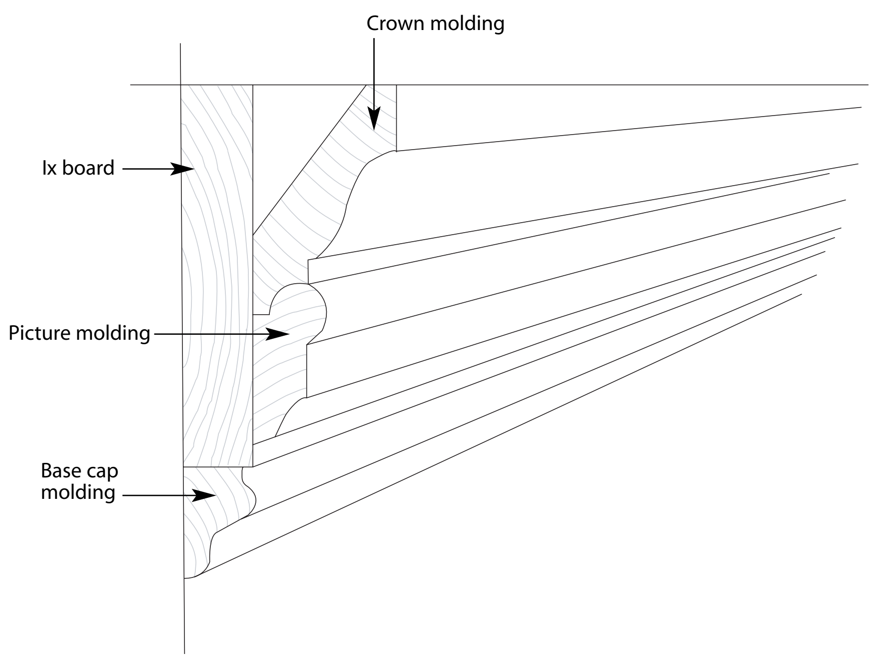


Figure 9
Multiple-piece molding

Cornice Trim

Figure 10 shows the three common types of cornices. A *closed cornice* has no extension of the roofline. An *open cornice* is built with exposed rafter tails. A *box cornice* is built to finish off a roofline that extends beyond the exterior wall.

Closed Cornice

The least expensive cornice to build is the closed cornice. You will commonly find them on the traditional saltbox colonial style house as part of its distinctive style. A closed cornice is also frequently a cost-saving feature in the construction of low-cost housing – that's why they're so common in tract homes built to meet the housing shortage at the close of World War II.

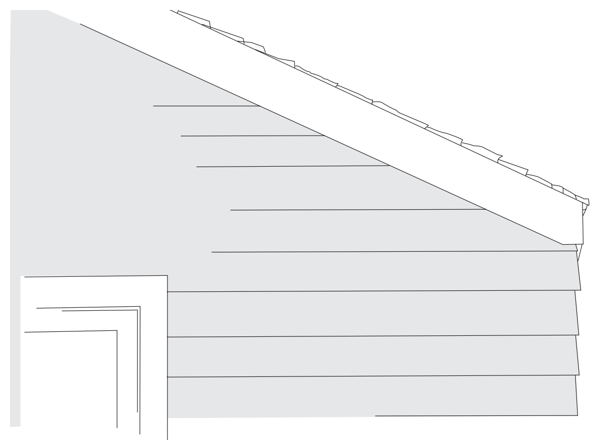


Figure 10a
Closed cornice

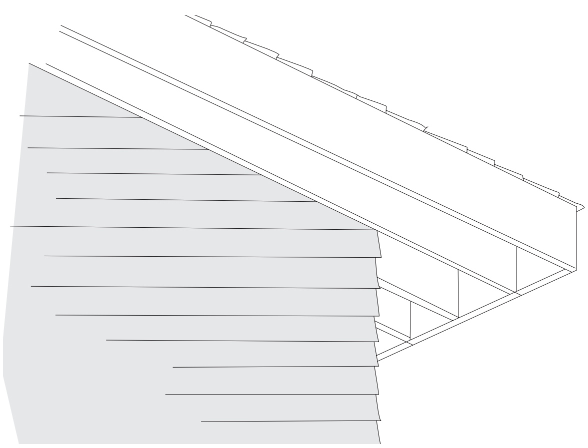


Figure 10b
Open cornice

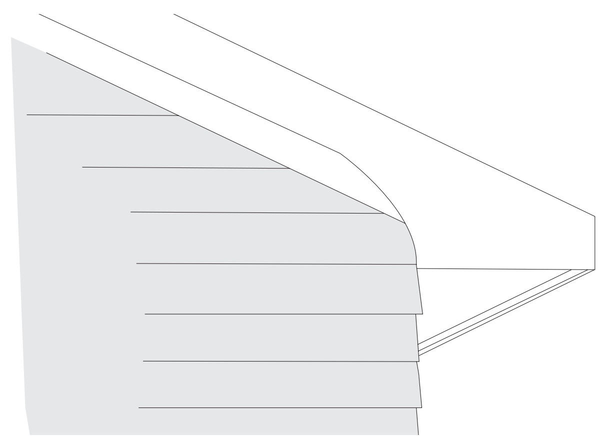


Figure 10c
Box cornice

Framing for a closed cornice is complete when you have plumb cut the rafters with the top plate of the framed wall. You then run the sheathing to the top of the rafters as shown in Figure 11. A gable roof is one style where you could use a closed cornice. You would run the sheathing to the top of the rafter line on the gable ends as well.

In most cases, you would install a frieze board with the top of the board flush with the top of the roof sheathing. Do this for the eaves as well as the rake of the gable. You can place the frieze board over some siding. However, with most siding types, you just run it up to the frieze board. You can either butt the siding to the frieze board or up under the back of the frieze board if it's rabbeted or notched.

To dress up a closed cornice, you can place a molding at the top of the frieze board. The molding provides decoration as well as a minimal roof extension for moisture protection. The shingles then extend over the top of the molding.

Open Cornice

An open cornice has open or exposed rafter tails. You need to install a frieze board as a trim piece to give it a finished look between the rafter tails. Typically, you would make the frieze board the same width as the rafters so the bottom of the frieze board and the rafters finish off in a straight line.

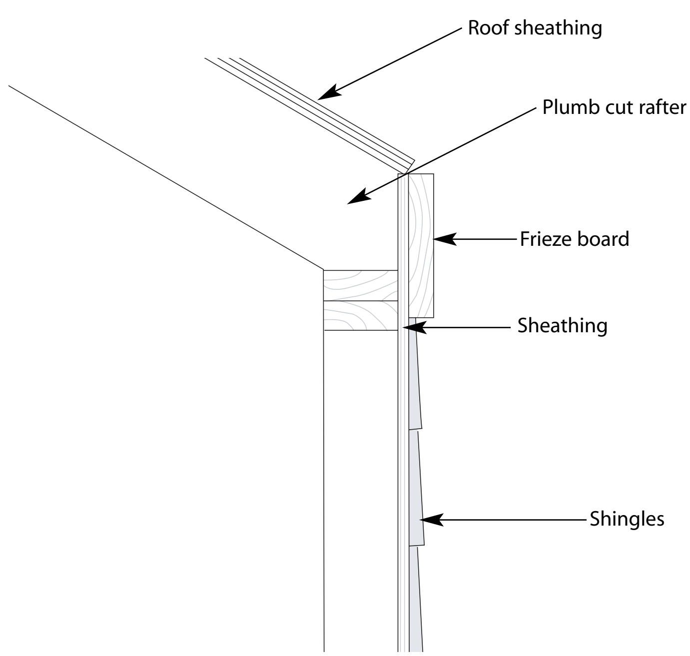


Figure 11
Framing for a closed cornice

To install the frieze board, rip the frieze board material to the desired width. Cut the frieze board material into lengths to fit tight between the rafters. Place each frieze board section tight to the bottom of the roof sheathing between the rafters as shown in Figure 12. Fasten by toenailing through the frieze board into the rafters using two 8d galvanized nails at each end. With tight clean cuts, no further finishing should be necessary.

In some cases, however, you may want to place molding at the top of the frieze board against the roof sheathing for decorative purposes. On Victorian or country-style houses, moldings are frequently used along with the fascia and frieze board. Use galvanized nails for exterior molding applications, or you can use air-driven galvanized narrow crown stables.

Box Cornice

Use a box cornice if you want to enclose the rafters extending beyond the roofline (Figure 13). There are two types of box cornices: narrow and wide. The primary difference between the two is the use of lookouts in the framing. Both types have a fascia board and soffit. You would install the fascia board vertically at the rafter tails, usually over a horizontal framing board called a sub-fascia.

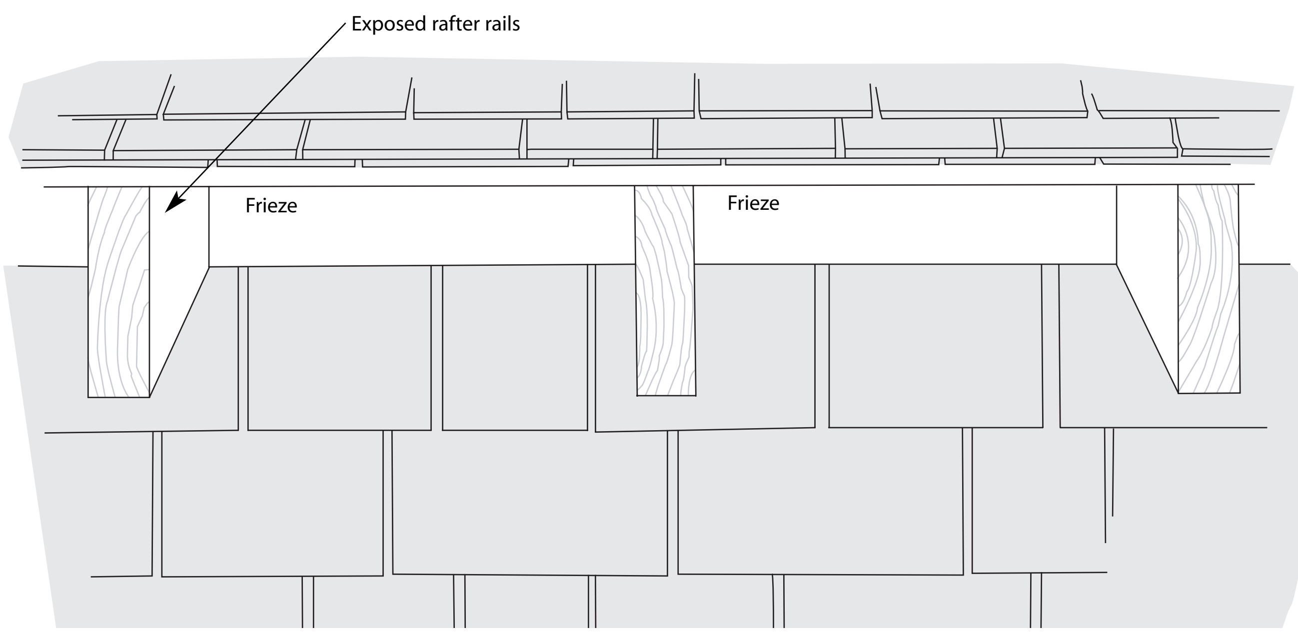


Figure 12
Framing for an open cornice

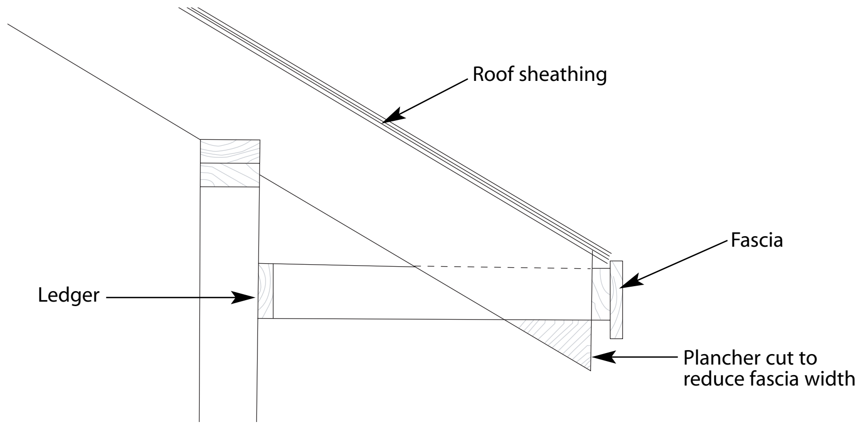


Figure 13
Framing for box cornice

The best fascia boards are made from a decay-resistant wood such as redwood or cedar. Choose boards that are clear as possible. Knots tend to bleed through paints and stains, so try to avoid them whenever you can. Some builders economize by using primed pine as the fascia board on projects built under a tight budget.

By using a plancher cut on the rafter tail, you can control the width of the fascia board. A plancher cut is a horizontal cut on the rafter tail that reduces the width of the rafter tail. After you've cut the rafter tail to the desired width and installed the sub-fascia, the roof is ready for the fascia installation. (Refer to *Roof Framing*, under Finishing the Roof beginning on page 554, for detailed information on cutting the rafter tail.)

Make the fascia wide enough so that once it's installed it will be tight against the shingles and still hang $^1/_2$ to $^3/_4$ inch below the soffit. As the soffit is usually $^3/_8$-inch plywood, the fascia should hang $^7/_8$ inch below the rafter tail for a $^1/_2$-inch finished reveal.

Cornice Fascia Installation —

1. Cut a 45-degree miter on both ends of the fascia board. One end will match another board at the corner and the other end is part of a scarf joint with the next fascia piece as shown in Figure 14. Make all your splices with a scarf joint rather than by butting. This produces a cleaner finished product that's less prone to problems as the fascia expands and contracts.

2. Set a block at both ends of the fascia run. Stretch a string between them to gauge the straightness of the fascia. Use this string as a guide to keep the fascia from weaving in and out on poorly cut rafter tails as well as from rising up and down.

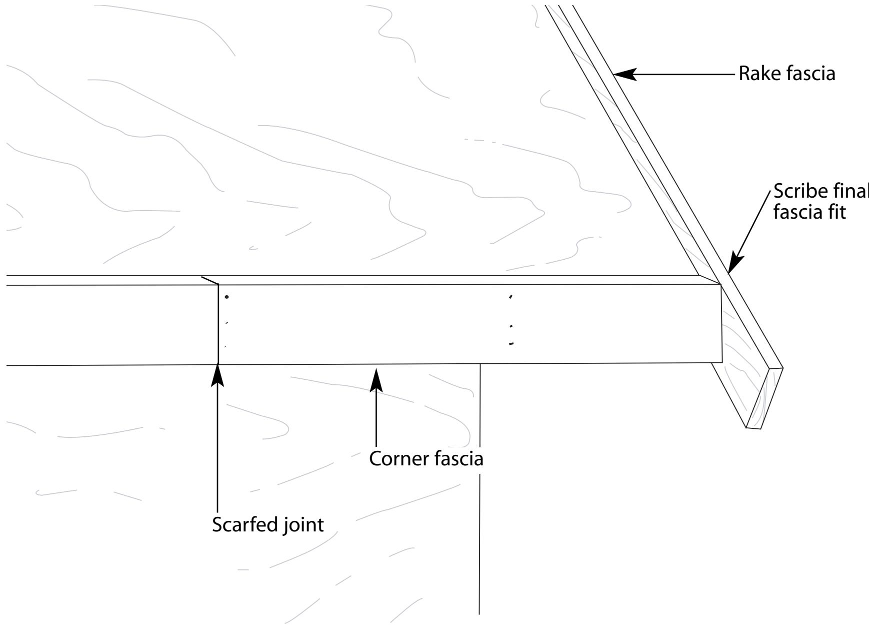


Figure 14
Installing corner and rake fascia

3. Start the fascia at the corner of the roof. Place the inside of the miter at the outside corner of the sub-fascia. Use a scrap cut of fascia with a 45-degree cut to check the placement of the corner and make certain the fit will be tight.
4. Hold the top of the fascia in line with the string.
5. Nail the fascia to the sub-fascia at each rafter tail with two 10d galvanized casing nails. You may need additional nails on wider fascia.
6. Make 45-degree scarf cuts on the second and subsequent intermediate boards that you place.
7. Give the final board a 45-degree miter cut for the scarf joint before you make any adjustments to the angle. For a good fit, many carpenters prefer to hold the board in place to check the fit of the scarf joint and mark the final miter cut. You can also obtain a good fit by using measurements and a square.

Rake Fascia Installation — The rake fascia runs from the ridge to the bottom of the roof where it meets the cornice fascia.

1. You'll need to make a compound miter cut for the 45-degree cuts used to match the cornice fascia board to the rake fascia board. It's a compound miter because the two angles need to be cut at once for a successful cut. Use a trim saw built specifically for making compound miters. There are several varieties available from different manufacturers.

You can also make a compound cut on a radial arm saw, or freehanded using a circular trim saw. Cut the compound miter by setting the angle of the blade at 45 degrees. Then make the cut at an angle matching the pitch of the roof, the same as that used for your rafter tail cut.

2. Check the cut and fit of the rake and cornice fascia boards by holding the rake fascia in place against the cornice fascia as shown in Figure 14. If the fit is acceptable when held in what will be its permanent position, mark the cut for the ridge at the same time.

3. Again, the ridge cut should be the same angle as the tail cut and the ridge cut of the common rafters. If you use trusses, it will be the same as the pitch of the roof. The peak cut, however, will be a 90-degree miter cut instead of the compound miter cut used where the rake meets the cornice.

4. Fasten the rake fascia to the fly rafter using 8d galvanized casing nails. Place the nails 16 inches on center, using at least two nails at each location.

Boxed Return Installation — You can use a boxed return to complete an attractive corner. The boxed return covers what would be a void at the end of the cornice soffit with an angled piece of fascia.

1. Cut an angled piece of fascia to fill in the end area. The bottom of the angled piece should remain horizontal and be level with the bottom of the cornice fascia. The top edge should follow the angle of the rake fascia. You can make the cut straight or use decorative curves or angles cut on the wide edge of the angle as shown in Figure 15.

2. Install a back piece of fascia for the rake soffit to butt into.

The Soffit

The exterior soffit is the area underneath the eaves. We suggest $^3/_8$-inch A/C plywood with exterior glue for wide soffits. However, you can also use rough sawn plywood or hardboard. Use $^3/_4$-inch boards as soffit material for narrow soffits.

Wide Cornices

Wide cornices have lookouts between the ribbon installed against the house and the sub-fascia. Refer to *Wall Framing*, under Gable and Eave Framing, for framing details. The lookouts are 2 × 4s placed on edge. They support wide soffits and prevent them from sagging or bowing.

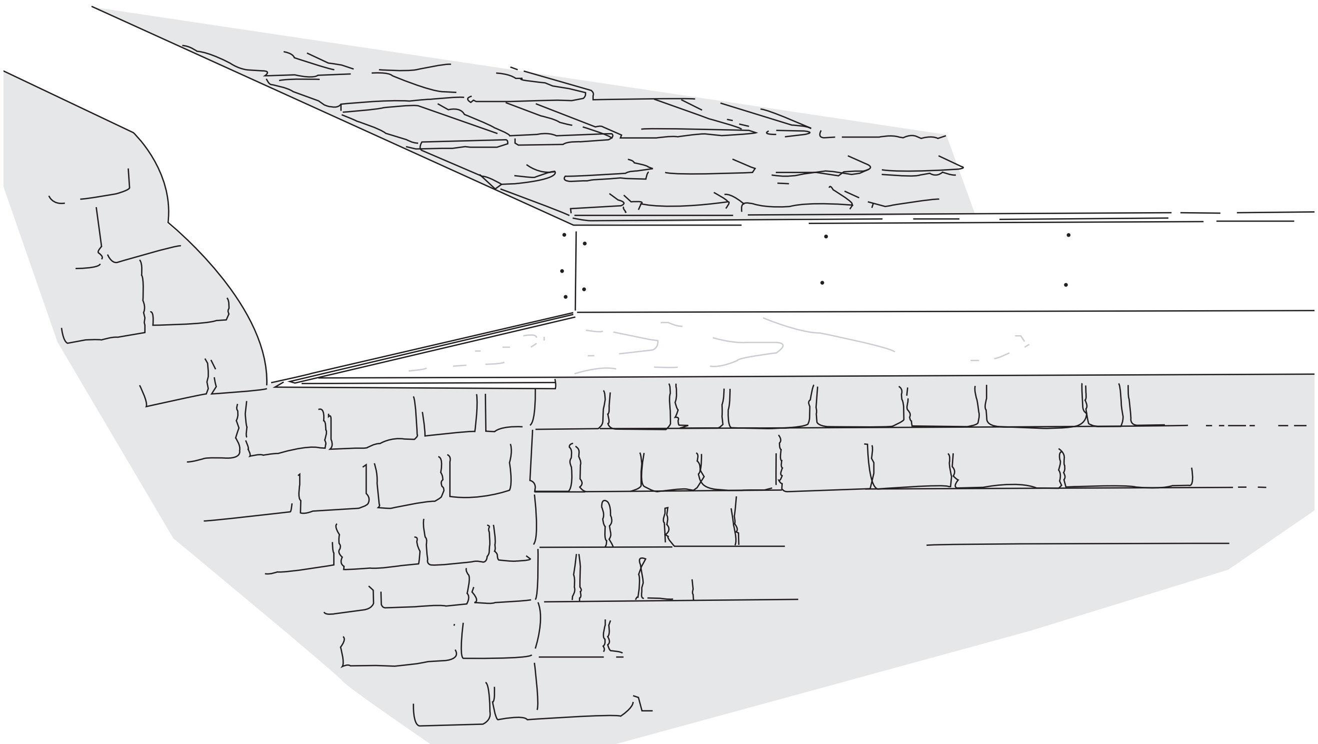


Figure 15
Decorative curves cut into boxed return

Install the soffit before the frieze board, siding, or any moldings. You can cut the soffit material loose for ease of placement. When you install it, place it tight against the fascia. Any gaps between the soffit and the wall sheathing will be covered by the frieze board and/or the siding.

Making straight edges on the soffit material creates clean, attractive joints. Joints are necessary against the fascia as well as when butting to another piece of soffit material. In most cases, the straightest cut on a sheet good will be a "factory cut," any of the original four side edges of sheet material.

When installing sheet material in soffit areas, you'll need to rip it to the proper width. It's important to always keep in mind where the factory cut will end up when preparing to cut the soffit. Try to lay out the cuts so that factory edges are in exposed areas, like butt joints and along the fascia. A job site cut with a slight irregularity placed against another job site cut that also has a slight irregularity creates a larger, obvious flaw. Place job site cuts against the structure where they'll be covered by the frieze board.

> ### Tools and Materials
> - Basic carpentry hand tools
> - Table saw
> - Framing square
> - Flat bar
> - Hand plane
> - Soffit material — plywood or other sheet material. 6d galvanized siding nails or galvanized finish nails
>
>   or
>
>   Pneumatic stapler and galvanized staples (shoot the staples with the grain of the plywood)

Installing Wide Soffits —

1. Fasten the soffit sheeting to the lookouts, the ribbon board and the sub-fascia. The lookouts are on the same layout as the rafters, so that means full 8-foot lengths of plywood will fit the layout.
2. The end soffit sheets are potentially the most difficult. They must fit against the cornice fascia and the box return fascia. Use the steel framing square to check the square of this corner. This edge should be a job site cut. Save the factory cut for the butt joint at the opposite end. Make the cut leaving the pencil line on. Use a hand plane to clean up slight irregularities.
3. Install the soffit. Nail at 8 inches on center around the perimeter and on the lookouts.
4. Install the full-length soffit sheets on layout. Use a flat bar to apply pressure in positioning the soffit. Nail as in step 3.

   Install the rake soffit using the same procedures as for the cornice soffit. The rake soffit is attached to the fly rafter and the lookouts.

Narrow Cornice

Narrow cornices are built very similar to a wide cornice. The primary distinction is that you don't need lookouts on a narrow cornice. Make plancher cuts on the rafter tails to which the soffit material is fastened.

A narrow cornice is often laid out for a width that accommodates a standard 1-by board width. You can install the fascia for the narrow cornice using the same steps given for a wide cornice. Many carpenters, however, prefer to place the soffit board in a narrow cornice before they install the fascia. If you install the soffit board before the fascia, you must use straight soffit boards. Then fasten the fascia by nailing into the ends of the rafters as well as into the side of the soffit board. Use a minimum of two galvanized siding nails or finish nails at each rafter end, with one to two nails placed into the edge of the soffit board (depending on the rafter spacing).

When you use boards as soffit material (see Figure 16), install them in much the same way as plywood. Use a flat pry bar to position the board before nailing to bring the soffit tight against the fascia. Finish off any gap against the structure with moldings, a frieze board, or the siding.

When joining two boards together, don't use a butt joint. Make a 45-degree cut across the ends of the adjoining boards. When you join them, angled cuts are less likely to show gaps caused by expansion or contraction of the soffit boards.

The Frieze Board

A frieze is the board that separates the siding from the cornice or the rake (look back to Figure 12). When you use a soffit, the frieze separates the soffit from the siding. With an open cornice and exposed rafters, use a frieze board to finish off between and around the rafters. If you want more detail, you can use moldings in conjunction with the frieze board.

Use a frieze board on all houses with wood-product siding. Finish stucco and brick veneer houses with the siding extending up to the soffit.

Frieze Board Material

You would usually use the same type or style of material for the frieze board as the fascia. The choice of material is generally based on regional availability. As with all exterior trim, make sure you select a species of wood that will stand up to moisture. Depending on the final paint or stain treatment, your choice can range from naturally rot-resistant woods such as redwood and cedar to poplar or pine.

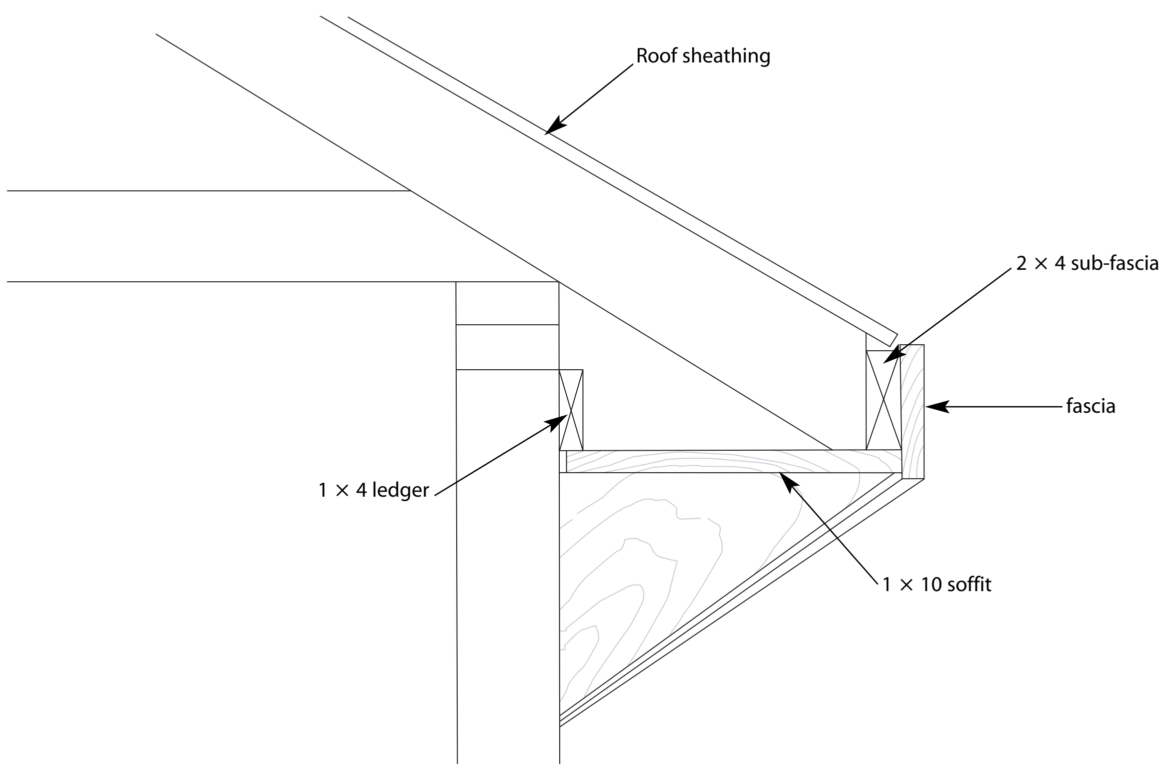


Figure 16
Narrow cornice using 1-by boards for soffit

Frieze Board for a Closed Cornice

Place the frieze board for a closed cornice after you install the soffit. Depending on the type of siding you use, you can place the frieze either before or after you install the siding. You would usually install the frieze board after the siding when you use a sheet siding such as textured plywood. The frieze then works as a trim piece to cover the joint between the siding and the soffit.

Installing Frieze Board on a Closed Cornice —

1. Start the frieze board at a corner:
   a. When starting with an square outside corner, cut a 45-degree miter to meet the frieze board coming from the other angle.
   b. When starting with an inside corner, butt the frieze into the corner.
2. Make all splices with scarf joints rather than by butting. This makes a cleaner finished product, less prone to problems as the fascia expands and contracts. If the run is too long for a single board, make a 45-degree cut for the scarf joint with the long point to the inside. The second piece will be easier to fit if you have its long point extending over the first piece.
3. When starting with an outside corner, place the inside of the miter at the outside corner of the siding or boxing. Use a scrap cut of frieze material with a 45-degree cut to check the placement of the corner and make certain the fit will be tight.
4. Nail the frieze board through the boxing into the studs using two 10d galvanized casing nails. You may need additional nails for wider frieze boards.
5. Make 45-degree scarf cuts on the second and subsequent intermediate boards that you place.
6. Give the final board a 45-degree cut for the scarf joint. For a good fit, many carpenters prefer to hold the board in place to check the fit of the scarf joint, and then mark the final miter cut. But you can also get a good fit using measurements and a square.

Installing Frieze Board on the Rake — The rake frieze board runs from the bottom of the roof where it meets a cornice return to the point at the peak where it meets the opposite rake.

1. Peak cut: Make a plumb cut for the peak. Mark the plumb cut on the frieze board using the rise and run of the roof pitch. (See Roof Framing for more information on plumb cuts as well as how to find the roof pitch if it's unknown.)
2. Cornice return cut: You must cut the rake frieze board to meet the cornice return. If the cornice return is boxed and you need to make a plumb cut, make it the same angle as the plumb cut for

the peak cut. If you need to make a horizontal cut on the cornice return, make a level cut. Use a framing square to mark the level cut on the frieze board using the rise and the run of the roof pitch.

3. Make the ridge cut the same angle as the tail cut and the ridge cut of the common rafters. If you use trusses, it'll be the same as the pitch of the roof.

4. Fasten the rake frieze board through the boxing to the sub-framing members using 8d galvanized casing nails. Place the nails at 16 inches on center using at least two nails at each location, depending on the width of the frieze board.

Frieze Board with an Open Cornice

Place the frieze board between the exposed rafter tails of an open cornice. In most cases, you would cut the frieze board to the width of the rafters, as shown in Figure 12. This allows the frieze board to be tight with the top and flush with the bottom of the tails. Then cut board lengths to fit between the rafter tails. You have a more difficult situation when the frieze board is designed to be wider than the rafter tails. Then you have to cut slots into the frieze board for the tails so they'll fit.

Installing Open Cornice with Flush Frieze Board —

1. Select a board width that will fit, or that can be ripped to fit, tight at the top and be flush with the bottom of the rafter tails.

2. Even though the spacing of the rafters should be the same, measure each opening. Also, check the rafter tails to see that they aren't twisted. If the tail is twisted, adjust the cut on the frieze board to fit.

3. Face nail the frieze board into the backing using two 8d galvanized nails at each end.

Installing Open Cornice with Slotted Frieze Board —

1. Select a board to install, sizing it for the appropriate width. Cut it to length using the same steps as for the boxed cornice. If the frieze board is to wrap around a corner, you'll need a miter for the corner. If it will join another frieze board, you'll need to make a scarf cut.

2. Place the board into position below the rafter tails. Temporarily secure the board in position for marking by tacking it in place.

3. Mark the location of the tails on the frieze board.

4. Place the board on sawhorses and cut out the tail locations.

5. Hold the board in position and fit the rafter tails into the slots.

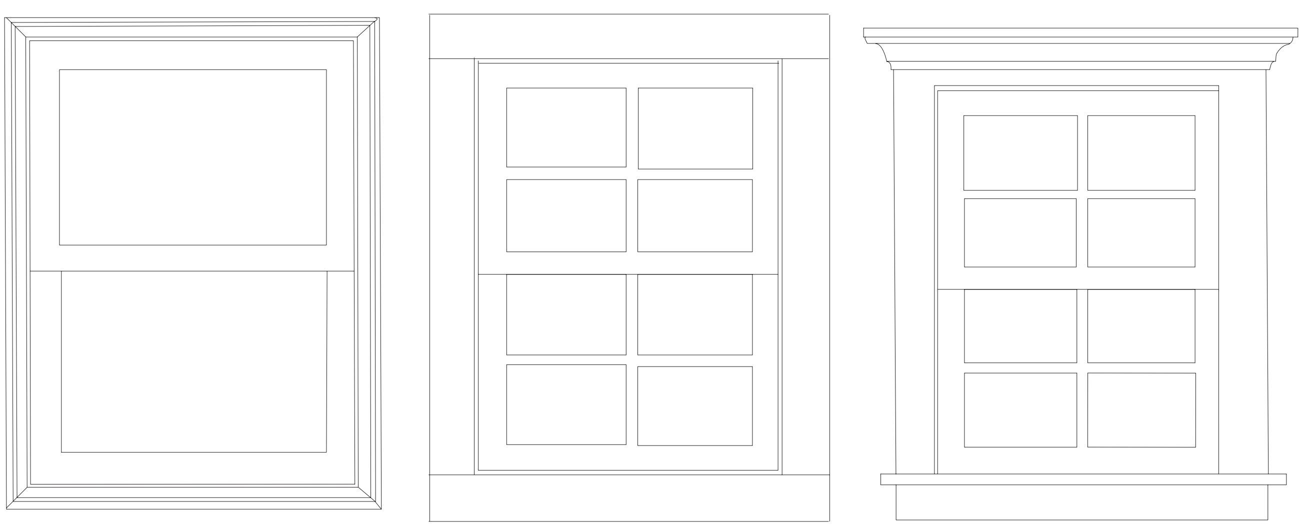
6. Fasten the board in place using 8d galvanized nails. Nail through the sheathing and into the sub-framing.

Exterior Door and Window Trim

The casings around doors and windows can be decorative, but their primary purpose is to span the gap between the window or door and the framing. Exterior trim for wood windows comes already attached to the window. Unless otherwise specified, the standard trim on the window will be a brick mold pattern. Check the section on *Windows and Skylights* to see how you use this trim in setting and fastening the window unit in place. To match an existing style on an older home or when building a house with a style that isn't compatible with brick mold, you can make and install your own exterior trim on site.

Exterior trim on older homes or "country-style" homes is frequently made of 5-inch-wide by $^{5}/_{4}$-inch trim. Pine is the most common trim material, although poplar is another good choice in a paint grade wood for this use. It may be tempting to use stock $^{3}/_{4}$-inch wood, but most sidings protrude beyond $^{3}/_{4}$-inch-thick window and door trim. This is certainly true if you use this type of trim with shingle siding. Install wide window and door trim using butt joints instead of the miter joints found on the narrower brick-mold type trims.

Figure 17 shows three typical types of exterior window trim. Fasten both narrow and wide trim with nails going into both the window jam and the window rough framing. Use galvanized nails or narrow crown galvanized staples as fasteners.



Brick molding style *Country-style window* *Decorative molding and sill*

Figure 17
Types of exterior window trim

Installing Mitered Exterior Window and Door Trim

1. Using a gauge for consistency, mark the reveal of the trim on the window jamb as shown in Figure 18.
2. Cut the head piece first by measuring the distance between the two side reveal marks. Cut 45-degree miter cuts on each end.
3. Install the head piece by setting it in position on the reveal marks and fastening it through both the window jamb and the rough framing. (See Figure 19.)
4. Cut a miter for the top of the first side piece. Flip the piece over and place the inside corner of the miter at the intersection of the side and bottom reveal. With the piece running long over the top of the head piece, mark the length at the intersection of the side piece and the top outside corner of the top piece. Make the second miter cut off of this long point mark.
5. Install the side piece using the reveal marks for placement.
6. To finish the window trim, repeat Step 4 on the second side piece, followed by the bottom piece.

Use the same procedure for doors, without the bottom piece.

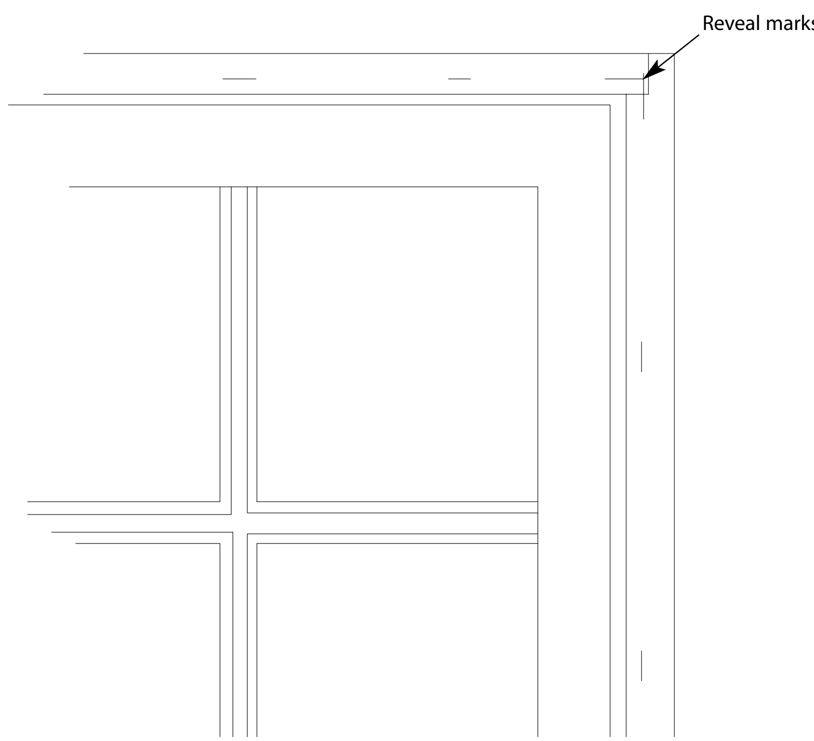


Figure 18
Mark reveal for window trim position

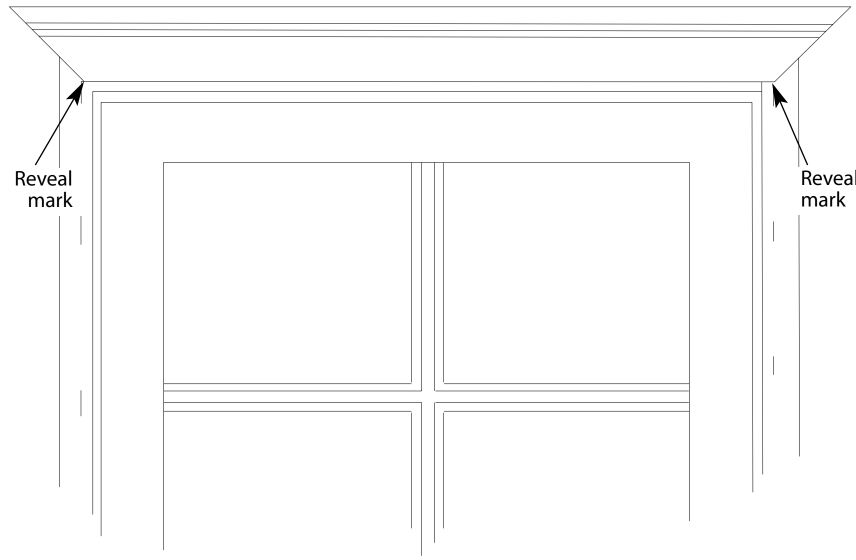


Figure 19
Installing head trim piece

Installing Butted Exterior Window and Door Trim

1. Using a gauge for consistency, mark the reveal of the trim on the window jamb.
2. Place a board the width of the trim on the side reveal marks and mark the outside. This will be the overall length of the head piece.
3. Cut a head piece using the measurement from Step 2. Install the head piece using the markings from Step 2 and the top reveal marks from Step 1 to determine its correct position. Using galvanized fasteners, fasten the head piece in place. The fasteners should go into both the window jamb and the rough framing.
4. Cut the side pieces by measuring from the bottom of the head piece to the reveal marks for the bottom piece.
5. Fasten the two side pieces in place.
6. Measure across the bottom from the outside to outside of the side pieces to find the bottom piece length.
7. Cut and install the bottom piece.

To further dress the windows, you can use wider trim in combination with decorative moldings on the headpiece. Note that when you use a decorative molding, you must use a cap molding and it should be flashed for moisture protection.

Manhours

Manhours to Install Interior Trim			
Component	**Unit**	**Manhours**	**Suggested Crew**
Casing to 2" wide around framed door or window up to 4' wide	Each	.30	1 finish carpenter
Casing to 2" wide around framed door or window over 4' wide	Each	.50	1 finish carpenter
Add for block trim	Each	.15	1 finish carpenter
Crawl-space vent	Each	.15	1 finish carpenter
Running molding (baseboard, picture or chair rail, wainscot cap, etc.), 1 piece stain grade. Double for 2-piece molding. Deduct 33% for paint grade.	LF	.05 - .10	1 finish carpenter

Manhours to Install Exterior Trim			
Component	**Unit**	**Manhours**	**Suggested Crew**
Simple cornice (frieze and crown molding)	100 LF	7 - 8	1 carpenter, 1 laborer
Closed cornice with ventilated soffit	100 LF	3.5 - 4	1 carpenter, 1 laborer
Wide box cornice, including lookouts	100 LF	15	1 carpenter, 1 laborer
Single-member fascia up to 6" wide	100 LF	12	1 carpenter, 1 laborer
Typical exterior door trim	Each	1	1 carpenter, 1 laborer

For information on related topics, see:

Adhesives, page 25

Cabinetry, page 91

Doors, page 223

Fireplaces and Chimneys, page 291

Flooring, page 359

Painting, page 427

Paneling, page 459

Porches and Decks, page 485

Resilient Flooring, page 503

Roof Framing, page 513

Windows and Skylights, page 747

Wood Flooring, page 759

Ventilation

When a house is tightly sealed and well insulated, adequate ventilation becomes all the more important in both warm and cold climates. In a warm climate, you need good ventilation to allow warm air to escape. In cold climates, you need a system to allow moisture to dissipate and not become trapped during the winter. Trapped moisture can damage the insulation and the framing members. This is especially important in older structures because they're less likely to have adequate vapor barriers. Structures without vapor barriers require more vents than those with vapor barriers.

Attics

You should place ventilation in all unheated attics and crawl spaces. You can use these ratios to determine the number of vents required:

- 1 square foot of ventilation for every 150 square feet of floor space, for a ratio of 1:150.
- If half the vents are placed at least 3 feet above the eaves or cornice vents, the ratio is 1 square foot of ventilation for every 300 square feet, or 1:300.

These ratio are based on the assumption that you'll place $^{1}/_{4}$-inch corrosion-resistant mesh screen over the vents. If you use mesh that's smaller than $^{1}/_{4}$-inch, you'll need more ventilation for the same square footage. Using louvers prevents rain or snow from getting in, but louvers block the air flow, and so again, you'll need more ventilation for the same footage. Adding screening to the louvers further restricts air flow and increases the requirements even more.

Keep in mind that ventilation requirements can vary from area to area, so you should always check with your local building code to make sure these ratios work for your area. In milder climates, you may want to use more vents than code requires because they're an inexpensive, efficient way to keep an attic drier in the winter and cooler in the summer.

Adequate ventilation depends on air flow and requires inlet vents to draw in air as well as outlet vents to let air escape. Logically, since warm air rises, the inlet vents should be placed in the eaves and the outlet vents should be placed at the peak of the roof. This design pulls fresh air through the attic and forces stale air out.

Of course this simple design of inlet and outlet vents doesn't work for every roof type. A flat or low-slope roof requires vents in the soffit, either a continuous vent or individual vents between each joist. Likewise, a cathedral ceiling is more complicated to vent because it lacks a sizable dead air space. You should vent a cathedral ceiling like a flat roof, along the eaves, and add a ridge vent.

Installation

The most commonly used types of vents are soffit, gable, ridge, and roof vents. When installing any vent, be careful not to cut into any framing member. If the structure has engineered, manufactured trusses, the framing members mustn't be cut in any way. If you do, you'll void the engineer's liability, and the liability will become entirely yours.

If the opening for the vent falls over a framing member, don't cut it. Instead, place the vent over the framing member and allow for the reduced square footage in required venting.

You can cut into stick-framed rafters, but you'll need to frame the opening with wood blocking. This is easy to do in new construction; remodeling will require some rebuilding if the vent interrupts the rafters.

Tools and Materials

- *Measuring tape*
- *Chalk line*
- *Saw (trim, saber, reciprocating) or drill*
- *Utility knife*
- *Ladder*
- *Hammer*
- *Foam baffles*
- *Gasketed roofing nails (for ridge or roof vent)*
- *Caulk*
- *Roofing cement (for roof vent)*
- *Wood for blocking*
- *Vent*

Soffit Vents

New Construction — Some metal or vinyl soffit material comes with cutouts for vents, but most of the time you'll need to make your own. See Figure 1.

1. Before you install the soffit, nail or screw continuous screened vent to the underside of ceiling joists.
2. Install the soffit along both sides of the vent.

Remodeling — In an attic space that's large enough for some air movement, use framed rectangular soffit vents. Follow the square footage guidelines for the number of vents needed. For cathedral ceilings or flat roofs where there's very little air circulation, install vent plugs between each rafter.

1. Measure space for each vent so that the interior fits snugly into the space and the flanges extend over the hole on all four sides. Use a drill for vent plugs or a saw (trim, saber, or reciprocating) to cut out a vent hole for framed vents.
2. Place foam baffles between rafters to keep insulation from falling into the vents.
3. Screw or nail framed vents; twist vent plugs into place.

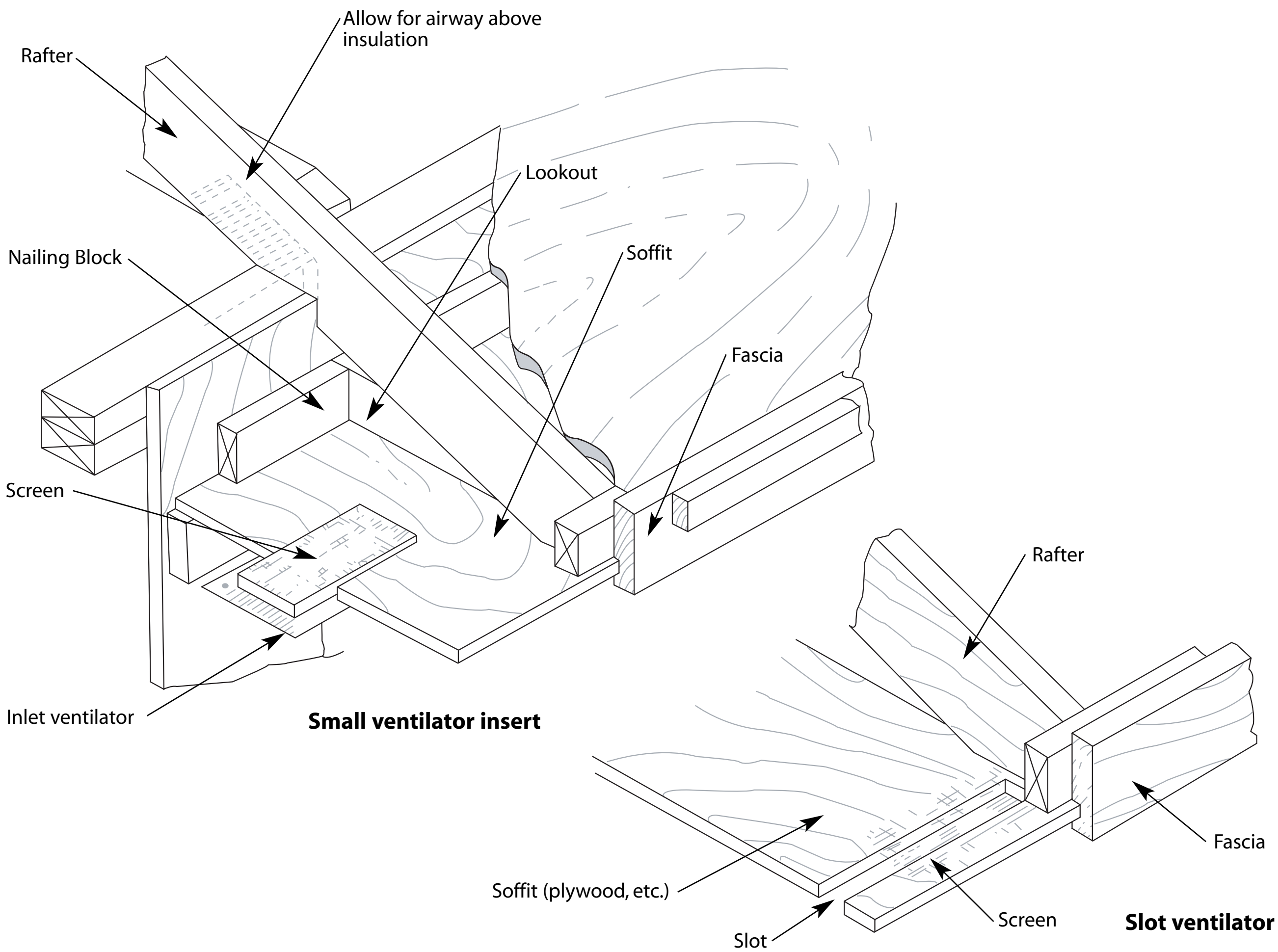


Figure 1
Soffit ventilators

Gable Vents

Engineered Truss System —

1. Measure the space for the vent so that the vent's interior fits snugly into the space and the flanges extend over the hole on all four sides. Use a trim, saber, or reciprocating saw to cut through the siding and sheathing. *Do not cut framing members*.
2. With a circular saw, cut the siding back so that the vent sits flush with the siding.
3. Frame the opening, adding wood blocking where necessary. Set the vent into the opening and nail or screw it to the blocking.
4. Place trim over the flanges and caulk around the trim.

Stick Framing —

1. Measure the space for the vent so that the vent's interior fits snugly into the space and the flanges extend over the hole on all four sides. Use a saw (trim, saber, or reciprocating) to cut through the siding, sheathing, and framing members. See Figure 2.
2. Follow Steps 2, 3, and 4 above for engineered truss framing.

Ridge Vents

Regardless of whether the structure has engineered trusses or has a stick-built roofing system, you mustn't cut into the framing members.

1. Snap a chalk line on both sides of the ridge, 1 inch from the peak. Cut the shingles and felt along the line with a utility knife.
2. Use a circular saw to cut through the sheathing. *Do not cut into the framing members*.
3. Apply a bead of caulk to the bottom of the vent. Use gasketed roofing nails to nail the vent in place. Figure 3 shows a ridge vent on a cathedral ceiling.

Roof Vents

1. Measure for the roof vent, placing it between framing members. With a utility knife, cut through the roofing materials in layers — first the shingles, then the felt. Use a trim, saber, or reciprocating saw to cut through the sheathing.

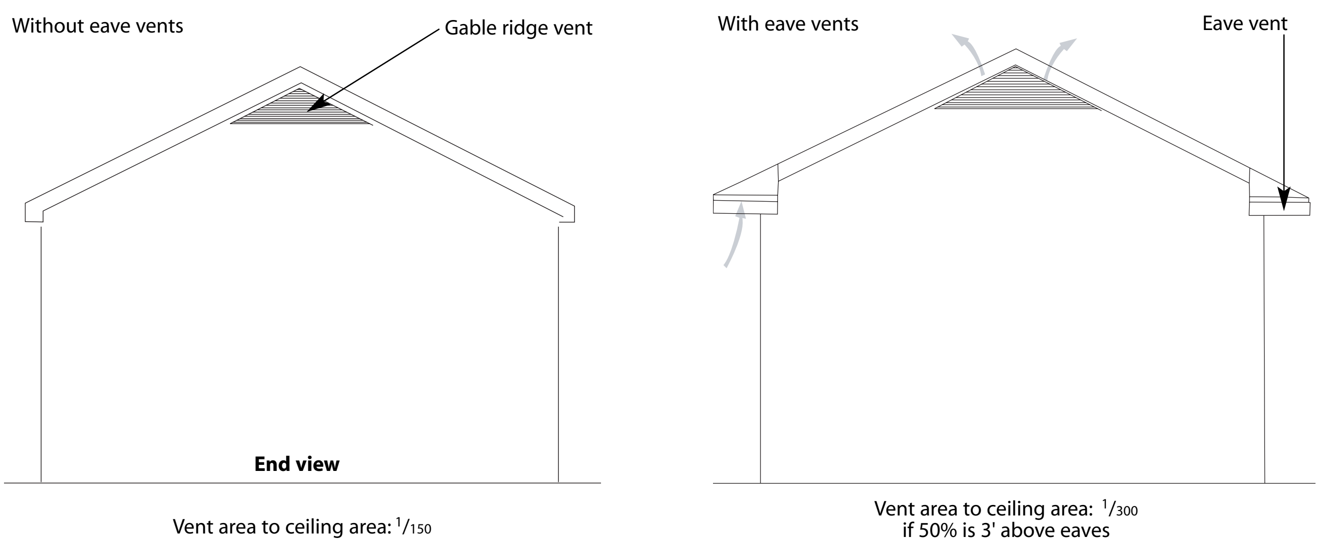


Figure 2
Gable vents

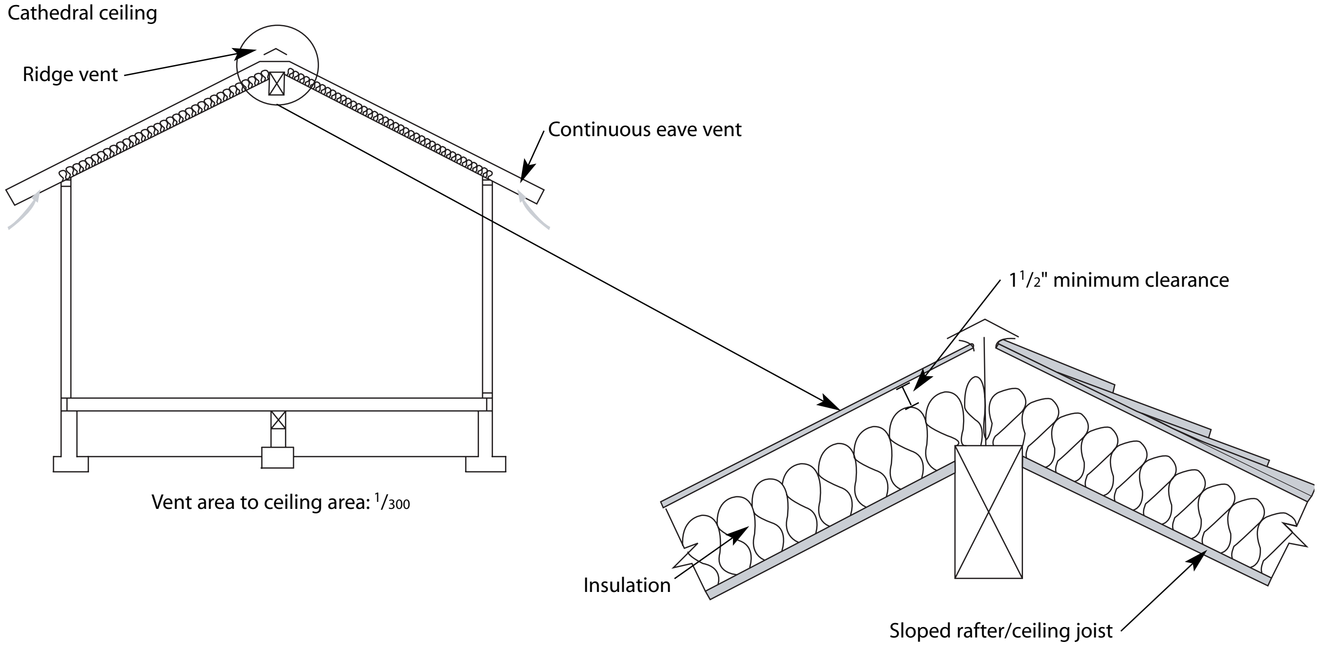


Figure 3
Ridge vent

2. In the attic, frame the opening with wood blocking.
3. On the roof, remove roofing nails in an area large enough to slide the vent base in. Apply roofing cement to the bottom side of the vent's base, and maneuver it into place.
4. Slide the vent into place and nail it, using gasketed roofing nails. Nail down the loosened shingles. In Figure 4, you can see both louvered and turbine roof vents on a hip roof.

Crawl Spaces

Vents in unheated crawl spaces should be placed to provide cross ventilation. Like attic and roof vents, you determine the number and size of the vents you need by using ratios. In spaces without vapor barriers, use 1:150 or 1 square foot of ventilation for every 150 square feet of underfloor space. You must have a minimum of four vents. As with attic and roof vents, screen size and louvers affect the square footage of the ventilation required.

In dry climates where groundwater isn't a problem, the ratio changes to 1:1,500, or 1 square foot of ventilation for every 1,500 square feet of underfloor space, providing you've placed adequate vapor barriers.

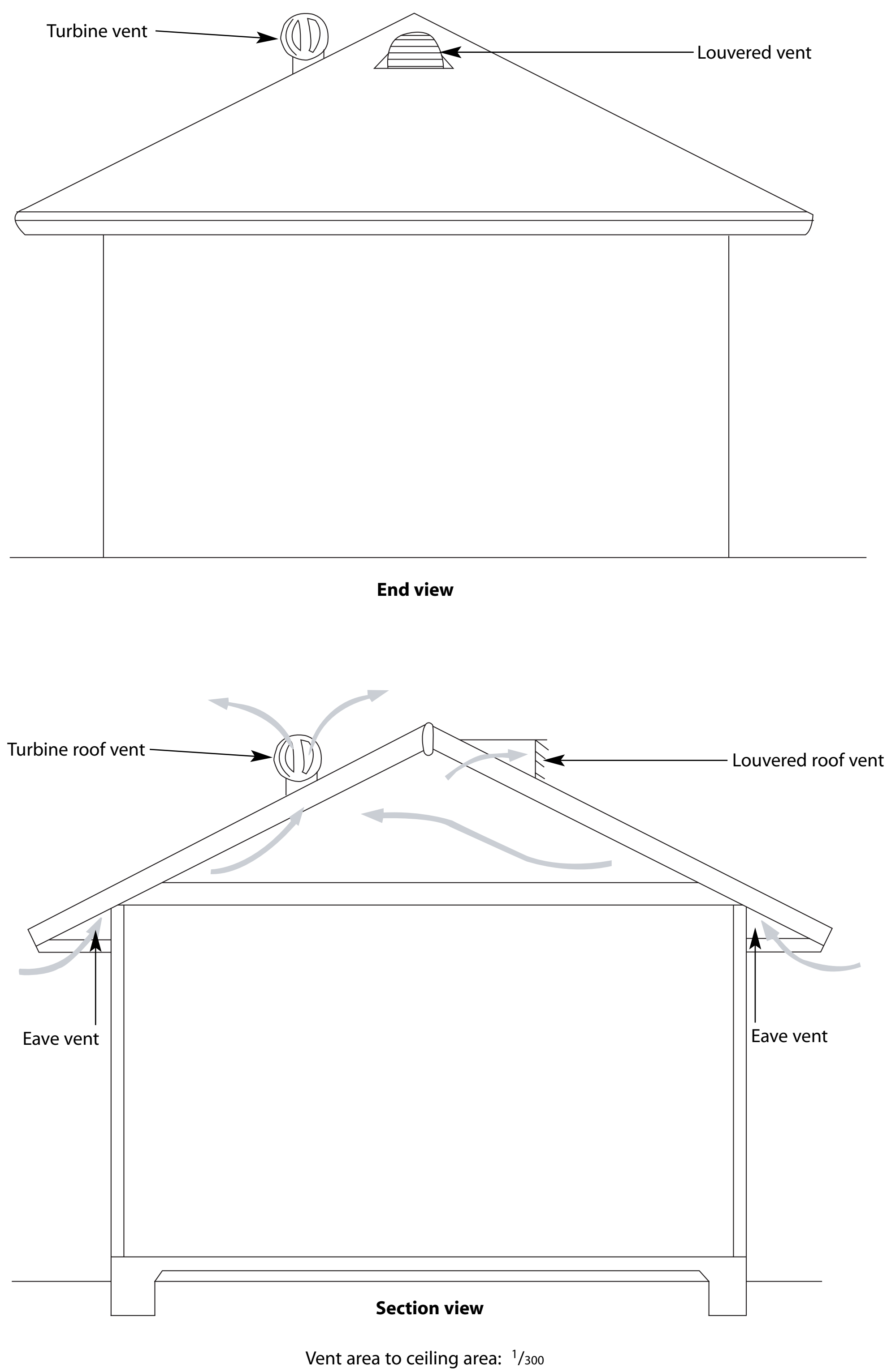


Figure 4
Turbine and louvered roof vents on a hip roof

Adequate vapor barrier protection would be a vapor barrier covering the ground and insulation, and another vapor barrier between the insulation and the floor. You must have a minimum of two vents, placed so that they provide cross ventilation.

Crawl space vents are fairly easy to install. Commercially manufactured vents come in a variety of opening sizes and screen sizes. Sometimes you can simply install a screen over an opening. See Figure 5. For concrete block foundations, you can remove a single block to provide a vent space. A concrete foundation requires cutting with a concrete saw. (Refer to *Concrete Cutting*, under *Concrete*.) The vent or screen should be slightly smaller than the opening with the sill sloped toward the exterior for better drainage.

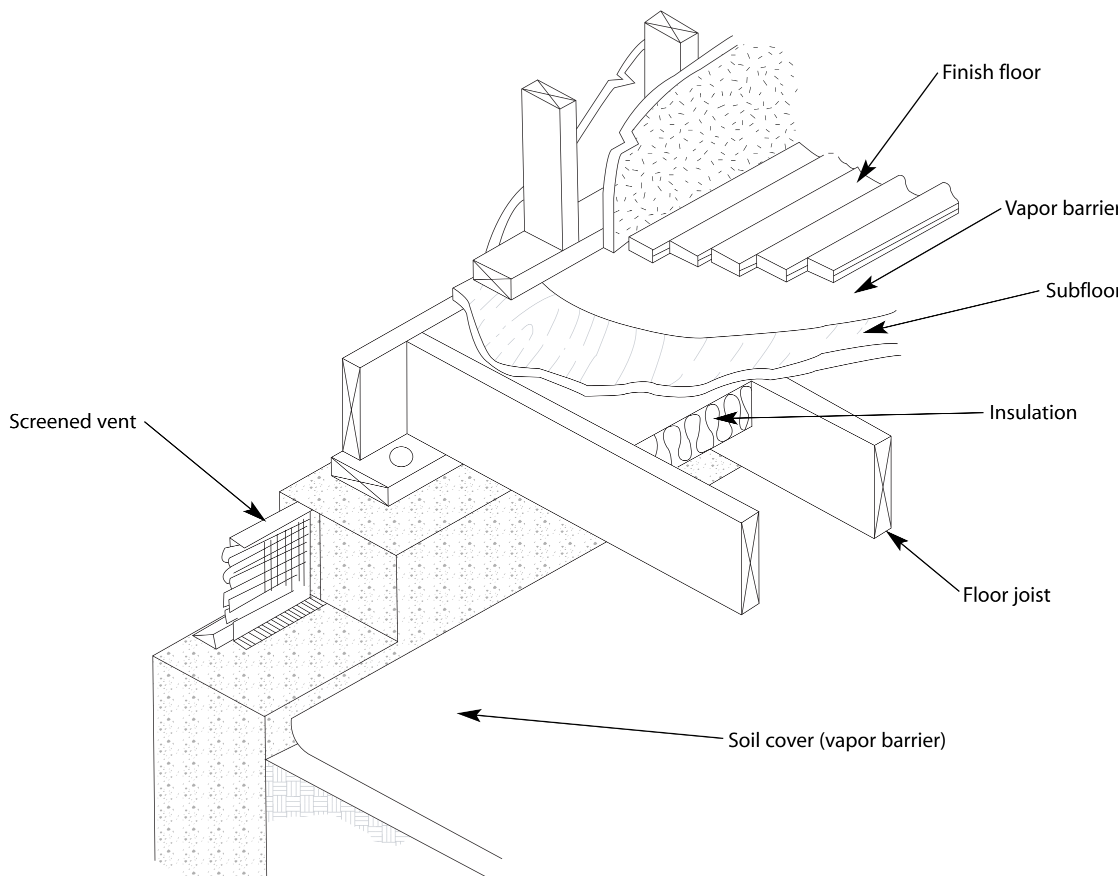


Figure 5
Crawl-space ventilator

Manhours

Manhours to Install Vents			
Type	**Unit**	**Manhours**	**Suggested Crew**
Soffit vent	Each	.50	1 carpenter, 1 laborer
Gable vent	Each	.50	1 sheet metal worker
Ridge vent	LF	.10	1 sheet metal worker
Crawl-space vent	Each	.50	1 sheet metal worker

For information on related topics, see:

Heating and Air Conditioning, page 379

Insulation, page 395

Radon and Other Pollutants, page 499

Roof Framing, page 513

Wall Framing

Wall framing, as well as the entire framing process, is an evolutionary procedure. New techniques often evolve around new tools and materials, such as the changes brought about by the introduction of plywood. Other changes brought about by efforts to save labor, material or both include the different styles of placing studs in corners. We'll discuss these and other changes in framing throughout this section.

Not too long ago, balloon framing was the most common framing style. Today you'll find that platform framing is generally preferred. Both balloon and platform framing evolved from post and beam timber framing. If you're adding on to or remodeling a home, you may run into either of these two styles. However, if you're working in new residential construction, you'll find that it's almost exclusively platform framed.

As framing styles change, suppliers follow. Studs are now available in precut lengths for platform framing. The 8-foot stud lengths used in platform framing are both easier to obtain and less expensive than the 18-foot studs needed for balloon framing. That makes platform framing more cost effective.

Framing Styles

Balloon-style framing is most distinctive when you see it on a two-story house. One-piece studs run from the sill plate to the top plate of the second floor. The second-floor joists rest on a ledger cut into the studs. They are attached by nailing to the studs themselves. You may find that the interior central bearing walls are also balloon framed. The ceiling joists and rafters bear on the exterior walls and central bearing points. Figure 1 illustrates balloon-style framing, although it isn't used much any more.

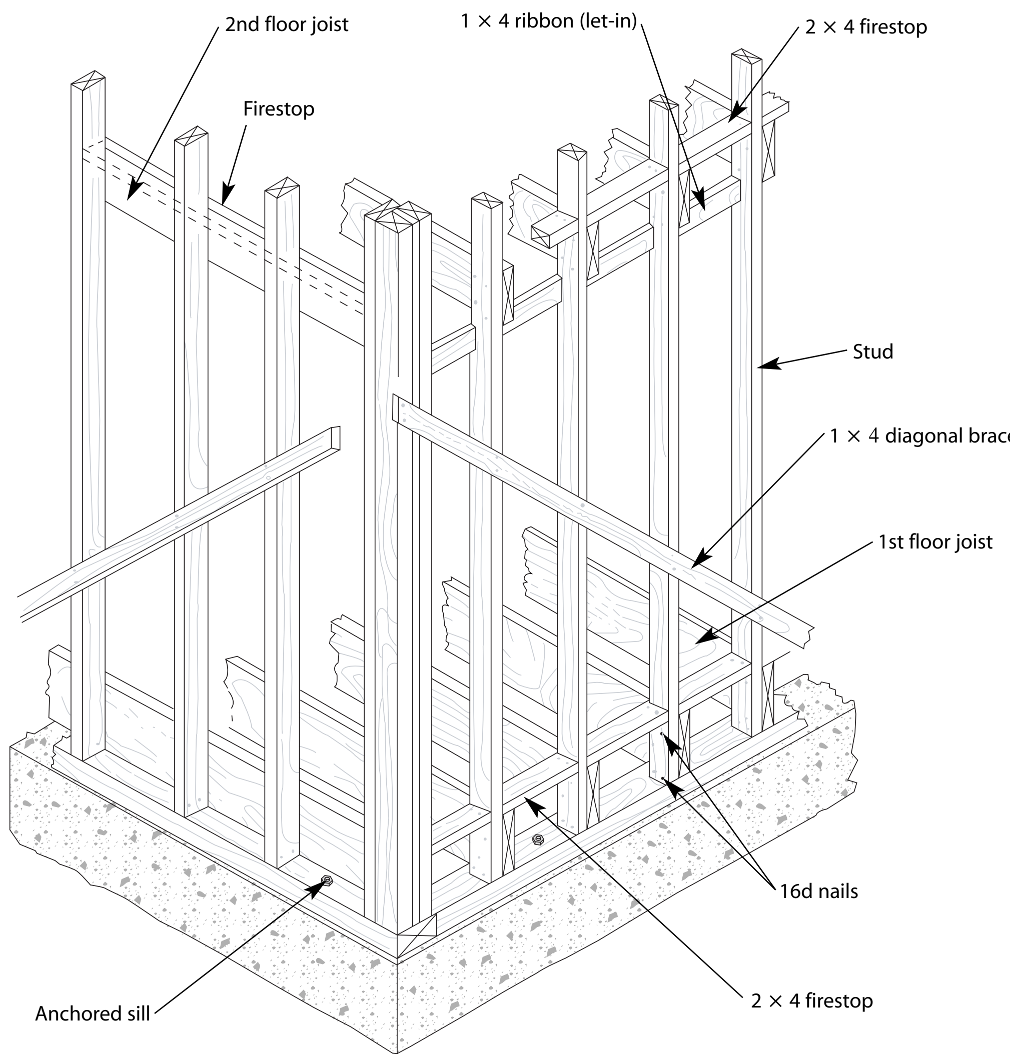


Figure 1
Wall framing used in balloon construction

Platform Framing

Platform framing uses a precut stud 92 1/4 inches long for 8-foot walls, although you can use longer studs to create higher ceilings. The studs are placed on a floor-joist platform. (Refer to *Floor Framing*.)

When you build a two-story platform-framed structure, the first-floor walls are placed on the floor-joist platform, as in single-story construction. Another floor-joist platform is built on top of the first-floor walls to support the second floor. The roof system, either trusses or rafters and ceiling joists, rests on the second-story walls. Since platform framing is the accepted standard at present, we'll focus on this method. Figure 2 shows typical platform framing.

Wall Framing Components

Here are the basic wall framing components (you can see most of them in Figure 2):

- *Studs* are the primary supporting vertical members. They may be either structural or nonstructural. Fasten studs to the bottom and top plates with either two 16d nails driven through the plate into the stud, or four 8d nails toenailed through the stud into the plate. Standard precut $92^1/_4$-inch studs are used for a single-floor system. If you're using a double-floor system with $^1/_2$-inch particleboard underlayment throughout the house, $92^5/_8$-inch precut studs are also available.

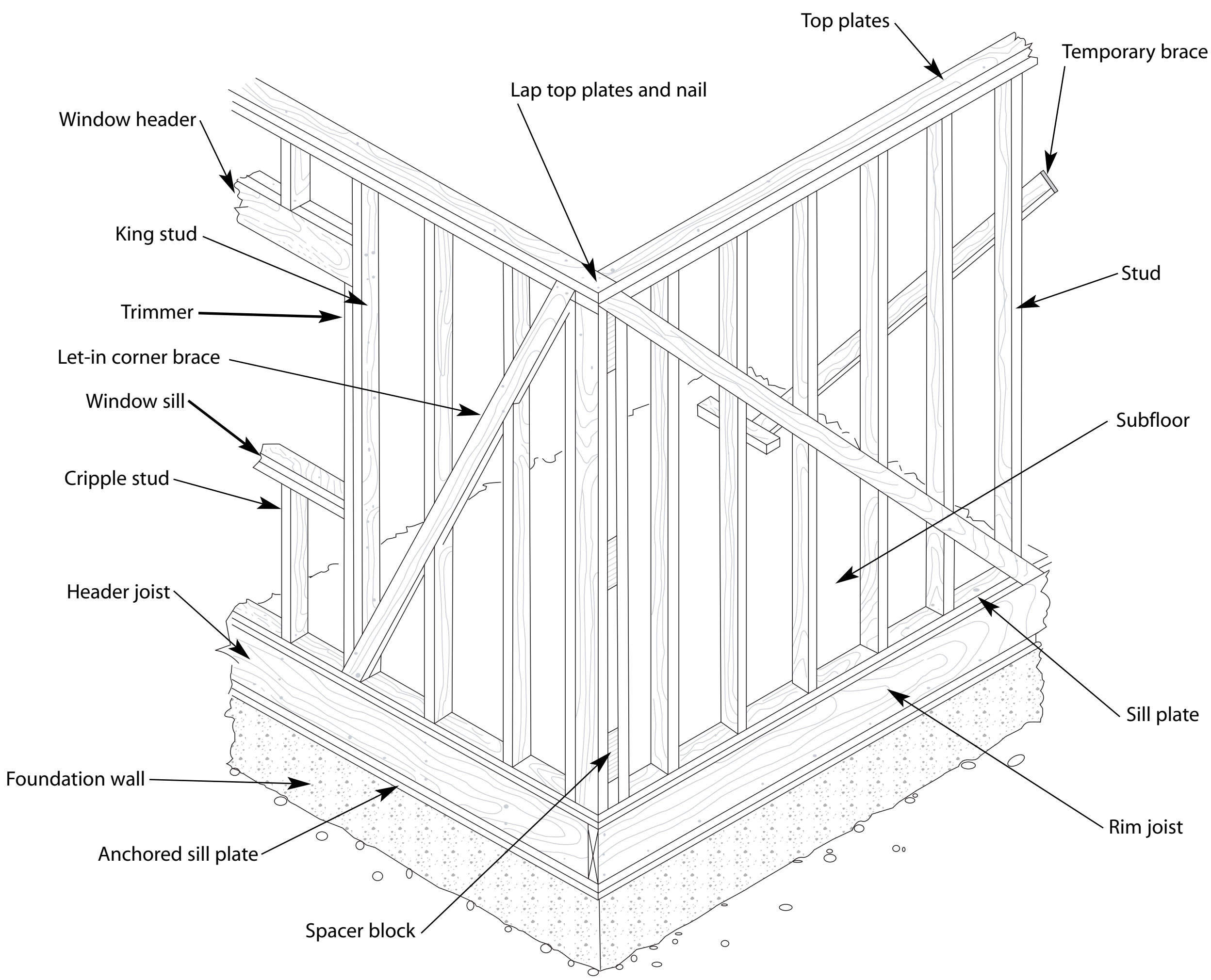


Figure 2
Wall framing used with with platform canstruction

- The *sill plate* (also called the bottom plate, base plate or sole plate) is the bottom horizontal member of the wall framing system on which the studs rest. Use the same dimension lumber for the sill plate as you use for the studs. Fasten the sill plate to the platform by face nailing through the plate into the joist or blocking with 16d nails at 16 feet on center.
- The *top plate* is the horizontal member placed on top of the studs. Like the bottom plate, the top plate is made of the same dimension lumber as the studs. Fasten the top plate to the studs with two 16d nails face nailed through the plate into the end of the stud or four 8d nails toenailed through the stud into the plate.
- A *double top plate* is a top plate that's doubled with a second plate of the same dimension as the first. The purpose of this second plate is to tie the walls together, as well as to provide a stronger bearing point for the roof trusses or second floor platform that's placed on it.
- *Corner posts* are also referred to as triples, or just corners, although regional variations may include many other names. Corner posts are built up of multiple studs. Their purpose is to tie the corner together, offering support as well as backing for the finishes that will be attached to them. Traditional framing methods use a three-stud corner post, but we'll also cover alternative two- and three-stud methods. See Figure 3.

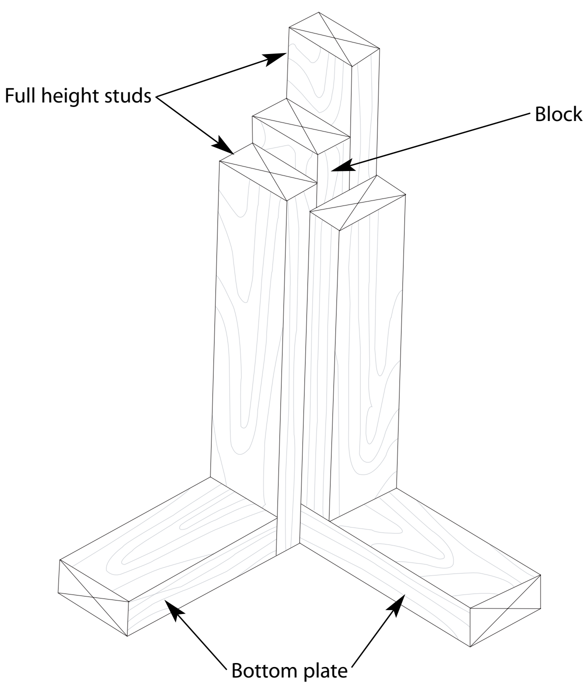


Figure 3a
Built-up corner

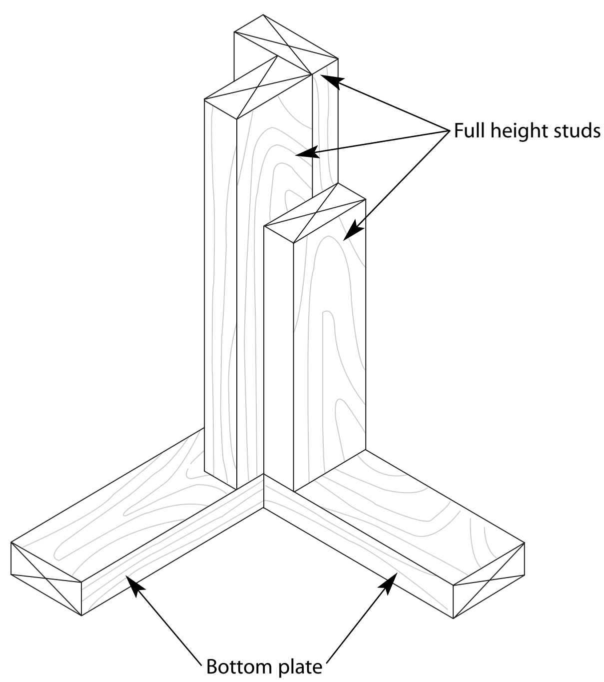


Figure 3b
"L" or "California corner" method

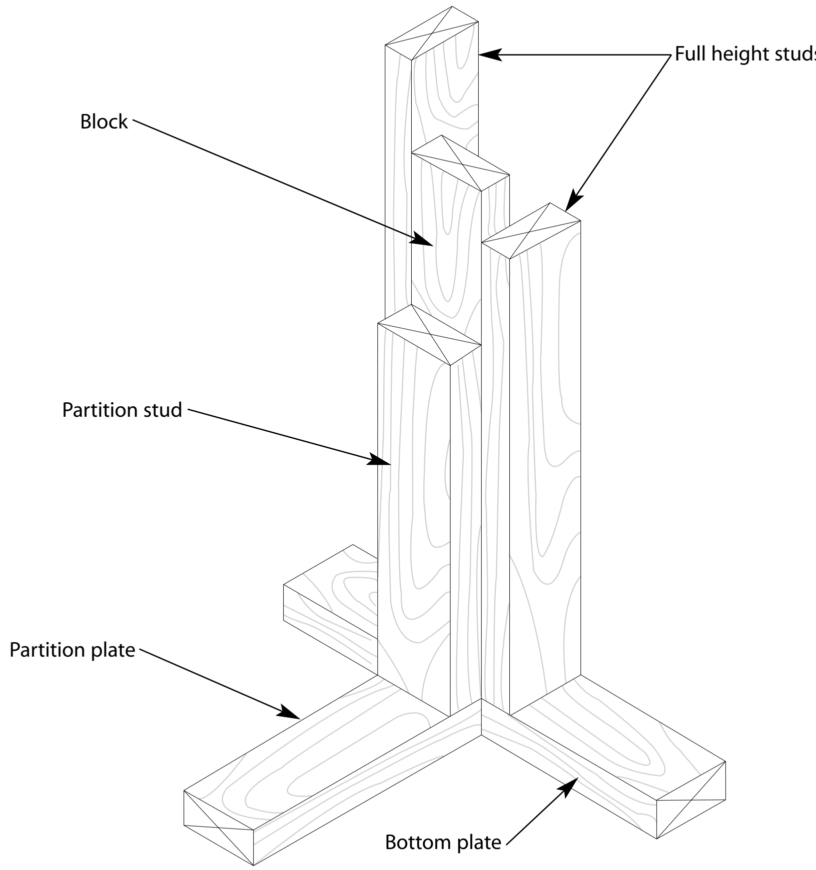


Figure 4
"Channel" for partitions

- *Partition posts* are also referred to as channels, because of their shape, as well as a few other regional name variations (Figure 4). When a wall Ts with or intersects another wall, you use this built-up three-stud unit to provide a solid corner as well as a nailing backer for the drywall or other finish.
- *Headers* are used above door, window, and other openings. Their purpose is the same as a girder or other beam. They're designed to span a specific distance and carry the load placed on it.
- A *sill* is the horizontal member at the bottom of a door, window, or other miscellaneous opening.
- A *sill jack* or *cripple* is a short stud, such as one between the base plate and a window sill.
- A *king stud* is the full-length stud that runs from plate to plate at the end of the header in a wall opening.

- *Trimmers* are the supporting studs set next to a king stud. A header rests on top of the trimmer and against the king stud. Headers over 8 feet long require two trimmers, one supporting each end of the header.
- *Rake walls* are sloped walls, such as a gable end wall in a house with vaulted ceilings.
- *Backing* is vertical studs placed as supports for fixtures, such as showers.
- *Blocking* consists of horizontal blocks placed between studs or cut into the studs as a complete piece (Figure 5). They provide nailing support for finishes such as paneling and vertical siding (see *Siding*), and an attachment base for hardware, such as grab bars or towel bars. However, one of the most common uses is as fire blocking. Most codes require fire blocking in any vertical space of 10 feet or more. For fire blocking, lay the block flat to seal the entire space, rather than upright as you would to provide a fastening base for attachments.

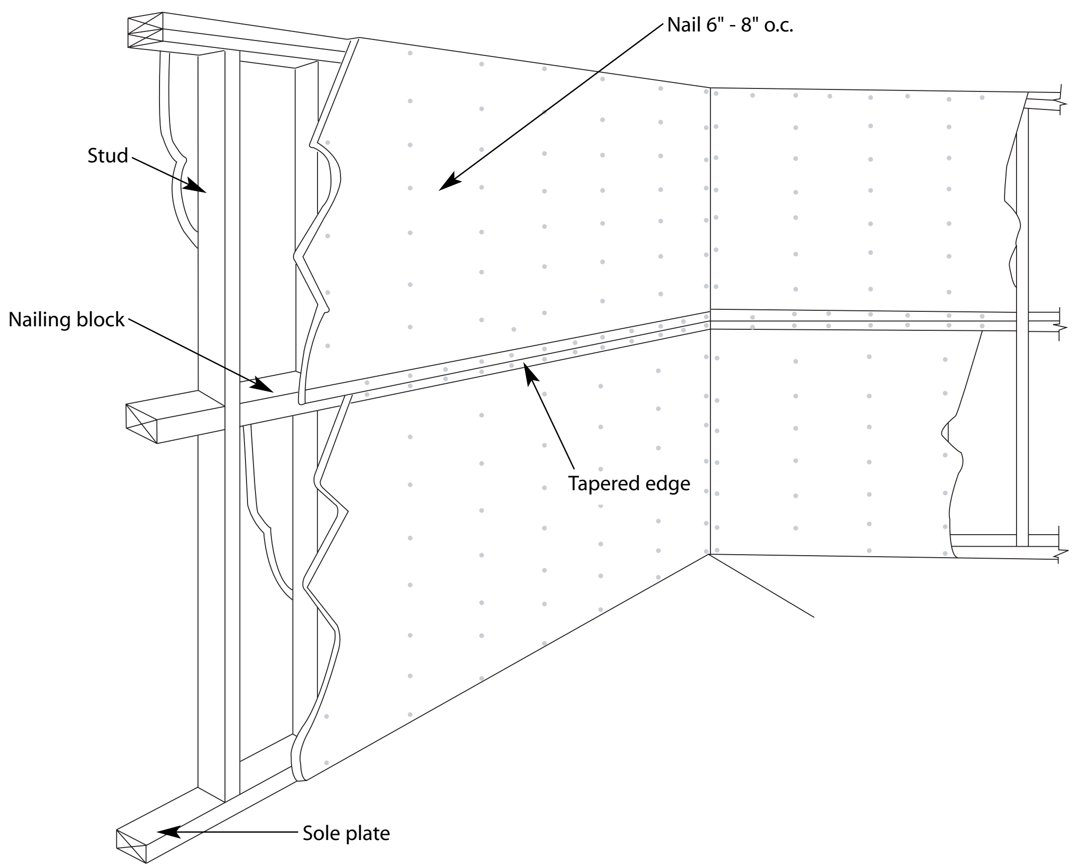


Figure 5
Blocking for gypsum board finish

Choosing Stud Spacing

Much has been written about stud spacing and cost saving. There's a brief discussion about this subject in the Framing section under Module Planning. There are two important factors to consider when choosing stud spacing. The first and most obvious is that the spacing must be structurally sound and installed according to local building codes. The second is subtler and must be determined by the builder or designer for each project. It involves the consumer's perception of quality construction.

On a custom home, you wouldn't want to go with 24-inch on center spacing if the client might perceive that as cheap or shoddy construction you're using to boost your profits. On a single house, the money you would save wouldn't be worth it. In a tract development of 250 homes or more, it might very well be worthwhile. There the savings, when multiplied 250 times, become significant. Tract housing also attracts a different type of client with different expectations. They aren't usually involved in the building process, but rather looking at a whole finished product.

Table 23-IV-B of the 1997 *Uniform Building Code* and Table R602.3(5) of the 2003 *International Residential Code for One- and Two-Family Dwellings* provide acceptable stud spacing for different stud dimensions. Spacing at 24 inches on center is acceptable for load-bearing walls in a single-story house, though 16-inch spacing is required for walls supporting a second floor. If you have questions about stud spacing, check with your architect, engineer, or local building department to determine what's acceptable in your area.

Here are some of the advantages of each spacing:

- *16-inch spacing* provides additional strength, whether required or not. The shorter span for wall panels creates less give in drywall or other finishes, and it gives a general perception of quality construction
- *24-inch spacing* provides some cost saving, as fewer studs are required. And fewer studs translate to greater insulation coverage and fewer cold transfer points on exterior walls.

Wall Framing Procedure

There are many separate tasks involved in wall framing. Many of these tasks can be done simultaneously, with different members of an efficient framing crew working on different jobs. By planning ahead, you can put up the actual on-site framing quite rapidly, which is what the general contractor or owner is interested in seeing.

Always start wall framing with a clean platform or deck. This is your work area, and the base for the first step, which is to mark the position of the wall plates on the deck using a chalk line. The next step is cutting the wall plates and laying out the stud spacing, followed by assembling and erecting the walls, doubling the top plates, and then sheathing the exterior walls. Let's look at these jobs one at a time.

The Wall Layout

Your first task in wall framing is to lay out the walls. This is simply a matter of blowing up to full size what the architect has drawn to scale. Instead of using a scale and a drawing board, you'll be working with a tape measure and a chalk box on a plywood platform.

You should have checked the foundation for square when the platform was built. Now, as the walls are about to be set, begin by confirming that the platform is square and all the measurements conform with the plans.

You can check for square on a square or rectangular platform by comparing the measurements of diagonal corners. On a square platform, the two diagonal measurements will be the same. A platform in the shape of an L can be checked using multiples of 3, 4 and 5. Pick a multiple that will fit the platform you are checking. Using 5 as the multiplier results in a triangle with sides that equal 15, 20 and 25. From the junction of the L, measure 15 feet along the short side of the L and 20 feet along the long side. The diagonal measurement between these two marks should be 25 feet if the platform is square. You can use any multiple of 3, 4 or 5 to check for square in this manner.

After you've checked the platform for conformity and made any necessary adjustments for the wall layout to fit, chalk the inside plate line for the perimeter plates. If everything lays out according to plan, the outside plates will be positioned so that the siding laps snugly over the foundation wall, providing a tight weather seal. These lines must be marked square. Lay out and chalk the interior partition walls with parallel measurements from these lines. Lay out the walls so that all measurements correspond to those on the plans. If you must make any changes, note them on the plans.

Positioning the Plates

Using the plans for measurements, or the chalk lines if necessary, cut matching top and bottom plates. (You may cut the bottom plate from lumber that's bowed more than would be acceptable for freestanding uses.) Take care that you match the two plates exactly. When the walls are erected, the plates will all be drawn tight. If the top and bottom plates aren't exactly the same length, it will be impossible to plumb the wall.

Temporarily tack the bottom plate in position using a minimum of nails. Two 8d nails is all that should be necessary. The top plate can then be tacked to the bottom plate in the same manner. Lay out all of the plates at one time, again making certain that all joints meet tightly. This will ensure that when the walls are erected, they'll fit just as tightly at the top, creating a plumb and square structure.

Begin plating with the exterior walls. As walls intersect, some will run through with other walls butting into them. These walls are often called *by-walls* and *butt-walls*. All of the exterior walls are by-walls. As you plate the interior walls, you'll have to decide which walls will run through and which walls will butt. Usually the longest walls are designated by-walls. The walls parallel to the by-walls should also be by-walls when possible. When making these decisions, try to keep the erection of the walls in mind. Avoid creating situations where you'll have to slide or carry a wall into position or place one in a slot created by two other walls.

Marking the Plates

Some framers prefer to mark the layout on the face of the plates once they've been cut and checked for accuracy. You can do this by marking the top plate on the face and the bottom plate on the edge, or by removing the top plate and laying the plates side by side so that the marking is fully across the face of both plates.

Other framers prefer to roll the plates on their sides and mark the stud spacing on the sides of the top and bottom plate while they're still temporarily nailed face to face together. These edge markings are adequate for most crews. Good framers have little problem quickly placing studs and eyeballing them square off of the edge markings. Whichever method you use is up to your personal preference. Once you become proficient with either method, the difference in speed should be minimal.

Once you have all the plates in the position you've chosen for marking, the first step is to place all of the openings. Make the header markings $1^1/_2$ inches longer than the rough opening on each side to allow for the trimmer. Place an X on the side of this mark (the outside of the header opening) to indicate the position of the king stud. Some framers place an O for omit or a T for trimmer on the inside side of the line. On openings longer than 8 feet, allow 3 inches on each end for double trimmers. Mark these with two O's (OO) or double Ts (TT) to indicate to the persons placing the studs that a double trimmer is needed. Mark the header length on the plate or use a system of numbering the headers as they're cut. If the headers are being built off of the platform while you do the layout, you can place them in their proper location without confusion.

Mark the rough opening measurements in the header location. Depending on the skills of your crew, also write the jack or cripple lengths. Marking the sill jack lengths along with the sill and header lengths allows less skilled workers to start cutting window and door packages while you're laying out the walls. More skilled workers usually have the experience to do that with only the rough openings marked.

After you've marked all the headers and openings, you can mark the stud positions. Start laying out the stud positions on the walls perpendicular to the floor joist. These are usually the long walls. Start the spacing with the exterior sheathing in mind. Mark the first space from the outside of the building to the center of the first stud. On a 16-inch on center layout, the inside edge of the first stud is at $15^{1}/_{4}$ inches. Set a nail on the $15^{1}/_{4}$ inch mark and then mark the remaining spaces at the 16-inch on center markings that you'll find on most tapes. The studs will always run all the way through the house on this spacing once it's started. The spacing doesn't start over on a by-wall when it intersects with a butt-wall. By starting the spacing like this, you can fit the sheathing at the first corner on a 4-foot or 8-foot module with no cutting necessary.

By looking at an exterior by-wall, it's fairly obvious that the layout for the interior walls can't all start out with modular spacing and have the exterior stay on module. This is also true when you look at an interior by-wall layout following an intersection with a butt wall. An off-module layout is unavoidable on interior walls — that's just a reality of framing. Dealers usually stock drywall in 8-foot, 10-foot, and 12-foot lengths. It's also available in lengths up to 16 feet. Because of the relatively low cost of drywall, having to cut the first piece of drywall because the first stud spacing is off layout isn't a significant expense.

Assembling the Walls

You can begin assembling the walls as soon as the layout and detailing of the framing components on the plates is done. With good detailing, this is a simple task of putting slot A into slot B. You can complete the wall assembly using many different methods and speeds. However, following a set procedure will promote a sense of order, be safer, encourage good workmanship, and still allow you to complete the work fast enough to make money.

The first step is to stock the work area with the necessary materials. This includes the studs, headers, sill jacks, corners and channels as well as the fasteners needed for installation. Deciding which of these should be placed on the deck and which should be placed for easy access beside the deck depends on the size and layout of the deck itself, as well as your crew size and framing procedure.

Many crews split up and build headers, corners, and partition posts or channels as well as cut window sills and sill jacks while the plating is being done. That way, when the plates are ready for assembly, very little cutting is required, and the entire crew can work at assembling and erecting walls. Studs can be culled and crowned as you place them in position, or if you have extra labor available, this task can also be done ahead. When the plates are ready for assembly, place all the framing components for ready access, usually somewhere on the deck itself. We'll go into more details on these individual components later in this section.

Use the following procedures to assemble the wall sections:

1. Separate the top and the bottom plates that you temporarily nailed together during layout and plating.
2. Place the bottom plate at or near its layout position. Place the top plate slightly beyond the approximate length of the studs being used.
3. Place studs in every marked position. Even if the studs have been culled ahead, quickly sight the studs as you place them. Discard any unusable studs and place all others with their crown up. Place corners and partition channels where they're needed.
4. If the headers are built of 2 × 12s, you can place them in position. If you're using smaller headers, they'll require header jacks. These headers will be easier to install after you've nailed the studs.
5. Begin nailing the full-depth 2 × 12 headers to the top plate by face nailing through the top plate into the header. Use two 16d nails at each end. Nail the remainder of the header at 16 inches on center, staggered the length of the header.
6. Nail the king studs into position. Face nail the ends through the top and bottom plates using two 16d nails at each end. Face nail six 16d nails through the king studs into each end of the header.

   Or for smaller dimensioned headers, nail the king studs into position followed by the header, trimmers, and header jacks. Nail the header jacks with two 16d nails through the top plate into the end of the jacks. Toenail the bottoms to the header with four 8d nails.
7. Place and nail the remaining trimmers, sills, and sill jacks into position. Nail all framing members using two 16d nails face nailed through the plate or king stud into the end of the stud header or sill. Nail the trimmers with two 8d nails toenailed into the plate; nail the length of the trimmer from plate to header with 16d nails staggered at 16 inches on center. Nail two 16d nails angled through the top of the trimmer, two into the corner of the header, and finally two into the king stud.

8. Nail off the remaining studs, corners, and channels using two 16d nails into the ends of each stud.
9. Place double top plates in position where possible without making the wall sections too long to handle.
10. Overlap top plate splices by 4 feet. For by-walls, leave a space above the channels (partition posts) and corner post the width of the top plate. For butt-walls, extend the double top plate past the end of the top plate the same distance as the width of the top plate.
11. Nail the double top plate to the top plate using two 16d nails at the ends of each plate. Nail off the remainder of the plate with 16d nails staggered at 16 inches on center.

Optional Assembly Tasks

In addition to basic wall assembly, many framers like to add further steps before the wall is erected. These include cutting in the bracing, backing and, in some cases, even the exterior sheathing. When bracing and blocking are installed before erection, they're usually cut in as described below. We'll go into more detail on bracing when we cover Framing Components a little later in this section.

Cut-in Bracing —

1. Use a 12-foot long 1 × 4 for an 8-foot wall brace.
2. Square up the wall section to be braced as well as you can. It doesn't have to be perfect at this point, just close.
3. Place the brace at an approximate 45-degree angle from the top of the outside corner and angle it to the base plate.
4. Scribe a line marking the placement of the brace.
5. Make cuts on the outside edges of the scribe to a depth of $^3/_4$ inch for a loose fit. Cut or knock out the wood between the saw cuts where the brace will be let in. The loose fit will allow you to adjust the wall for plumb without the brace binding in the slot.
6. Place the brace in the slot, and trim the top and bottom so that its total length will be just short of the total length from the bottom of the base plate to the top of the double plate.
7. Nail the bottom of the brace into the base plate with a minimum of two 8d nails.
8. While nails may be started for attachment to each of the studs that are cut in, leave the remainder of the brace loose until the wall is in position and plumb. The brace may be tacked during erection, but be certain to loosen the brace when you plumb the wall.

9. After the wall is erected and plumbed, nail off the remainder of the brace using two 8d nails in each stud and plate.

Cut-in Blocking —

Place blocking as a nailer for drywall or as a hardware attachment piece. Blocking is most often placed, as its name suggests, as blocks of wood the length of the stud spacing. Frequently, as in the case of the blocking required along the edge of a bathtub, you may need a series of blocks to cover the entire length. Some framers find that it's easier to cut in the blocking before erecting the wall. This is done in the same manner as described above for cutting in a brace. As with the brace, the cut-in blocking should remain loose until the wall has been plumbed. See Backing and Blocking later in this section for further details.

Erecting and Setting the Wall

The first step in setting framed walls is to make sure you haven't built any walls that are longer or heavier than your available crew can handle. Your ability to handle a wall will vary with the type of wall as much as with the length. For instance, a wall with many windows will be top-heavy with headers. You'll have to find out from experience how much you and your crew can handle. To start with, try about 10 feet of wall per person. But be sure to have bracing and ladders in position before you begin, just in case. When you raise a wall and it's wobbling in place, it's not a good idea to let go and go looking for a brace, or even to try to grab a ladder that's 10 feet away instead of 2 feet away.

Raising the First Wall

1. The first walls to raise should be the outside by-walls followed by the outside butt-walls. Start with a by-wall in an outside corner.
2. Nail 2 × 4 braces that are approximately 12 feet long to each end of the wall being raised. Face nail both braces into the side of a stud near the top plate with one 16d nail. This lets the brace hinge as you're raising the wall. Nail the braces on outside corners to the outside of the corner post. You can then nail the brace to the side of the rim joist where it will be out of the way when the butt-wall is raised. Nail the second brace on a stud at or near the other end of a wall. When you raise the wall, you'll attach it to a block that's been temporarily nailed to the floor.
3. Raise the wall into position, sliding, kicking, and tapping the base plate to the plate line that's marked on the framing platform.

4. Nail several 16d nails through the base plate at each end of the wall to secure the wall into position.
5. Plumb the wall at each end and nail the braces securely.
6. Nail the base plate to the floor joist or blocking, using 16d nails at 16 inches on center.

After you raise and stabilize the first wall, the remaining walls require less bracing as they're attached to and support each other. You may not need any bracing for short walls. The key to raising walls is to make certain that all base plate and top plate joints are tight. If there are gaps after the walls have all been raised, getting all of the walls plumb will be impossible without tearing something apart.

Raising the Remaining Walls

1. Have any bracing you may need, depending on the length of the wall, ready before you begin.
2. Have a ladder ready so that you can attach butt-walls into the slots left in the double top plate.
3. Raise the wall and move it into its marked position.
4. Tap the base plate tight against the adjoining base plate, and nail the end tight.
5. Nail the top plates together, again making certain that the plates are tight. Butt-wall double top plates that overlap by-walls need two 16d nails face nailed into the top plate of the by-wall.

Plumbing and Stabilizing the Walls

After you've erected all of the walls and tied them together, you need to plumb, brace, and stabilize them before you nail the permanent cut-in bracing and apply the exterior sheathing:

1. Have the bracing material on hand. You'll need 12-foot material for a brace that's at about a 45-degree angle on an 8-foot wall.
2. Plumb off of corner posts, doorways, or other critical positions.
3. *Rack* the walls into position by pushing against them repeatedly until you can hold them in position while bracing is applied. On stubborn walls, nail a brace to the top corner with the bottom loose. Lever against the base of this brace with a wrecking bar, or tap against the end with a sledge hammer (put your foot on top of the brace to prevent it from bouncing back when you tap it).
4. Cross-check plumb corners by checking an opposite corner, which may have been pushed or pulled as the first corner was racked. If both corners don't read the same, the plates weren't cut the same, or the plates weren't drawn tight when framed. Find and correct the problem before you go any farther.

5. When the walls have all been plumbed and temporarily braced, nail the permanent cut-in bracing with two 8d nails into each stud and plate.

Now you're ready to apply the wall sheathing. As we'll discuss later in the detailed section on bracing, cut-in bracing isn't required in most areas if you use plywood sheathing on the corners.

Sheathing Materials

A variety of materials are available as sheathing options. The traditional option has been wood. Prior to the widespread use of plywood, 1 × 10 boards applied at a 45-degree angle were used for wall sheathing. The labor-saving benefits of plywood quickly made it the overwhelming choice over board sheathing. However, other alternatives are also frequently used for either their cost-saving or energy-saving benefits.

OSB (oriented strand board) is less expensive and, for the most part, structurally interchangeable with plywood. Asphalt-impregnated fiberboard sheathing is a nonstructural sheathing that costs less and provides a slightly higher R-value than plywood. Foil-faced foam sheathing, while also nonstructural, is valuable for its insulating properties. You can find more information on these products in the *Framing* section, under Engineered Wood Products.

A framed structure with 8-foot walls built on floor joists requires sheathing panels larger than the standard 8-foot panels to cover the studs and the joists. While larger sizes aren't widely available in OSB and plywood, 9-foot panels are available in asphalt-impregnated sheathing. If you have to use 8-foot panels for OSB or plywood, you'll need a filler strip for the additional height.

If you're using plywood or OSB structurally without the added support of cut-in wall bracing, the plywood should cover from the top plate of the wall down to the bottom plate. This connects the top and bottom plates and the corner post, creating one integrated unit. If you're using a cut-in brace, it's better to place the splice at the top where the sheathing will lap the connection of the bottom plate to the floor joist and the filler strip will most likely be above the line of an enclosed soffit.

Plywood Wall Sheathing Installation

Since both OSB and plywood are wood products and react similarly to weather and changes in moisture content, their installation is similar. The American Plywood Association offers the following plywood wall sheathing installation guidelines.

You can apply plywood wall sheathing either vertically or horizontally. Most contractors use vertical installation for single-story structures.

1. If the plywood will also serve as structural corner bracing, use full 4 × 8 plywood panels at corners, and pieces that require cutting for inner panels.
2. Maintain 1/8-inch spacing between all panels.
3. On 8-foot walls, put the filler strips at the bottom on rim joists if stripping is required.
4. Use 6d panel nails on panels up to 1/2 inch. Thicker panels require 8d nails.
5. Nail panels 6 inches on center on edges and every 12 inches on intermediate supports.
6. Gluing isn't recommended for wall sheathing.

Wall Framing Details

We provided a brief description of the various wall framing components at the beginning of this section. Now we'll cover them in more detail, including their standard use in new construction, the assembly of the various components, some alternative assembly methods, and their use in common remodeling situations.

Corner Posts and Partition Posts

Corner posts and partition posts, or channels, are built as a means of attaching a butt-wall to a by-wall, and at the same time providing backing for drywall or other interior wall finishes (refer again to Figure 4). The traditional post in both uses is a built-up member created from multiple studs.

Building a Partition Post

Partition posts are traditionally built with three studs, or two studs and blocking, into a U, or channel shape. That shape provides the source for its regional names, one of which is *channel*.

To build a traditional partition post, use two straight studs of the same dimension as the by-wall, and three blocks of the same dimension as the butt-wall. Place the two end blocks so they won't protrude beyond the end of the studs. Center the middle block. You can make the placements approximate, without wasting time with measurements. Face nail the studs into the edges of the three blocks using two 16d nails per block for each stud. You can frame the assembled post along with the standard studs. When you place the partition post, position it so that the blocks are on the side of the wall to which you will attach the butt-wall.

Building a Corner Post

Like partition posts, corner posts have traditionally been built as three-stud corners. You can build them with three studs stacked together, or with two studs sandwiching three blocks between them.

To assemble a traditional corner post, you'll need two straight studs and three spacer blocks that are at least 12 inches long. Place one of the blocks near the center of the first stud and the remaining two at each end. Be certain that the end blocks do not protrude beyond the ends of the stud. Nail the blocks using two 16d nails in each block. Complete the post by sandwiching the blocks with the second stud. Square the ends of the two studs so that they're even before again face nailing two 16d nails into each block.

Alternative Corner and Partition Posts

In addition to the traditional corner and partition assemblies, there are alternative methods that you can use that still provide drywall backing. They're used to save material or labor costs, or sometimes to create larger wall spaces for better insulation. However, drywall clips are available, which eliminate the need for drywall backing entirely.

Headers

Headers are structural load-carrying beams that work in much the same way as girders. To accurately determine the size of a given header, take several factors into account. First, you must determine the load, including the weight of the dead and live loads per lineal foot of header. Then consider the length or span of the header. Finally, you need the bearing capacity of the species of wood that the header will be built from. Based on the span, load, and wood species, you can determine the size of the header.

It's important to understand that a 6-foot span doesn't always require the same size header, but that the load being transferred to the header, rather than the span, is the determining factor for sizing.

When dealing with a questionable load or a header length that hasn't been specified in the plans, consult an architect or engineer rather than risk liability with a size determination based on a rule of thumb.

Rough Openings

Rough opening heights remain constant for standard windows and doors. Figure 6 shows a typical window opening. With a single bottom plate, double top plate and $92^1/_4$-inch precut studs, the standard trimmer height is $80^3/_4$ inches.

Frame doors with headers that are 5 inches wider than the door you're installing. A 2-foot 8-inch door needs a 37-inch rough opening. This allows for a $1^1/_2$-inch trimmer and a $^3/_4$-inch jamb with $^1/_4$-inch shim space on each side. If you have any concern about the opening being plumb, you can allow more space.

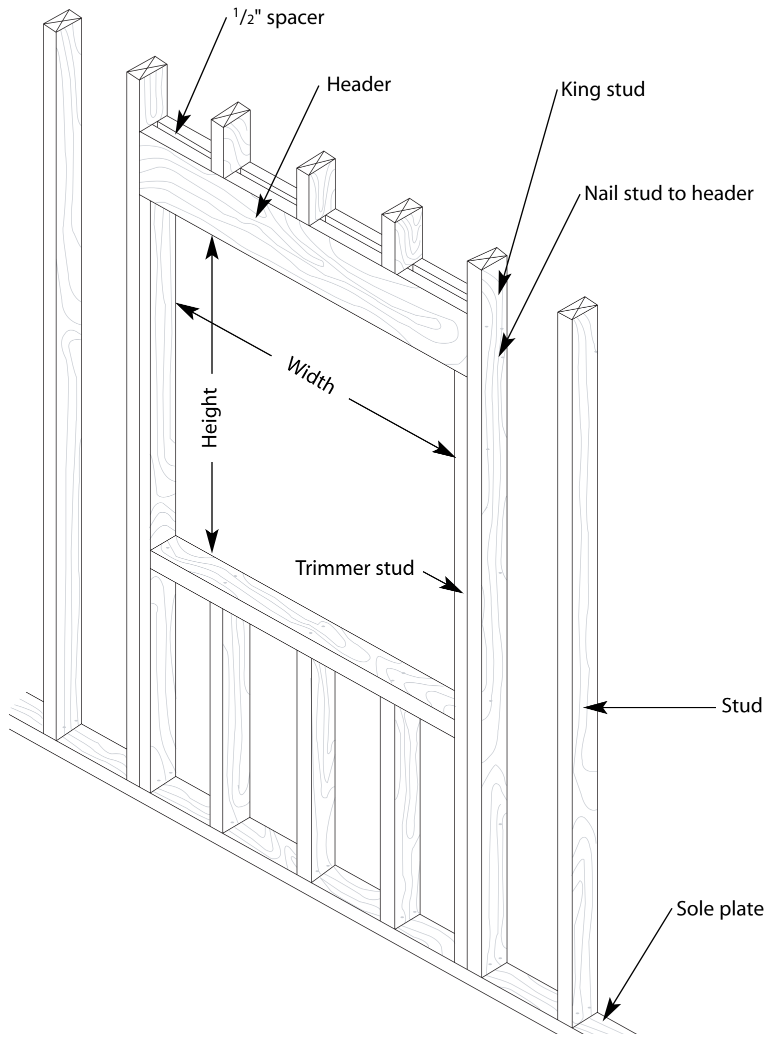


Figure 6
Header for window opening

Locate standard window rough openings vertically from the top of the trimmer. By building down from the standard trimmer height of 80 3/4 inches above the bottom plate, the tops of the door and window openings all remain the same. In standard installations the tops of the windows, whether they're 6-foot or 2-foot windows, are at the same height. It's the bottom elevations that vary.

Make metal window rough openings 3/4 inch larger than the nominal size of the window. For example, the rough framed opening for a 3-0 × 4-0 window is 36 3/4 inches wide by 48 3/4 inches high. The manufacturer provides the rough opening sizes for wood windows. However, with any window opening, wood or metal, be sure to confirm the rough opening measurements before framing.

Assembling a Built-Up Header

Headers are sometimes built of full dimension 4-by or glue-laminated material. However, in most areas, built-up headers are doubled 2 × 12s. With an 8-foot rough opening span built for 2 × 4 walls, you would assemble a built-up header as follows:

1. Cut two 2 × 12s into 8-foot 3-inch lengths, with all the ends square.
2. Cut a piece of $^1/_2$-inch plywood or other filler to bring the width of the header to $3^1/_2$ inches.
3. Sandwich this filler piece between the two structural header pieces.
4. Square up the ends and sides of the header pieces.
5. Fasten together using 16d nails. Nail a row of three nails at both ends and at 16 inches on center. After completing one side, flip the header and repeat.

Placing Headers After Erection of Walls

Some builders prefer placing the headers and building out the openings after the walls are erected. When you frame this way, you place the king studs, but leave out the trimmers and all the other opening components. After the wall is erected, you can finish the opening using the following steps:

1. For full dimension 2 × 12 headers:
   a. Place the trimmer studs at a slight angle against the king studs.
   b. Place the new header above the trimmers.
   c. Tap the bottoms of the trimmer studs tight against the king studs, forcing the header up tight against the top plate.
   d. Fasten the header in place by face nailing through the king studs into the ends of the header.
   e. Fasten the header to the top plate by face nailing through the top plate into the header with 16d nails staggered at 16 inches on center.
2. For smaller headers:
   a. Place and nail the trimmers in position.
   b. Place the header on top of the trimmers. Fasten the header by face nailing through the king studs into the ends of the header.

c. Fill in the header jacks as required. Toenail them to the header and the top plate using four 8d nails at the end of each jack. Or, face nail two 16d nails through the top plate into the top of the jack before you place the double top plate.

3. Place and nail the remaining sills and sill jacks into position. Nail all framing members with two 16d nails face nailed through the plate or king stud into the end of the stud header or sill. Nail the trimmers with two 8d nails toenailed into the bottom plate. Nail 16d nails, staggered at 16 inches on center, the length of the trimmer from plate to header.

4. Finish by nailing two 16d nails angled through the top of the trimmer, two into the corner of the header, and finally two more into the king stud.

Placing a Header in an Existing Wall During Remodeling

When adding a window or door to an existing building, you need to add a properly sized and supported header. If you use a built-up header, you can assemble it and support it with trimmer studs in the manner we just discussed. The preparation and installation, however, are slightly different. In most cases, it's easier to repair damage on the interior than the exterior, and so this installation is done from the inside:

1. Temporarily support the load the header will be carrying. In a residence with trusses, you can do this by building a temporary wall placed back just far enough to allow a minimum of working space.

2. Mark the rough opening in the wall material.

3. Locate the bottom of the top plate.

4. Remove the wall material that's marked out for the opening. It's almost always necessary, and in most cases easier, to remove the wall material from the bottom plate up to the bottom of the top plate. With drywall, it's easier to finish the new opening if the top strip of drywall over the top plate is left in place. By doing this, you can flat tape the new drywall to this piece rather than having to corner tape a new piece to the ceiling. This is especially preferable if the ceiling is textured.

5. Remove the existing studs.

6. Install new king studs.

7. For full dimension 2 × 12 headers, place the trimmer studs at a slight angle against the king studs. Place the new header above the trimmers and tap the bottoms of the trimmer studs tight against the king studs. This forces the header up tight against the top plate.

8. For smaller headers, place and nail the trimmers in position. Place the header on top of the trimmers and toenail through the top and sides of the header, attaching it to the king studs using 16d nails. Fill in the header jacks as required. Toenail them to the header and the top plate using four 8d nails at the end of each jack.
9. Place and nail the remaining sills and sill jacks into position. Nail all framing members with two 16d nails face nailed through the plate or king stud into the end of the stud header or sill. Nail the trimmers with two 8d nails toenailed into the plate. Nail 16d nails, staggered at 16 inches on center, the length of the trimmer from plate to header. Complete the nailing with two 16d nails angled through the top of the trimmer, two into the corner of the header, and finally two more into the king stud.
10. Fasten the header to the king stud by toenailing through the face of the header into the king stud using 16d nails.
11. Fasten the header to the top plate by toenailing through the face of the header into the top plate using 16d nails.

Rake Walls

When framing angled walls, most framers find the easiest way is to lay out the wall on the deck with a tape measure and chalk lines. With the shape of the truss laid out on the deck, you can cut the studs using measurements from the profile and assemble the wall in the same location.

Lay out rake walls before you erect the other walls, which may interfere with the space you need. Work out of a square corner so that you can pull measurements off two planes. All of the corners should be square, providing of course they were designed that way, but do a quick 3-4-5 square check before doing the entire layout.

Laying Out a Rake Wall

These steps describe the layout and assembly of an 11-foot-wide rake wall that is to be laid out and built following the rake of the bottom side of the rafter.

1. As a rake wall will most likely be a butt-wall, start the layout by placing a stud along the plate you're using for square to represent the through wall. Tack the stud in place to prevent movement during layout.
2. Lay out the basic square of the wall, marking on this stud the top of the through wall including bottom, top, and double top plates.
3. Chalk a top-of-wall line at least as long as the width of the wall, but a minimum of 12 feet.
4. Measuring off of the stud, mark the width of the wall on the deck.

5. To determine the height of the wall, you'll need to know the size of the birdsmouth being used. A full-bearing birdsmouth on a 2 × 4 wall is $3^1/2$ inches. With a full-bearing birdsmouth, the double plate of the rake will meet the double plate of the side wall, which makes a relatively easy layout. Unfortunately, a full-bearing birdsmouth is only practical on lower pitched roofs. The angle on a high-pitch roof, such as a 12/12, necessitates the removal of too much wood in a full-bearing birdsmouth and weakens the rafter. Refer to Marking and Cutting the Birdsmouth under *Common Rafters* in the section on *Roof Framing* for details on making a birdsmouth cut.
6. For a rafter-framed roof, chalk the top of the rake by first locating the start of the rake on the outside wall. On a full-bearing birdsmouth, this is the inside top corner of the double top plate. On a partial-bearing birdsmouth, this point is back from the inside top corner; you'll need to determine the distance from the birdsmouth you use.
7. From the start of the rake, measure out 12 feet. Mark a 12-foot line parallel to the side plate in the area the top of the rake should hit.
8. Measure the distance of the pitch, 4 feet for a 4/12 pitch, up the 12-foot line from the top-of-wall layout line. Snap a line from the start of the rake point to the pitch measurement on the 12-foot line.
9. The top point of the rake is located where this rake line intersects the 11-foot wall width line. This is the bottom of the rafter line, or top of the wall.
10. Under this line will be the top and double top plates. To mark their layout, square off of the rake line and mark 3 inches at the top and bottom of the rake. Snap a line on these marks for the bottom of the top plate or top of stud line.
11. To lay out the studs on the rake wall, snap a square line off of the top point that you used to determine the pitch. Use this line as the top layout plate.
12. Lay out the studs on the bottom plate with a matching layout marked on the top line that you established in Step 8 above.
13. Snap lines on the stud layouts. These lines will intersect the top of stud line and provide the layout of the rake.

Assembling a Rake Wall

1. Measure from the bottom plate to the intersection of the stud layout and the rake to determine the stud length. Cut the studs to match.

2. Face nail each end through the bottom and top plates using two 16d nails at each end.
3. Place fire blocking in compliance with the local building code. In many areas, this will be when the studs exceed 10 feet in height.
4. Cut in bracing as required.
5. Erect the wall in the same way as you would a standard wall. Figure 7 shows the rake wall with blocking at 8 feet.

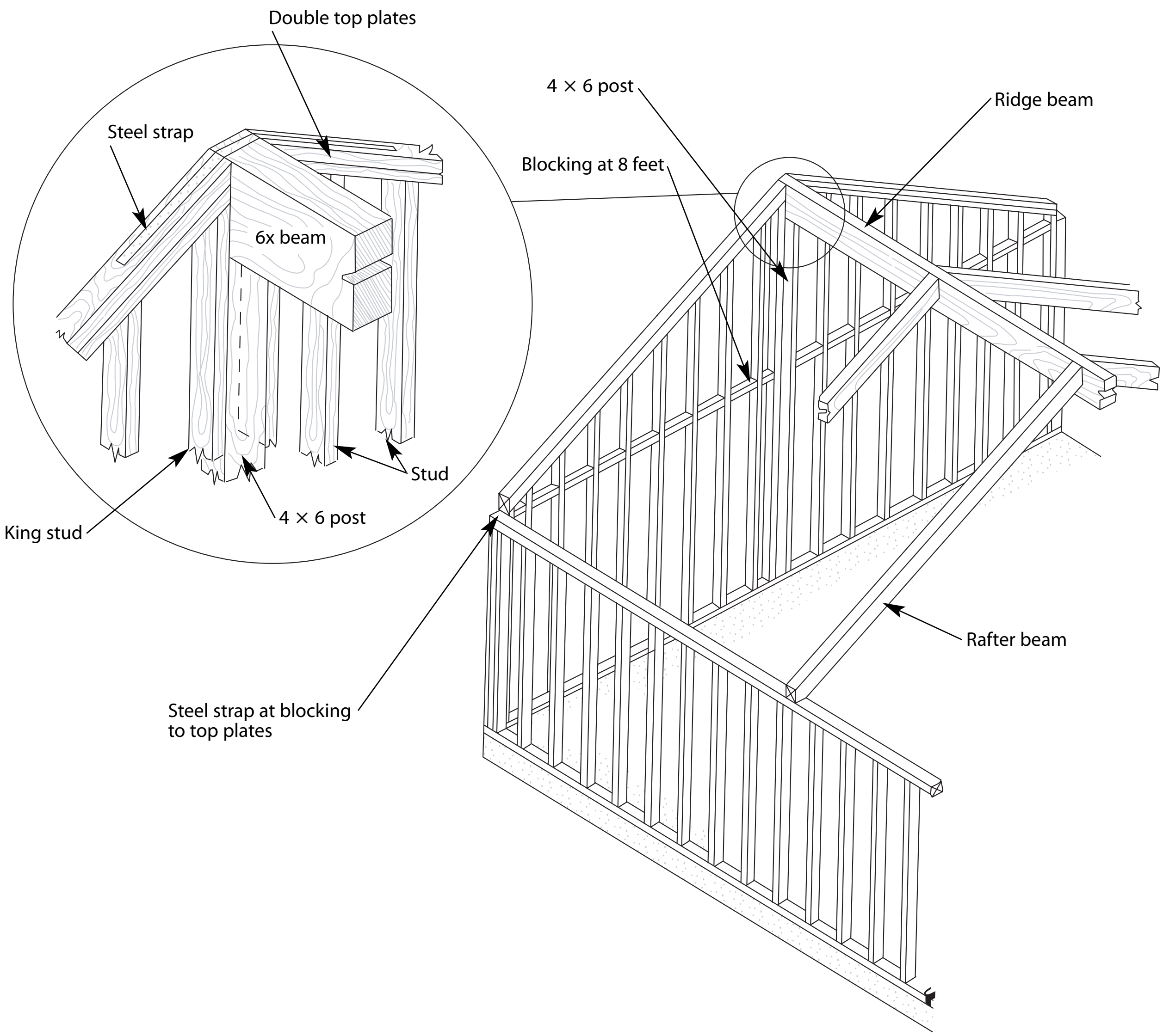


Figure 7
Framing a rake wall

Floating Walls

Nonbearing walls built on slabs in areas with expansive or otherwise unstable soils are often built as floating walls. The bearing walls are placed on a foundation stem wall designed to counter the movement of unstable soils.

The purpose of a nonbearing floating wall is to absorb a limited amount of movement in the slab without damaging the interior finishes. You may view it as somewhat of a compromise in that the floating wall is built with the expectation that there will be some movement in the slab it's built over. An alternative is to do an expensive overdig before placing the slab and import and recompact stable fill material. If you anticipate an acceptable amount of movement, especially in residential construction, building a floating wall is the less expensive choice.

Figure 8 illustrates a floating wall. There are two primary features that make a floating wall different than a standard wall. The most obvious is that there are two bottom plates. Somewhat less obvious is the fact that the wall hangs from the floor joist above it rather than resting on the slab below.

The double bottom plate is what gives the wall its floating feature. To make the wall float, you attach the bottom plate to the slab using power actuated nails or an anchoring system. Build a wall approximately $1^1/_2$ inches short using a standard layout with a standard top and bottom plate. Then hang the wall above the previously secured bottom plate. To prevent the wall from swinging freely, place large spikes through predrilled holes in the upper bottom plate and drive them into the lower bottom plate. If there's movement in the slab, the lower bottom plate will ride up and down on the spikes while the wall remains stable. The movement will be absorbed by the gap between the plates.

Backing and Blocking

You need backing and blocking for drywall nailers as well as for attachment points for hardware. Technically speaking, there's a distinction between backing and blocking: *backing* is vertical and *blocking* is horizontal. Most crews, however, use the term backing to refer to both.

Vertical backing is often just an additional stud placed in a specific location, such as along the edge of a shower. You may also find it on top of a wall for attaching ceiling drywall.

You attach backing based upon its location. When you place it next to another stud, nail the two together with 16d nails at 16 inches on center. When you place it independently as an additional stud, fasten it as you would a regular stud by either placing two 16d nails through the end or toenailing four 8d nails into the plate.

In addition to backing, some items, such as medicine cabinets, require special framing. You can use culls and cut-offs from earlier framing as backing and blocking.

Blocking

Blocking is traditionally installed as individual blocks nailed between the studs, using $14^1/_2$-inch blocks for studs on a 16-inch layout. Center the blocks on the anticipated centerline for supporting hardware. Fasten the blocks in place by nailing through the face of the stud into the ends of the blocks with two 16d nails at each end. For long rows of blocking, such as for bathtubs and showers, some production framers prefer to cut-in one continuous blocking piece.

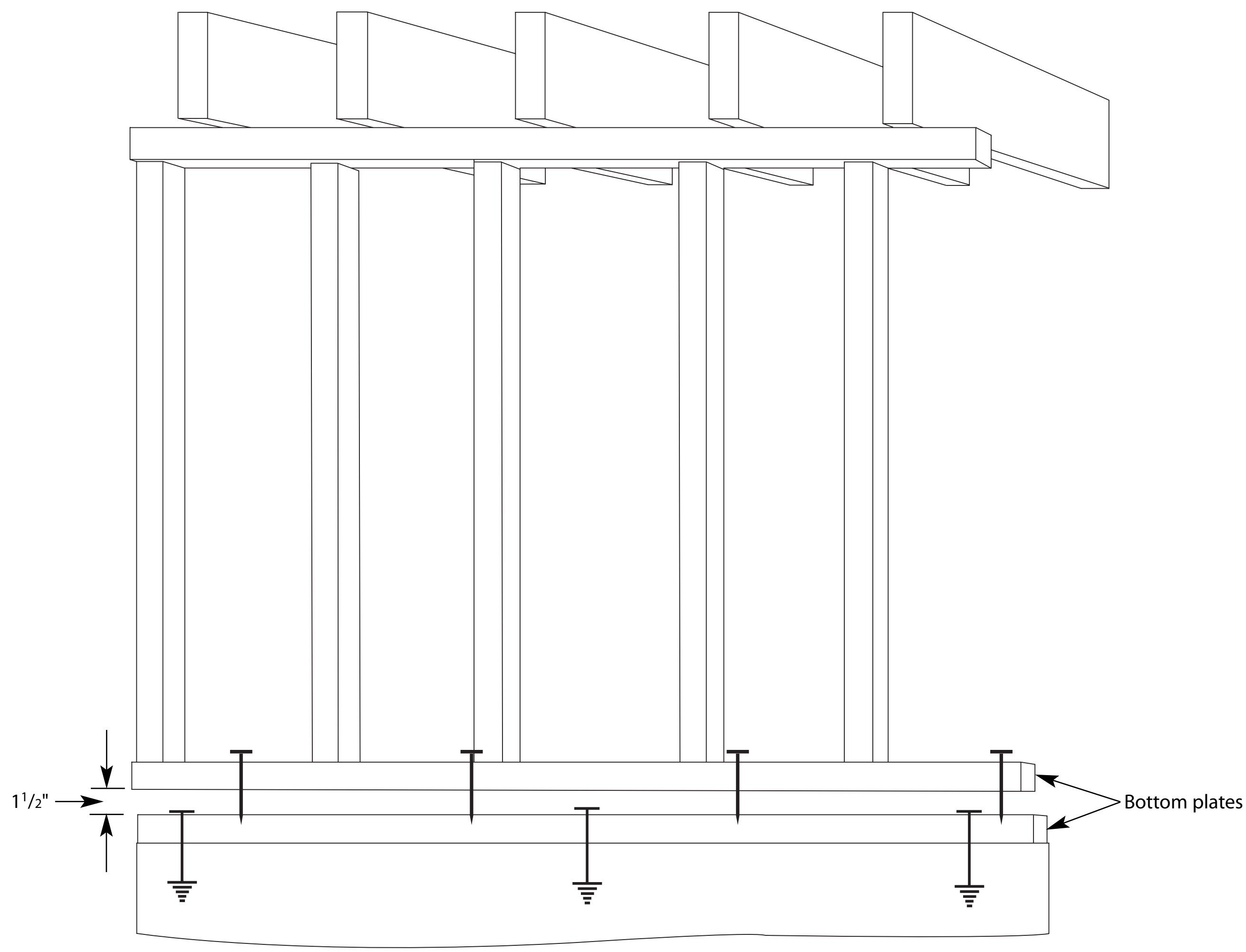


Figure 8
Framing a floating wall

Placing Individual Blocking Pieces — The usual method of placing blocking (and probably where it got its name) involves fastening short blocks in the stud spaces where you need support:

1. Locate the centerline of the hardware or fixture that you'll be installing. For placing individual blocking pieces, mark the studs on both sides of the stud space. You may either chalk or level longer lines.
2. For standard 16-inch stud spacing, cut your blocking pieces $14^1/_2$ inches long. Measure spaces thrown off by intersecting partitions individually.
3. Center the block on the centerline that you marked.
4. Nail the block in place using two 16d nails face nailed through the adjoining studs into each end of the block.
5. To place subsequent blocks next to the first, you'll need to start the nails next to the first block and angle them through the face of the stud into the block.

Placing Cut-in Blocking — Framers usually cut-in a continuous blocking piece after the wall has been assembled but before erection, although it can be done after erection as well. Place cut-in blocking as follows:

1. Locate the bottom edge of the blocking, and mark it on the studs on either end of the blocking.
2. Place the blocking piece across the studs and mark either side.
3. Set a circular saw at the blocking depth, usually $1^1/_2$ inches for 2-by material.
4. Cut along the scribed line.
5. Mark the side cut using a short block of the blocking material.
6. Using the circular saw, cut out the block between the kerfs cut in Step 4.
7. If you make your cuts on a wall before erection or before taking your final plumb checks and bracing, tack the block in place with one nail at each end. This allows the wall to rack as required while plumbing. After bracing, nail the block in place using two 16d nails face nailed into each stud.

Ceiling Backing

Starting with the ceiling, you'll need backing on the top of the walls running parallel to the ceiling joist as a drywall nailer. You can use a variety of materials for this backing, depending on what's available on the site during this step.

You can often use up 2 × 4 culls for this by placing them tight, centered on top of the wall. Nail them securely, keeping in mind that the purpose of this backing is solely as a drywall nailer. Using 16d nails at 2 inches on center should be adequate. In addition to double 2 × 4s, you can center a single 2 × 6 or wider material over the wall. You can also substitute 1-by material for the 2-by materials.

Blocking for Fire or Draft Stops

Add fire blocking in any vertical space 10 feet or higher using framing material that matches the width of the wall. The simplest method in a 2 x 4 framed wall is to use 2 x 4s placed flat at the midpoint of the wall height. Chalk a line the length of the wall and stagger the blocks above and below the line to make nailing easier. Face nail the blocks through the studs with 16d nails, either hand nailed or shot. For larger areas, such as a chase, you can often use insulation as a draft stop.

Blocking for Bathtubs and Showers

Place blocking for bathtubs and showers along their top edge. Showers with tile enclosures also need blocking at the base where the tile backer meets the pan. The purpose of this blocking is to provide you with a firm edge for attaching drywall. This is especially important with the bathtub, as the blocking provides the additional support you need to prevent the grout from separating from the tile due to movement.

Blocking for Medicine Cabinets

For a standard small medicine cabinet, you only need two pieces of blocking. Place both pieces flat, with the top blocking 6 feet above the floor and the bottom piece 4 feet above floor level. The result should look like the framing for a small window.

Larger cabinets require special framing, with the sizing dependent on the size of medicine cabinet you're installing. For an opening larger than one stud space, treat it like a window opening. For interior nonbearing openings under 4 feet, a flat 2 × 4 usually makes an adequate top piece. (Check the requirements in your jurisdiction.) Size loadbearing walls based on the load in the same way as for a door or window opening. Keep in mind, it's the contractor's responsibility to confirm loads and structural questions with the project's designer.

Blocking for Hardware and Accessories

Place blocking for bathroom accessories such as towel bars and handicap grab bars just as you place blocking. To find the horizontal placement centerline, check the Bathroom Fixtures section for the standard hardware heights. Base lateral placements on the length of bar you're installing, as well as on specific location requirements. You should be able to find details for placement on the prepared plans. On smaller jobs or remodels, consult the client for the desired placement.

Install blocking for curtain rods in line with the bottom of the window header. If there's a question about the type or location of the curtains, use wider blocking.

You'll need to determine the type of toilet paper dispenser that you'll be installing before you place the blocking. Flush-mount dispensers require flush blocking and recessed dispensers require recessed blocking. For a recessed dispenser, simply place the 2-by blocking flush with the opposite side on 2 × 4 framed walls. You can also attach toilet paper dispensers directly to drywall with special clamps.

Drilling and Notching

After you've completed the framing, electrical and mechanical crews will install their systems. These installations involve drilling and notching the framing members. Most building departments conduct the framing inspection following the mechanical installation and inspections. It's important that these trades are familiar with drilling and notching procedures so that they don't damage structural framing members. The building codes for your area will specify acceptable drilling and notching sizes. Competent mechanical contractors will be familiar with the guidelines provided by the mechanical codes for your area.

For more information on related topics, see:

Bathroom Fixtures, page 43

Doors, page 223

Electrical Installation, page 269

Fireplaces and Chimneys, page 291

Framing Materials and Planning, page 363

Heating and Air Conditioning, page 379

Insulation, page 395

Plumbing, page 471

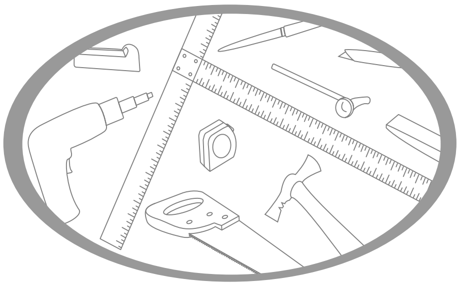
Porches and Decks, page 485

Windows and Skylights, page 747

Manhours

Manhours to Install Wall Framing, per LF of Wall

Item	Manhours	Suggested Crew
Plates, 2 × 4		
double top	.046	2 carpenters
single bottom, nailed	.023	2 carpenters
sill or bottom, bolted	.034	2 carpenters
Studs, 2 × 4, 16" oc	.267	2 carpenters
Blocking, 2 × 4	.034	1 carpenter
Bracing, 1 × 6, 16" oc	.051	1 carpenter
Headers or lintels, 4' wide, 4 × 6	.048	1 carpenter
Sheathing, plywood	.018	2 carpenters



Wallpaper

Wallpaper is a popular choice as a decorative wallcovering — and it's likely to remain popular because of the endless options it offers for personalizing a room. Wallpapering isn't difficult as long as the walls you're covering are adequately prepared and you have a few basic tools.

Every paint and decorating store has shelves of books with samples of every conceivable kind of wallcovering. Often, the wallcoverings have coordinated borders and fabrics that you can order. You can have matching trim and drapes or upholstery to give a room a "decorator" look.

As a rule, prepasted wallcoverings are easier to hang than the unpasted ones. Refer to the chart in Figure 1 for a guide to which of the more common wallcoverings might be best for you to work with.

In addition, you'll need the equipment listed in Figure 2.

Tools

You'll need very few specialized tools for wallpapering, and other than a sturdy ladder, they're all inexpensive:

- *Ladder*
- *Sharp scissors*
- *Wide taping knife*
- *Long straightedge or framing square*
- *Level or plumb bob*
- *Chalk*

Estimating Wallcoverings

Wallpaper is manufactured in dye lots, like carpet, so colors may vary considerably from one production run to another. Try to accurately estimate the amount you'll need, being generous on the number of rolls. If you run short, the rolls from a new batch may not match the old. Most stores will allow you to return extra rolls, but check before you buy. Special orders aren't always returnable.

A standard single roll of wallpaper runs 24 feet long and 18 inches wide, for a total of 36 square feet of material. Depending on the size of the area you'll be covering, you may want to buy it in double or triple rolls, which contain 72 or 108 square feet. Keep in mind that the pattern of the print will affect how much waste you'll have in a roll. You can easily match a small print or a random pattern; they have little, if any waste. A large print or drop pattern may result in a lot of waste. For instance, a wallcovering that has a drop pattern of 6 inches will waste 15 feet (almost half a roll of paper) just matching the pattern in a 10 × 12 foot room. The estimated waste per roll will be stated on the roll.

Type	Ease of Hanging	Notes
Standard	Easy	Will tear easily; hard to clean
Vinyl coated	Easy	Tougher than standard paper; can be wiped, but not scrubbed
Vinyl	Easy	Sturdy and scrubbable; must use adhesive with mildew retardant; requires vinyl-to-vinyl glue for overlapping
Foil; metallic	Difficult	Shows every bump and dip in the wall; hang only on flawless surfaces
Flocks	Washable, easy; nonwashable difficult	Washable flocks are easiest to clean; nonwashable difficult
Natural-look: grasscloth, hemp, cork, burlap, tule, etc.	Varies with type	Use lining paper
Embossed	Difficult	Some are designed to be painted; use a soft brush and cloth, rather than seam roller and smoothing brush, to avoid crushing design
Fabric	Difficult	Prepaste the wall and apply; use clear, nonstaining cellulose paste

Figure 1
Ease of application of common wallcoverings

Equipment:	Specialized Use:
Paste brush and bucket or short-handled paint roller and tray	For spreading the adhesive
Smoothing brush	For smoothing out air bubbles under the paper
Seam roller	For pressing and smoothing seams
Utility knife with new blades	For cutting the paper. Dull blades only tear paper; don't skimp
Water tray	For prepasted paper
Long table	To put the paper on when pasting
Sponge and bucket of warm water	To clean up excess paste

Figure 2
Wallpapering tools

To estimate the number of rolls you'll need, measure the perimeter of the room and multiply by the height of the ceiling. Deduct the square footage of large areas that you won't be covering, such as doors, windows, and bookcases. Divide your total by 36. This will give you the number of rolls you'll need. To be safe, add 15 to 20 percent for waste or one single roll, whichever is greater.

Preparing the Wall

Make sure wall or ceiling surfaces are clean and as free of imperfections as possible. If the wall has a rough surface or blemishes, you can hang a lining paper first to cover the flaws or even out the surface. For some types of wallpapers, such as grass cloth or foil, the manufacturer may recommend a lining paper because it will absorb excess moisture that may otherwise cause the wallpaper to separate from its backing. Lining paper is easy to hang; it doesn't have a pattern that you have to match. Hang it horizontally and leave a $^1/_8$-inch gap between seams.

Sealing

You need to seal the surface before hanging the paper. Even walls and ceilings that have previously been painted need to be sealed. Drywall and plaster can pull the moisture out of the paste, preventing the wallpaper from adhering to the surface.

Prepare the surface by washing it with TSP or a similar strong detergent. Rinse well, and when it's dry, apply a sealer or seal it with sizing. Sizing is a glue created specifically as a base for wallpaper. You can roll it on just like paint. Drywall that's been previously painted only needs the sizing. You'll need to seal bare wood with either a latex or alkyd sealer or shellac. If you're wallpapering with a vinyl or foil, use an alkyd sealer rather than latex because these papers don't adhere as well to latex. After the sealer is dry, apply a sizing just as you would for drywall.

Removing Old Wallpaper

The toughest walls to prepare are those that are already papered. If the paper is solidly on the wall, you may be able to just add a second layer. Before you paper over an existing wallcovering, reglue any loose spots and apply a coat of sizing. Sometimes, you can seal loose seams with a steam iron. Hold a damp, lint-free towel over the loose seam. Set the iron on a steam setting and place it over the towel to soften the adhesive. Press the seam into place.

If you have to strip the paper, how you do it depends on the type of adhesive that was used. Cellulose and wheat pastes are water-soluble. They're commonly used with corks, burlaps, grasscloths, fabrics, and strippable coverings. Vinyls and foils are usually applied with adhesive that's not water soluble. To soften the adhesive behind wallpapers, you may have to sand or score carefully through the top layer to allow the water or solvent to soak through.

Sometimes you can strip papers off easily by simply loosening a corner or top edge and pulling down. Remove the remaining paste by softening it with a sponge and warm water and scraping with a wide taping knife.

Other papers may be more stubborn, requiring a chemical solvent or an electric steamer to remove. You can sponge or spray chemical solvent directly onto wallpaper once it's sanded or scored. Otherwise, pull the paper back from the wall a little and spread the solvent where the paper meets the wall. Let the solvent sit for a bit to soften the adhesive, and then pull the paper downward. Repeat as necessary.

You can use electric steamers to soften adhesives, then pull off the loosened paper and scrape the adhesive from the wall. Steam a small area at a time. Use a taping knife to loosen the paper and to scrape away the old adhesive.

Stripping paper is a messy job. Be sure you cover the floor and furniture before you begin. Be especially careful with carpet because you can damage the binder in the carpet by soaking it with water or chemical solvent. It may cause the carpet to pull away from its backing.

Hanging the Paper

For small or random patterns, hang the first strip over or next to a door. For large patterns, you may want to find a focal point in the room and begin there, working out in both directions and ending over a doorway. Before you hang the first sheet, measure and mark where each strip will go, as shown in Figure 3. By doing this, you can anticipate problems and make any needed adjustments.

The longer the strip, the more difficult it is to hang, particularly if you're papering an old house with less than perfect walls. If at all possible, start with shorter pieces until you get a feel for it.

Basic Guidelines

1. Use a level or plumb line as your starting point and mark it with a pencil or snap a chalk line. (See Figure 4.) Place the paper's edge against this line rather than aligning it with the ceiling, which may not be level. Measure and cut the first strip of paper. Allow an extra inch or two at the top and at the bottom.

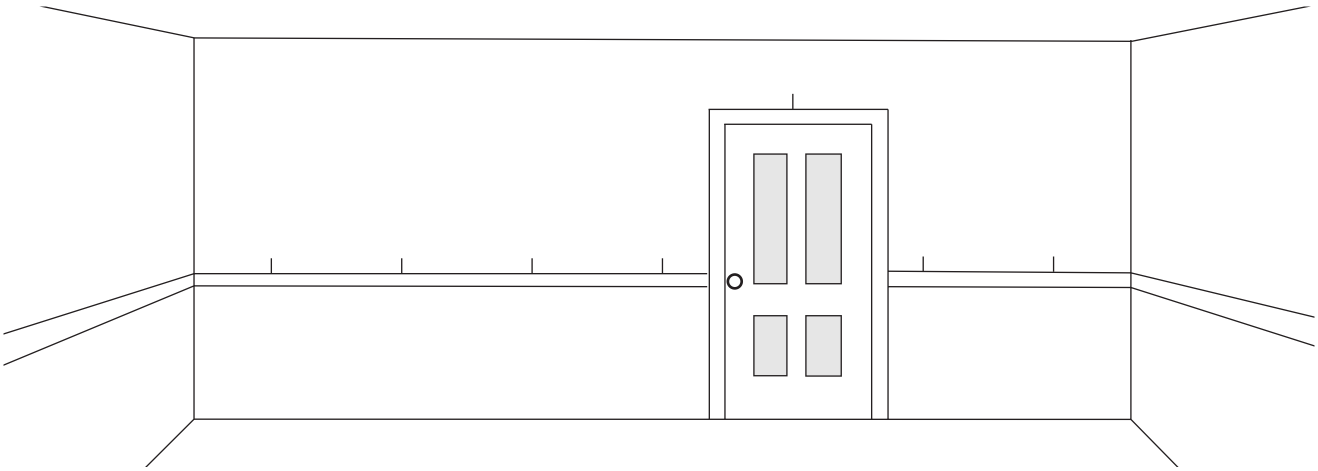


Figure 3
Mark wallpaper layout on wall

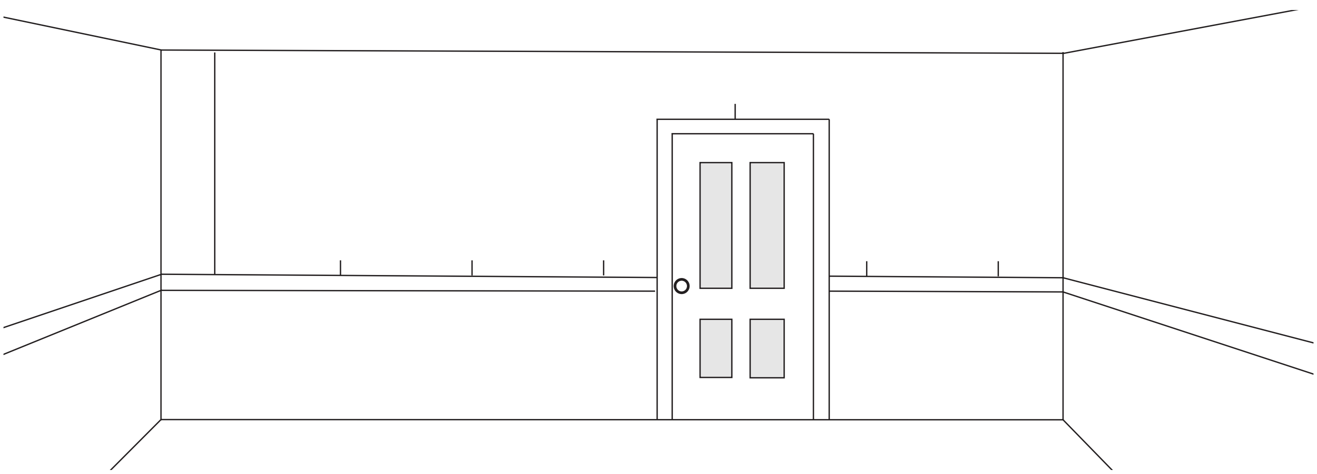


Figure 4
Use plumb line to align paper

2. Soak prepasted paper according to the manufacturer's directions, or apply paste to unpasted paper. Place the paper against the pencil line, adjusting as necessary. Crease the paper at the ceiling and baseboard.
3. Using the smoothing brush or a paint roller, gently stroke out bubbles and excess paste. Work from the center out, taking care not to stretch or wrinkle the paper. If the paper should wrinkle, lift it off the wall to that point and smooth it back in place.

4. Trim the excess paper with a sharp razor. Wet wallpaper is tough and has a tendency to tear if your blade is dull. Don't skimp on using fresh razor blades or you'll have rough, jagged edges that are hard to fix or hide.
5. Repeat this procedure with each strip. Manufacturers may suggest slightly overlapping seams with some kinds of wallcoverings. With most papers, though, you should butt the seams together, almost buckling them. As the moisture leaves the paper and the adhesive dries, the paper will shrink slightly, leaving a clean seam. Don't stretch the paper as you align it.
6. Allow the strips to dry for 10 or 15 minutes then use a seam roller to press the seams down. Wipe off any excess paste as you go.

Double-Cut Seams

This is a more complicated way to finish a seam. It's especially good for corners or patching or repairing damaged paper.

1. Hang the second strip of paper, overlapping seams with the first a couple of inches as shown in Figure 5.
2. Holding a metal straightedge against the paper, cut through both layers. Remove the cut piece from both wallpaper strips. Smooth the edges back down and after 10 or 15 minutes, seal with the seam roller.

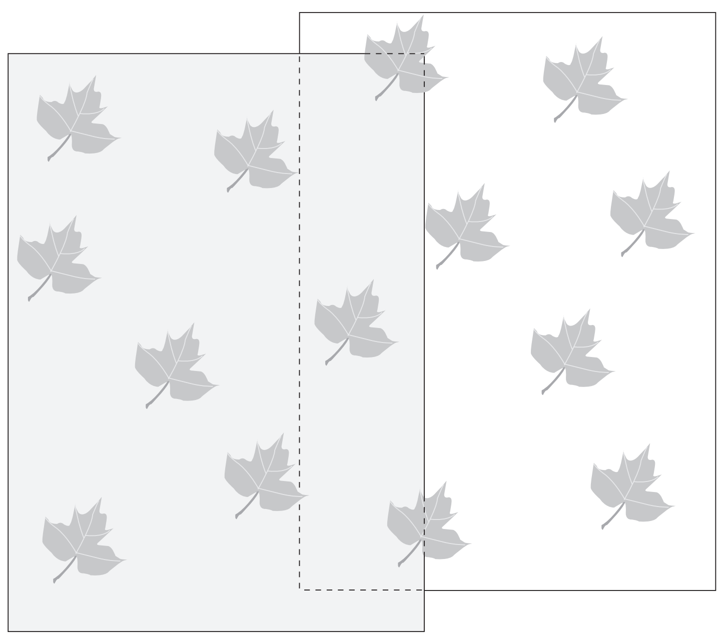


Figure 5
Overlap seams and cut through both layers

Inside Corners

1. Measure from the last strip to the corner, adding $^1/_2$ inch. Using a straightedge to ensure a straight cut, trim off the excess paper. Save the trim piece.
2. Hang the paper as described above, carefully pressing it into the corner.
3. Hang the saved piece, allowing it to overlap if necessary. If the walls aren't plumb or the corner is rough, you may need to cut a new piece the width of the saved piece, and hang that instead.

Outside Corners

Outside corners are usually easier than inside ones. For a smooth line, use a double-cut seam as described above.

Recessed Areas

1. Hang the paper over the area. Cut through the middle of it to within 1 inch of the side.
2. Cut up and down 1 inch from the side. At the top and bottom, cut diagonally into the side.
3. Press and smooth the flaps to the surface, trimming the longer ones as needed.
4. Cut a piece to fit the unpapered area. Paste, smooth, and seal as described above.

Trim and Cutouts

Use sharp scissors or a razor to cut diagonal lines back to where the paper is smoothed against the surface. Trim the excess paper from the molding.

For rectangular or square cutouts, cut an X almost to each corner and fold back or trim the excess, as shown in Figure 6. For round cutouts, use your scissors to cut a series of wedges, just like a pie, almost to the edge of your circle. Trim or fold back the excess.

Ceilings

Paper the ceiling before you do the walls. If you're papering both the walls and the ceilings, overlap the paper down the walls by $^1/_2$ inch. Otherwise, trim the excess where the wall and ceiling meet.

Ceilings are tricky to do without help. If you don't have a second person to hold up the excess paper, nail a piece of plywood to the top of a ladder to hold the paper as you work. If the pattern allows, paper the width rather than the length of the room. The shorter the pieces, the easier they are to handle. Booking the paper also makes it more manageable. To book the wallcovering, fold it like an accordion, with pasted sides together as shown in Figure 7.

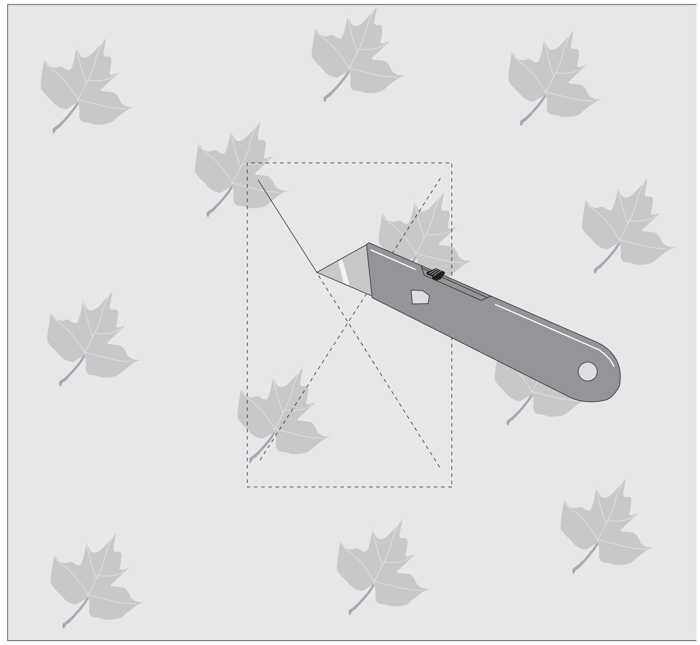


Figure 6a
Cut an x to each corner

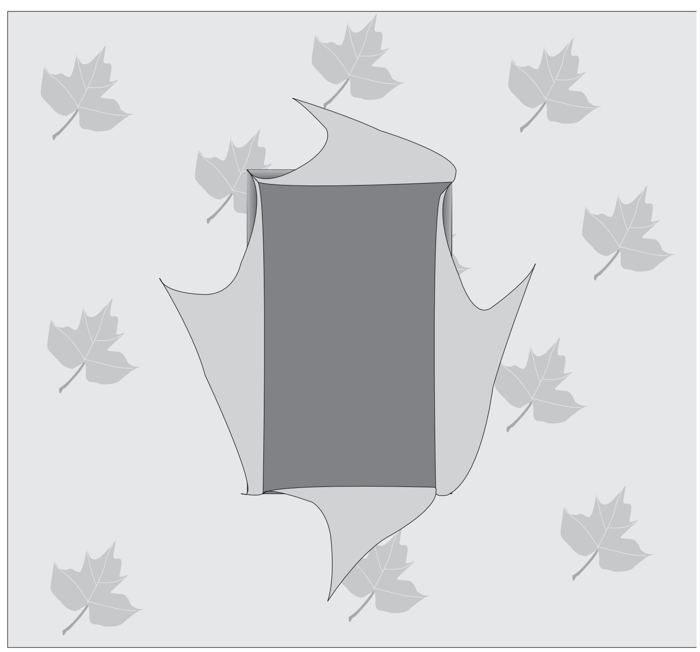


Figure 6b
Trim the excess to expose hole

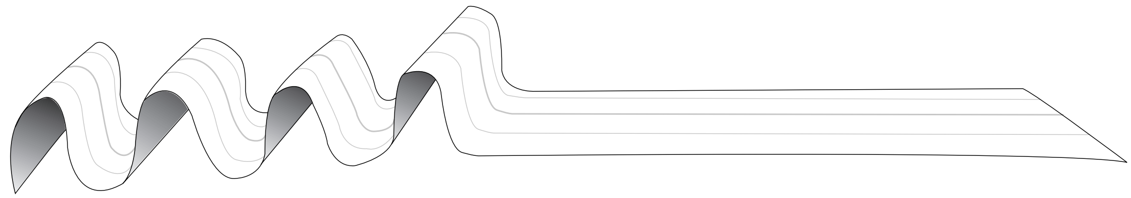


Figure 7
Booking wallpaper

Use the same papering procedures on the ceiling as you would for the walls, aligning and smoothing as you go, rather than hanging the entire sheet and then going back to straighten and smooth.

Manhours

Manhours to Install Wallpapering		
Item	**Manhours**	**Suggested Crew**
Wallpaper, residential, medium rooms, per 3 rolls (3 rolls = about 100 SF)	1.30	1 paperer
Borders (per 100 LF)	1.00	1 paperer
Surface preparation, typical (per 100 SF)	1.00	1 paperer
Ready mix adhesive application (per 100 SF)	.35	1 paperer

For information on related topics, see:

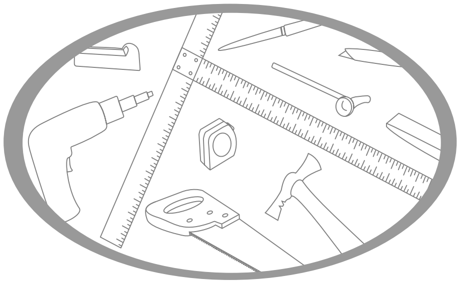
Adhesives, page 25

Drywall, page 241

Painting, page 427

Plaster, page 465

Trim, page 673



Windows and Skylights

We all want openings that let in light and fresh air when we want it, and keep cold air out when we don't. That's why we install windows and, less commonly, skylights. Skylights have much in common with windows and many window manufacturers include them as part of their line.

Windows

Most windows today are pretty good at controlling air movement in and out of buildings. The glass used to make the windows, however, is a poor insulator. That makes the glass area the best frontier for more efficient windows. While the perfect window has yet to be built, manufacturers are continually making gains through the use of new materials, new types of glazing, and new techniques.

The two primary parts of a window are the frame and the glass, and there are many options available for both.

Window Frames

Windows frames are made from wood, aluminum and vinyl, as well as aluminum-clad or vinyl-clad wood. A clad window has aluminum or vinyl covering the wood framing parts that are exposed to weather. The result is a window with the warmth and beauty of wood on the inside, combined with the maintenance-free qualities of aluminum or vinyl on the outside. Well-designed window frames are very efficient at controlling air infiltration and provide great weather resistance.

Window frames come in several different operating styles. Fixed units have a stationary glass that doesn't open. Operable windows are available in double-hung, awning, casement, and slider styles. Figure 1 shows a typical double-hung window. Figure 2 is a typical casement window.

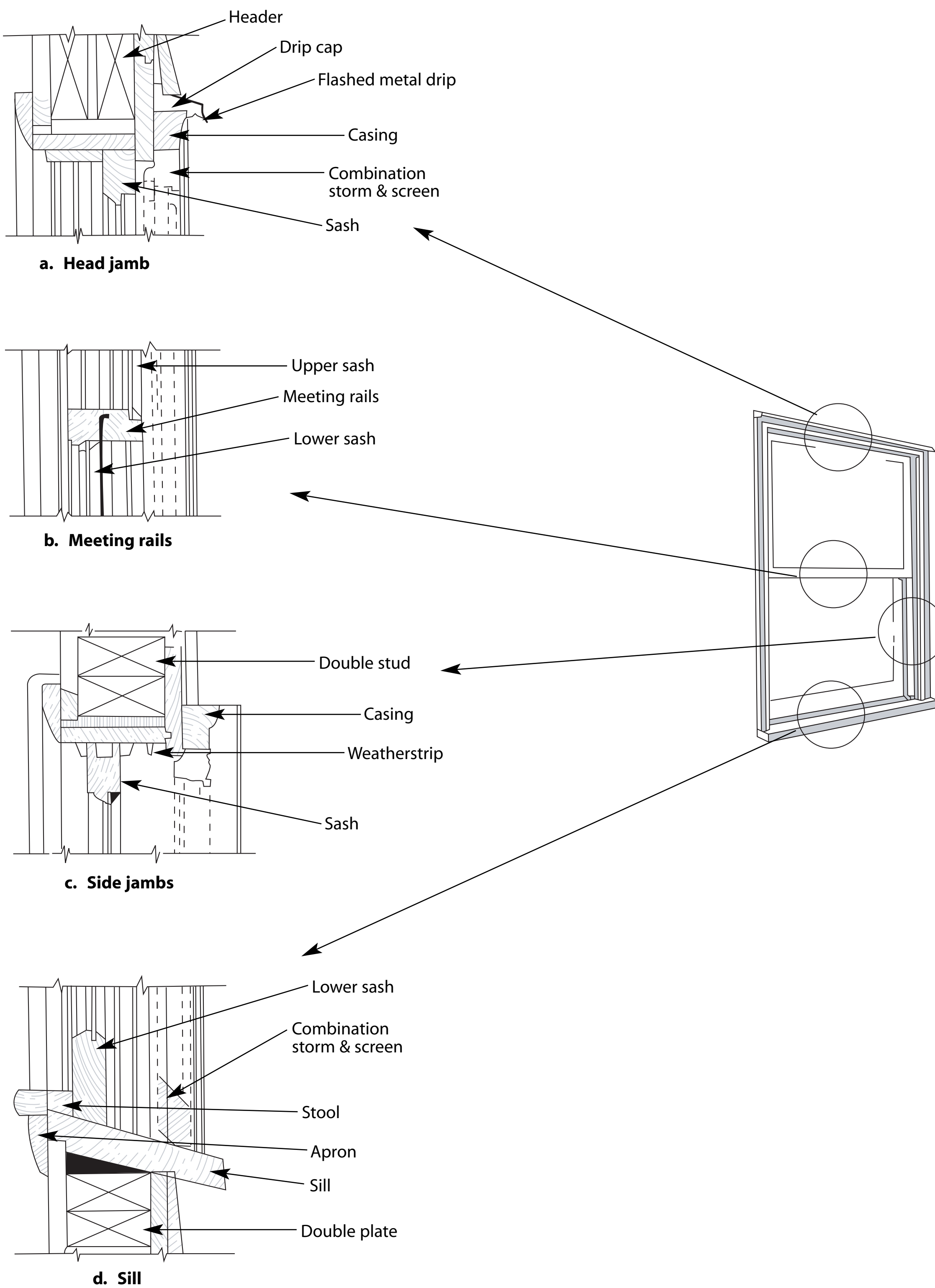


Figure 1
Double-hung window cross sections

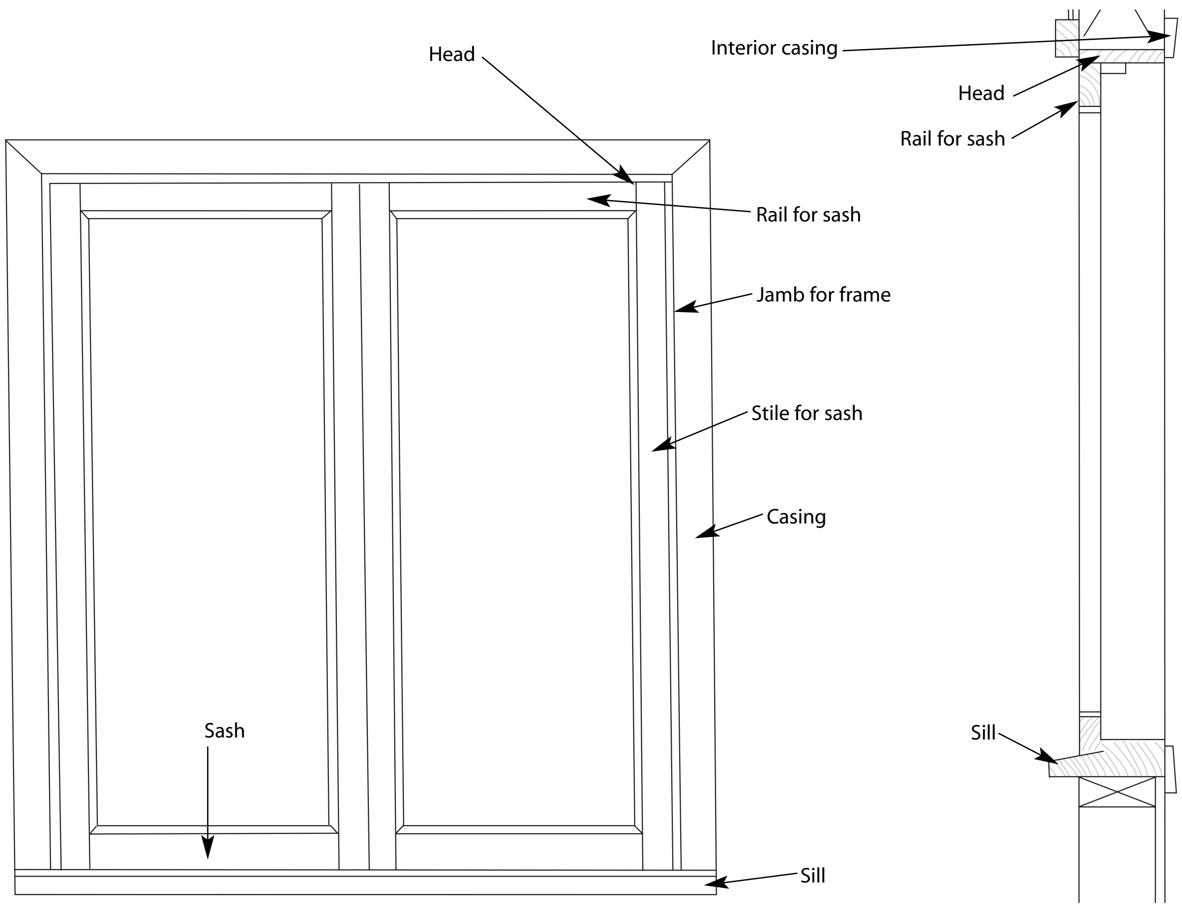


Figure 2
Typical wood casement window assembly

Glazing

When placed in a window frame, glass is called *glazing*. Window glazing is manufactured for a variety of special situations. For example, safety glass is required in windows near a doorway and in some skylights to prevent injuries caused by breaking glass. Depending on the requirements, safety glass may be either tempered or laminated.

- *Tempered* glass shatters into many small, but not sharp, pieces when it breaks. Automobile manufacturers use tempered glass for the side windows of cars.
- *Laminated* glass is made up of two thin sheets of glass with a vinyl-type material sandwiched between them. If a pane of laminated glass breaks, the glass is held together by the vinyl material and no glass falls out. Laminated glass is used for automobile windshields.

Wired glass is required in fire-rated doors. Wire embedded in the glass is visible in the windowpane.

Multiple Glazing

Glass is a poor insulator. One way manufacturers improve the insulating value of a window is by sandwiching multiple panes of glass in the window unit. Double-, triple-, or even quad-glazed windows are available. The dead air space between the layers increases the R-value of the window.

Low-E Coatings

Almost all manufacturers offer low-E coatings for windows. This is a reflective coating that's either on a plastic film between the glass panes or applied to the inside of one of the panes. Install the glass so the low-E coating is to the side of the window that you want to keep warm. That is, in cold climates where the interior of the house will be heated, the coating should be on the inner pane. In warm climates where you want the house cooled, the coating should be on the outer pane.

Argon Gas

Many manufacturers offer windows with argon gas in the dead space between glazings. Because argon gas is heavier and denser than air, it provides higher insulating values. Filling the dead air space with argon gas increases the thermal resistance of the window by one R-value.

Ordering Windows

Because of their many options, most windows aren't stock items. The lead time you need to order windows varies with the manufacturer. Check with the salesman or supplier for the lead time required for the windows you want.

There are many good windows on the market in most price ranges — but choosing a window sometimes involves compromising on either cost or quality. In general, metal windows are the least expensive, clad wood windows are the most expensive, and vinyl windows are somewhere in the middle. There's a gray area, however, when you may need to make a choice between using high-end metal windows and low-end wood windows. In that situation, you'll probably find that the high-end metal windows will outperform the low-end wood windows.

Once you've settled on a price range for the windows, compare the efficiency of the different types of window units to help you make your decision. The most important factor is the R-value of the glazing. Then determine the air infiltration rate; this indicates the tightness of the seal around the sash.

In metal windows, also look for the *thermal break*. Because metal is a good conductor of temperature, the thermal break prevents cold from being transmitted to the inside. The thermal break is usually a plastic strip dividing the metal frame.

Compare cost vs. value of the glazing that's offered. An energy-efficient window may include multiple panes, low-E coating, and argon gas all in one unit. But whether the owner will get a good return on the cost of such highly-efficient glazing depends on how extreme the climate conditions are in the region. In areas where there are extremes of hot and cold, the energy savings often offset the higher purchase price.

Confirm the window sizes with your supplier. Always give the width of the window before the height. For example, a 2-0 × 3-0 window is 24 inches wide and 36 inches high. You can combine window units into one large multiple unit. The manufacturer's catalog and supplier can help you with the designation for these units.

Window catalogs are arranged with a scaled line drawing of the window units offered. Listed with the window areas are the rough opening, frame size, and glass size required for the window. Because the rough openings for windows aren't standard, you must know *both* the window sizes and the window manufacturer before framing the building. That way you can install the windows after the window opening has been framed to the manufacturer's rough opening dimensions, the sheathing is on, and the roof is "dried-in."

Installing Windows

Tools and Materials

- *Hammer*
- *Level*
- *Pry bar*
- *8d finish nails*
- *10d galvanized casing nails or 2-inch galvanized roofing nails*
- *Shims*

Manufacturers supply windows for two types of installations. Traditional wood windows come with brick molding on the exterior. You install the window using 10d galvanized casing nails driven through the brick mold and into the trimmer studs, header, and rough sill. Metal and clad windows come with a nailing fin. It may be factory installed or you may need to install it on the job site. When you position the window, the nailing fin will be tight against the sheathing.

It takes at least two people to install a window; large windows require additional help. Secure the window by driving 2-inch roofing nails through the fin and sheathing, and into the trimmer, header and rough sill.

Use these guidelines for your installation:

1. Position one person on the outside of the window and the second (usually the helper) on the inside.
2. Place the window in the opening and have the helper on the inside center the window in the opening. Use a pry bar to gently slide the window into position.
3. From the outside, use a level to plumb and level the window. When it's in position, temporarily nail the window in place.
4. With the window nailed temporarily in place, open it and make sure it operates properly. Close the window and check the reveal. Make sure the distance between the sash and the frame is the same all around the perimeter for a good even reveal. You may encounter windows that can't be made both exactly plumb and level and still have a good reveal. Because it's more visually obvious, having an even reveal should be a higher priority than a perfect bubble on both plumb and level.

5. When you've adjusted the window so that it's level and operates properly, and has a good reveal between the sash and frame, nail it permanently in place.

Skylights and Skywindows

Like windows, skylights and operable skywindows may be framed in wood, vinyl or metal. While some skylights are glass, most come with Plexiglas domes. They're referred to as double-domed (double-glazed) or triple-domed (triple-glazed) skylights to indicate multiple glazing.

You can order Plexiglas domes in clear, white, or bronze tint. When you have multiple glazing, only one dome is white or tinted with the remaining dome or domes clear. You would order a double-domed skylight as bronze over clear, or clear over white to indicate how you want the domes positioned.

When skylights first gained popularity, the majority of installations were aluminum-framed curb-mounted double-domed units. High-quality clad-wood-framed operable units are now available from manufacturers such as Velux and Wasco, as well as many other window manufacturers. Most of these have factory-supplied flashing kits included as part of the package.

Skylight Installation

Because of the possibility of structural alterations, most jurisdictions require a building permit before you can install a skylight. You may be required to provide a drawing showing the location of the skylight and any proposed structural alterations to obtain the permit. Never locate skylights where they'll affect trusses. You can't cut or alter a truss without voiding the engineering.

Factory-built skylight units come with detailed installation instructions specific to the individual units. Follow their instructions, with one possible exception. If they provide or recommend strip flashing for the sides of the unit, consider using step flashing instead for a tighter roof seal. Depending on the size of the unit, you may need from one to several installers for a skylight installation.

When you install a skylight in anything but a flat roof or a vaulted ceiling, you need to build a light shaft as well. Figure 3 shows how to frame the shaft. You can build a shaft to fit most situations and create a variety of effects. Shafts plumbed straight down work well in small areas like bathrooms. You can bring more light into larger areas by angling the shaft (Figure 4).

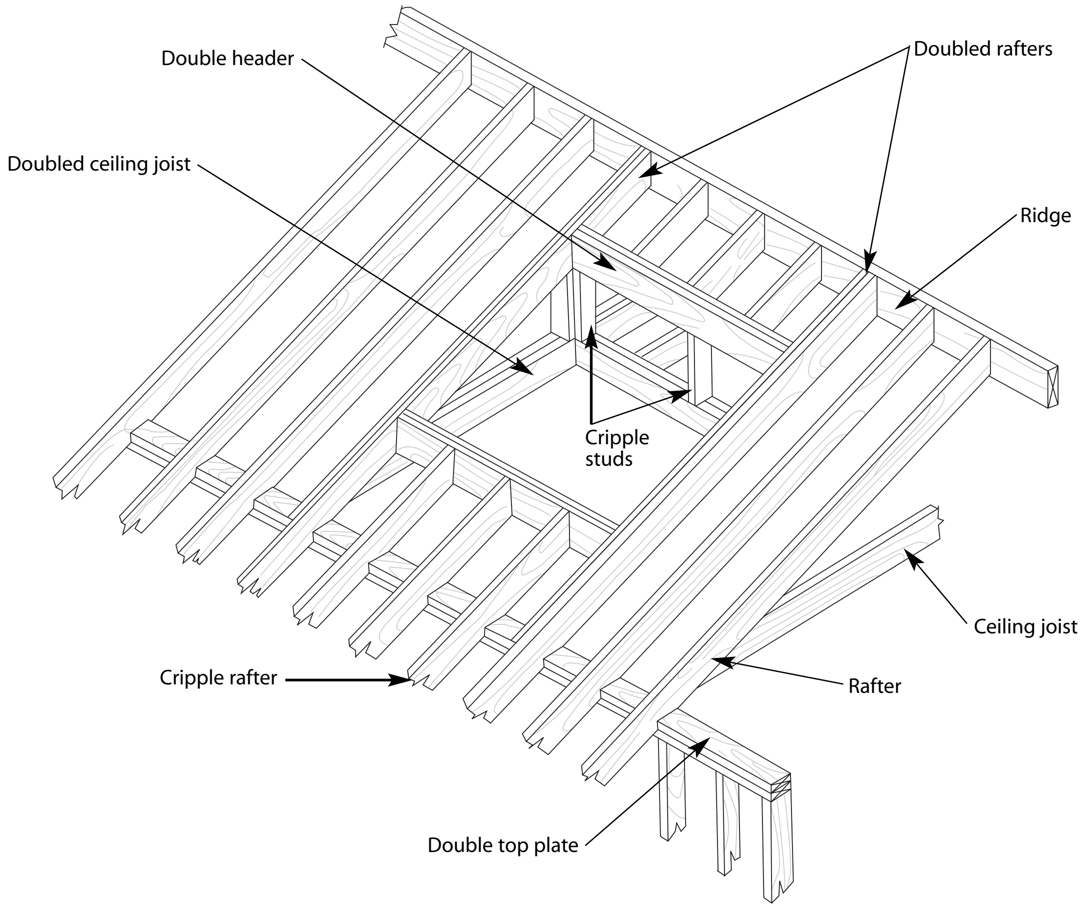


Figure 3
Framing at skylight opening

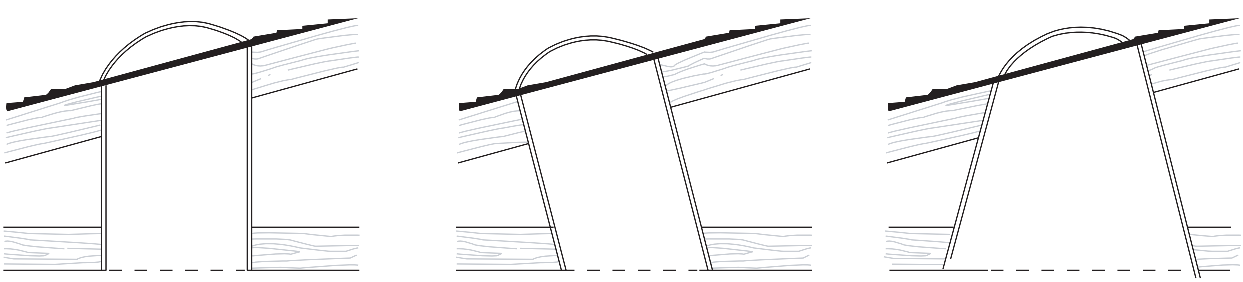


Figure 4
Shafts control light direction

Curb-Mounted Skylights

Curb-mount skylights are supplied with rough framing dimensions for the curb. Figure 5 shows a typical curb-mount installation. Most are sized so that the width matches trusses set at 24 inches on center. You can build the curb on the ground to the specified dimensions, normally out of 2 × 6 material, then install it on the roof. Use the following guidelines to install a curb-mounted skylight:

1. Locate the rafters or trusses, then mark the curb location on the roof. You can do this by placing the curb in position, squaring it, and tracing the inside onto the roof.
2. With the location marked, and rafter or truss locations noted, cut out the skylight area.
3. Place the curb in position over the hole. Square and toenail the curb into place using 16d nails.
4. Place a silicone bedding on the top of the curb and set the skylight in place.
5. From the inside, secure the skylight to the curb with pan-head screws. Most manufacturers provide predrilled holes for the screws.

Tools and Materials

For the curb:

- *Circular saw*
- *Reciprocal saw*
- *Framing square*
- *Hammer*
- *16d nails*

For the skylight:

- *Phillips pan-head screws*
- *Silicone caulk*
- *Cordless drill with a Phillips head attachment*

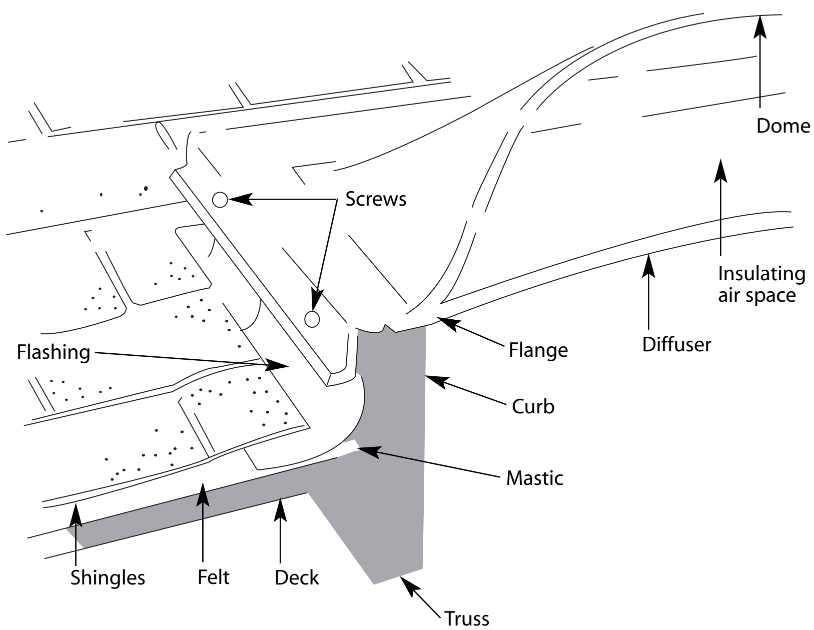


Figure 5
Curb mount

Skylight Flashing

Although you may hear people say that all skylights leak sooner or later, it isn't true. If a skylight is properly installed, using step flashing, you'll have a leak-proof skylight.

Companies such as Velux supply step-flashing kits for their units. If you're using a less expensive curb-mount skylight, you can build your own step flashing using galvanized or baked-enamel flashing. One of the keys to a leak-proof skylight is using a wide enough piece of head flashing, and *never* placing nails through it. If the head flashing is too narrow, water will back up against the skylight and leak or siphon back under the shingles and over the flashing. And, it should be pretty obvious what happens if you place a nail through the head flashing: It will leak!

If you install a skylight without step flashing and it leaks after the first rain, you'll have a very angry customer and a diminished reputation. Even if it takes a little longer, it's better to install your skylights right, using step flashing, and ensure a good job.

Curb-Mounted Aluminum-Framed Skylights

When installing a double-domed aluminum-framed skylight, you'll need to build the wood curb to place the skylight frame on — and in many cases you'll have to make your own flashing.

Even if the manufacturer provides some flashing, don't be fooled into thinking that the skylight has all the flashing you'll need. Some aluminum skylight manufacturers include a flashing kit with a top piece, a bottom piece, and continuous 4 × 4 pieces of flashing for the sides. Other skylights may have their own flashing already attached. It usually consists of 4 × 4 flashing around a curb that's ready to set on your roof opening. It looks really simple. And, as far as installation goes, it probably is. However, if you're concerned about a long-term happy customer, you should include step flashing in your installation.

Installation Guidelines

Step flashing consists of a top piece, a bottom piece, and a series of 10-inch 4 × 4 side pieces. You have a side piece for each row of shingles, and these are "stepped" up the side of the skylight, while being woven into the rows of roof shingles. The process of weaving and layering the flashing pieces into the shingle layers is what creates a leak-proof skylight. Use the following steps (illustrated in Figure 6) to make and install your own step flashing.

1. Follow the manufacturer's instructions for building and setting the wood curb required for the skylight.
2. Cut 10-inch step flashing from 4 × 4 galvanized metal.
3. Build a top and bottom piece from a galvanized metal sheet. The sheet should be 24 inches wide and 8 inches longer than the width of the skylight. This will leave a 4-inch extension on each

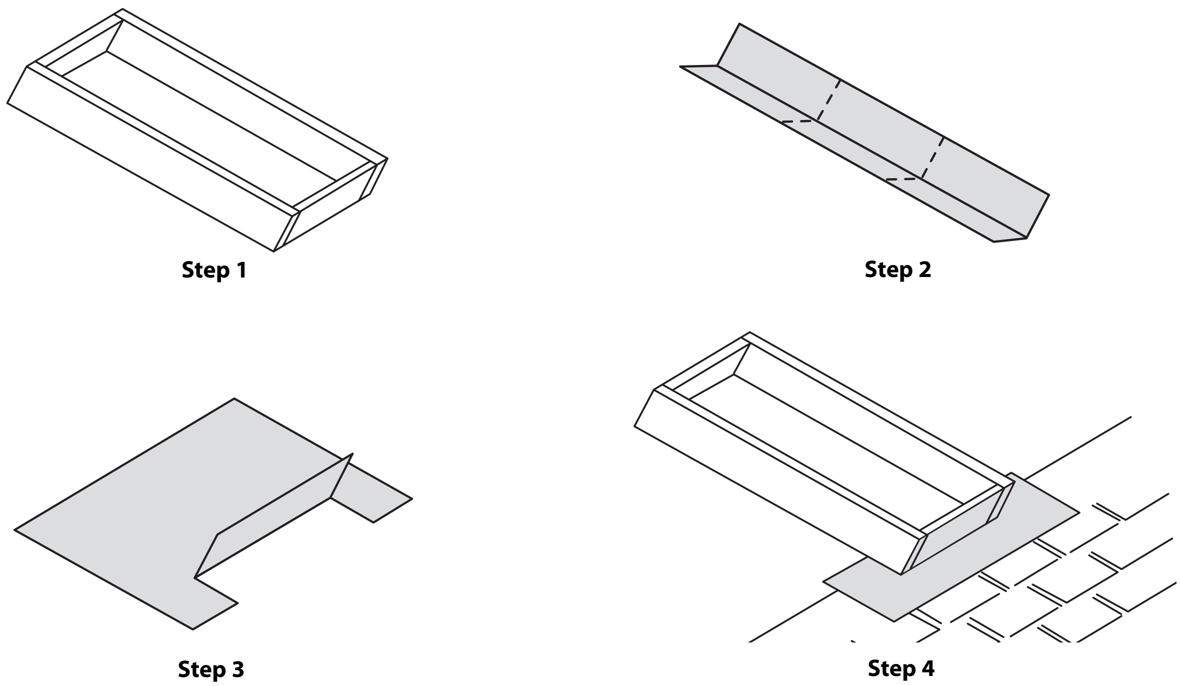


Figure 6
Installing step flashing

side of the wood curb. Measure 4 inches from each end and cut in 4 inches deep. Fold the notched section up.

4. Shingle up to the bottom of the curb. In a continuous 4 × 4 piece, notch the metal in 4 inches at the points where the metal meets the corners of the wood curb. Lay the piece across the bottom of the curb, on top of the shingles. Where you've notched the metal, lay the metal flat.
5. Take a 10-inch flashing piece and cut along the fold 4 inches in. Place this piece along the side of the wood curb. Fold the metal back flat against the bottom side of the curb so that the metal wraps the corner of the curb. Repeat this step with the next row of shingles.
6. Place the next piece of step flashing along the side of the wood curb. It should be positioned so that it's even with where you'll start the next row of shingles. Install the row of shingles. Place the next flashing piece; again, it should be at the point where you'll start of the next row of shingles. Install the next row of shingles. Continue on until you reach the top of the curb. If you place it correctly, the flashing won't show on the roof beside the curb. The metal will, of course, show on the curb itself.

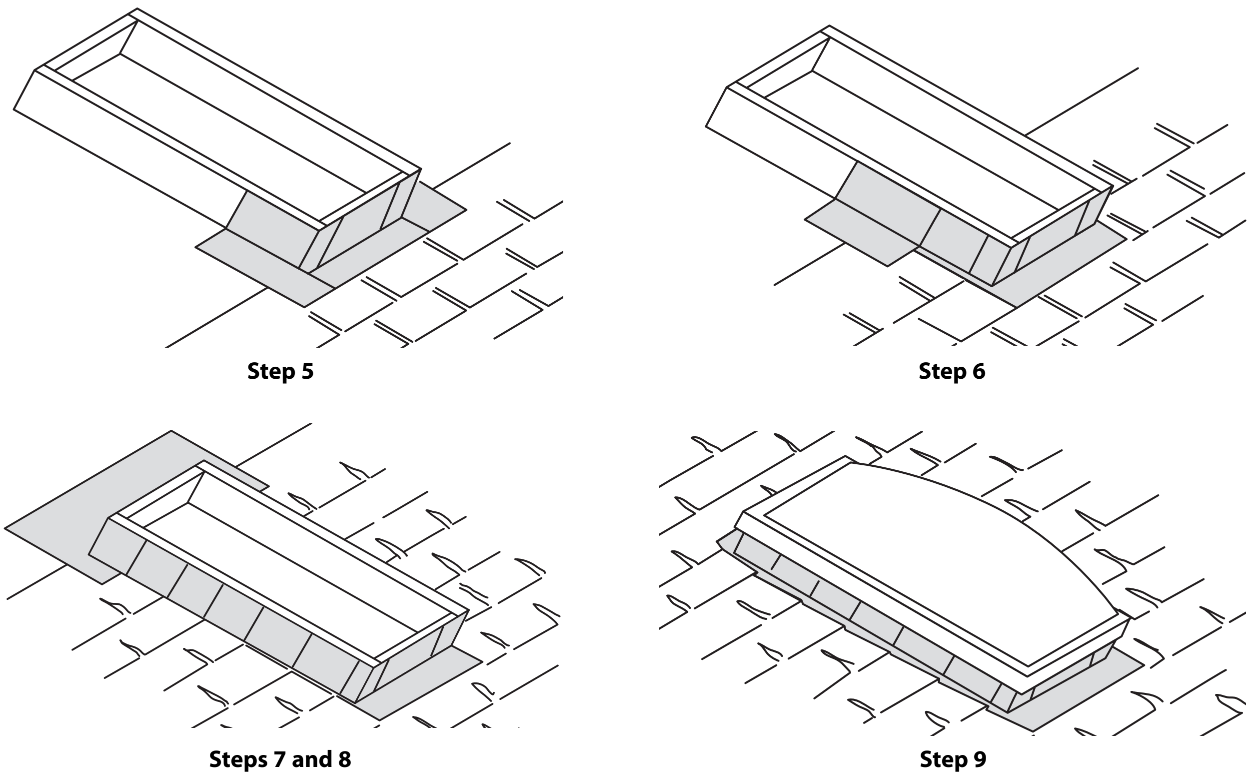


Figure 6
Installing step flashing

7. Flash the top of the skylight just like you did the bottom. When you get to the last piece of side flashing, take a 10-inch flashing piece and cut along the fold 4 inches in. Place this piece along the side of the wood curb. Fold the metal back flat against the top side of the curb so that the metal wraps the corner of the curb.
8. Next, lay the head piece at the top of the curb. Use asphalt tab stick to place any asphalt shingle rows that go over the metal. Don't use nails to fasten through the metal until you're at least 10 to 12 inches from the top of the curb. Because wood shingles are longer, you can nail through them at points where they extend more than 10 inches from the top of the curb.
9. Place the skylight on the curb as instructed by the manufacturer.

Tubular Skylights

Relatively new on the scene, tubular skylights add light to a room without requiring any major roof construction. They're designed to fit between rafters 16 inches on center, and the flexible reflective tubes bend to reach the ceiling at the preferred spot. Solatube and Sun Tunnel are two of the manufacturers you can contact for more information.

Manhours

Manhours to Install Windows, per each		
Item	**Manhours**	**Suggested Crew**
Wood casement, 36" × 48"	3.00	1 carpenter, 1 laborer
Wood double-hung, 36" × 48"	2.00	1 carpenter, 1 laborer
Aluminum slider, 36" × 48"	3.00	1 carpenter, 1 laborer
Add for time required to adjust the rough opening, and to install the window trim.		

Manhours to Install Skylight, per unit		
Item	**Manhours**	**Suggested Crew**
Single polycarbonate dome, curb mount, 30" × 30"	4.30	1 carpenter
Operable skylight, 30 5/8" × 38 1/2"	5.70	1 carpenter
Acrylic double dome with molded edge, ventilating, 30" × 30"	3.45	1 carpenter
Skywindow, fixed, self-flashing, 30 1/2" × 30 1/2"	1.30	1 carpenter

For information on related topics, see:

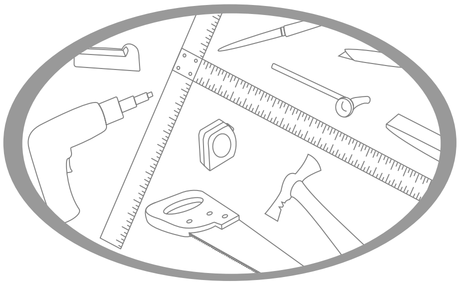
Framing Materials and Planning, page 363

Insulation, page 395

Roof Framing, page 513

Ventilation, page 701

Wall Framing, page 709



Wood Flooring

Wood floors have some important advantages. First, their beautiful simplicity adds natural warmth to any room. Second, when properly maintained, they last and last and last. There are castles in Europe that still have their original oak parquet floors, while their stone steps have depressions worn during centuries of use. Even old wood floors that have been neglected and abused can be rejuvenated with sanding and refinishing. And a final advantage of wood floors is that wood is a natural insulator. The insulating quality of a single inch of wood equals as much as 15 inches of concrete.

Beware of Moisture

Although wood flooring is durable and easy to care for, it does have one enemy: moisture. In fact, when failures such as cracks, movement, cupping, or buckling occur, they're probably related to changes in the moisture content of the flooring or surrounding materials (Figure 1).

Wood swells and shrinks as it absorbs and loses moisture. In the absence of moisture, wood will shrink to 0 percent moisture content, an oven-dry state. As dry wood absorbs moisture, it swells until it reaches 25 to 30 percent moisture content, or the fiber saturation point for wood.

How much expansion and contraction does this mean? Along the grain, the change is minimal, less than 0.1 percent. But for plain-sawed wood, it can mean as much swelling as $^{11}/_{64}$ inch in a typical $2^{1}/_{4}$-inch flooring strip.

This can happen from direct contact with moisture or even from the humidity in the air. When the humidity is 5 percent, wood has a moisture content of less than 2 percent. As the humidity rises to 98 percent, wood reaches a saturation point of over 25 percent.

Because wood flooring is manufactured at a 6 to 9 percent moisture content, it can swell or shrink depending on its final destination. For instance, wood in Nevada acclimates in a range from a winter low of 4 percent, to a summer high of 7 percent moisture content. Wood in coastal areas typically acclimates to an average 13 percent moisture content in the summer. Short term, day-to-day changes in humidity tend to affect only the wood surface; long term, seasonal changes are gradual enough that the expansion and contraction are slow.

In addition to humidity in the air, houses sometimes have poor exterior drainage, as evidenced by wet soil. Wet soil is defined as dirt that forms a firm ball when squeezed. A thousand square feet of wet soil can evaporate off as much as 20 gallons of water daily. If there's actually standing water, the evaporation — and resulting swelling in adjacent wood flooring — increases.

As the wood expands, the process can crush the wood's fiber. This results in *compression set*. The damaged fiber can't repair itself, and as the wood dries out and contracts, cracks eventually result.

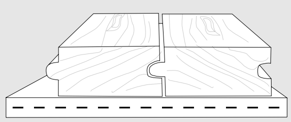
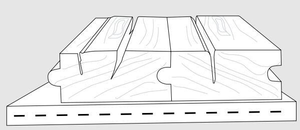
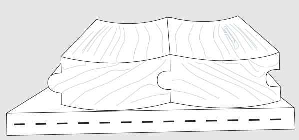
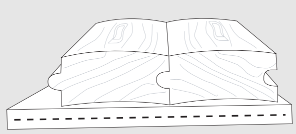
 **Cracks between floorboards**	These cracks most often reflect the swelling and shrinking in wood caused by moisture. Spaces that range in thickness from the width of a sheet of paper to the width a dime are normal and can be expected. Larger cracks, or those that don't disappear as the humidity rises, may be due to another problem.
 **Cracks or splits within the wood**	Very small minor cracks are part of the natural beauty of wood. Some finishes, such as bleach or white or pastel stains, will make them more obvious. Larger cracks within the wood may reflect a lower quality or grade of wood.
 **Cupped floorboards**	Excess moisture from below the surface can cause the wood to expand. The sealed surface prevents the moisture from evaporating, forcing up the edges. You can expect a certain amount of cupping with plank flooring and plain-sawed wood.
 **Crowned floor boards**	Edges are lower than the centers due to sanding cupped floors before wood is completely dry.

Figure 1
Wood flooring moisture problems

Preventing Moisture Damage

There are a few steps you can take to reduce or prevent the problems caused by moisture, both during construction and after installation.

Supplier, Delivery and Storage

When you order the flooring, add an extra 5 to 10 percent in all the grades to allow for waste. Buy only from a reputable flooring supplier who conscientiously protects the stock from moisture exposure and has a steady turnover in stock. The stock should be stored a minimum of three to six weeks prior to delivery so it can acclimate to the area.

Make sure the material is never delivered unprotected in rain, sleet, or snow. Don't schedule delivery until the windows and doors have been set and hung, the plaster or drywall finished, the rooms painted, and the trim in place. Otherwise, the wood will absorb excess moisture from these items. Keep the house or building heated. Ideally, three weeks before delivery, the temperature of the building should be set to between 65 to 75 degrees to further drive out excess moisture. Open the flooring bundles and spread out the pieces so each is exposed to the air. Allow the wood to acclimate on site for at least four to five days. Don't allow the indoor temperatures to drop below about 70 degrees in the winter or 62 to 65 degrees in the summer. Also avoid overheating.

Concrete Slabs

Never install wood flooring directly over concrete below grade. On grade, concrete slabs must have a vapor barrier between the soil and concrete. Test the concrete for moisture and prepare the subfloor as explained under Flooring. Crawl spaces must have good cross ventilation. Use 4 to 6 mil polyethylene film for a vapor barrier. Never pour additional interior concrete after the wood flooring has been delivered. Concrete cures by evaporation. The flooring will absorb the gallons of water that evaporate out of the concrete.

Wood Subfloors

Use $^5/_8$-inch or thicker plywood or $^3/_4$- × 6-inch boards laid diagonally across joists spaced 16 inches on center. Don't use nonveneered panel products. Shim where necessary to make the floor level. Thoroughly sweep the subfloor. Lay 15- or 30-pound asphalt felt, three-ply resin paper, or building paper, lapping the seams by 4 inches, to reduce squeaks, dust, and moisture creeping into the flooring.

After Installation

Keep the floors clean and well sealed, either with wax or polyurethane. Polyurethane can tolerate a damp mop, but don't even use a damp mop on waxed floors.

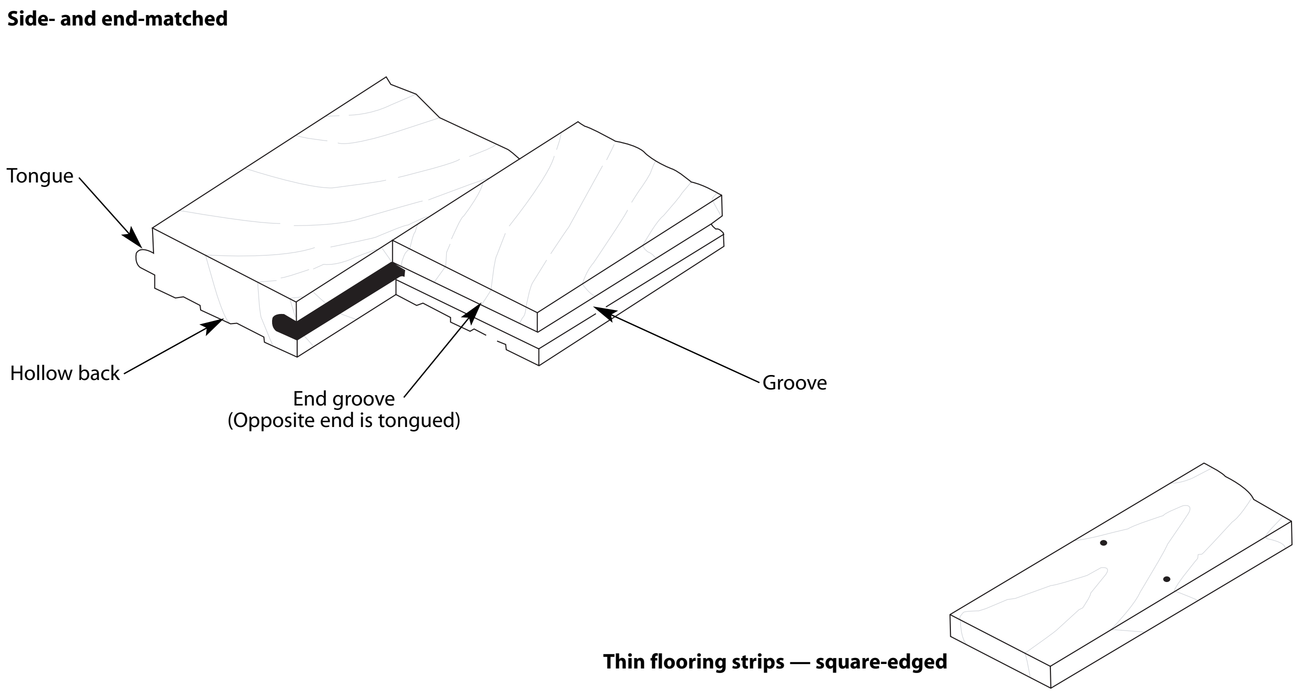


Figure 2
Types of strip flooring

Types and Grades of Flooring

If it's a tree, it's probably been made into flooring at some time or another. Although the majority of today's wood flooring is made of standard hardwoods such as oak or maple, countless other varieties are available. Cherry, pine, pecan and walnut are among the more popular. Less common are unusual woods such as mesquite, rosewood, and even hemlock. You can get really exotic woods (like rubea, esbea, or kambala) by special order from a surprising number of suppliers.

Regardless of the kind of wood used, the types of flooring generally fall into three categories:

- *Strip flooring*: This comes in strips ranging from $1\frac{1}{2}$ to $2\frac{1}{4}$ inches wide and in random lengths of 15 inches or more. It fits together with tongue and groove (T&G) edging, both on the sides and at the ends. *Shorts*, which run 9 to 18 inches long, are treated like strip flooring, even though the end effect may be visually different. See Figure 2.
- *Planks*: Planks are wider than strip flooring, between 3 to 8 inches, often have beveled edges, and may have countersunk holes that you plug with wood. These are designed to simulate the original wooden pegs that once fastened plank flooring to

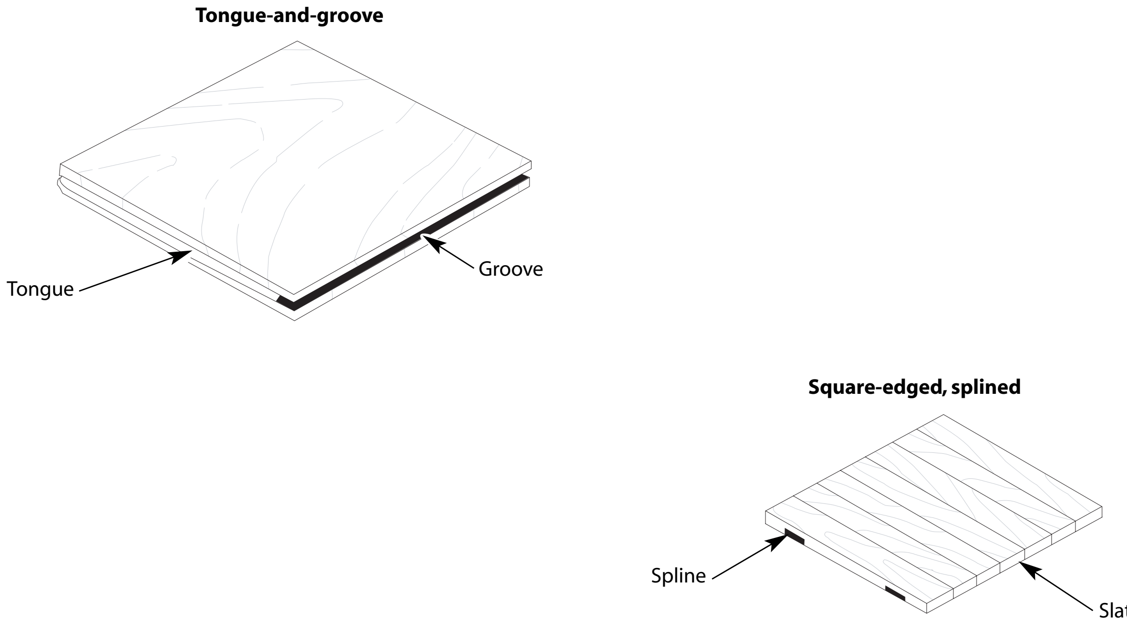


Figure 3
Wood block flooring

the subfloor. Plank flooring may also be put together by tongue and groove.

- *Unit blocks*: These blocks come in countless parquet designs: fingerblock, herringbone, ashlar, and whatever other creative combinations flooring manufacturers put together. Unit blocks may be either tongue and groove or straight edge (Figure 3).

Wood flooring is graded according to its appearance, rather than its strength or other qualities. Regardless of what it looks like, all grades will be uniformly strong since the strength comes from the interlocking tongues and grooves.

Each type of wood has a different grading system. A grade may include higher grades, but not lower quality grades. For example, No. 1 Common and Better Shorts in unfinished oak may include No. 1 Common Select and Better, but not No. 2. Grades are sometimes combined but they're always identified as such. Notice, too, that the average length decreases with lower quality grades. Figure 4 explains the grades of common flooring.

Laminate Flooring

There are several brands of laminate flooring on the market, including Pergo. These floors give the appearance of wood, although they're manufactured from laminates with wood-grain prints and

Wood	Appearance	Bundle Includes Lengths:
Oak, unfinished Clear	Generally free of defects, although it may have some burls, streaks, and pinworm holes	$1^1/_4$' and up, with an average of $3^3/_4$'
Select	Almost clear, but will contain more knots and other marks than clear	$1^1/_4$' and up, with an average of $3^1/_4$'
No. 1 Common	More markings than either of the other two; may need to have imperfections filled and finished to be serviceable	$1^1/_4$' and up, with an average of $2^3/_4$'
No. 2 Common	More markings than Clear or Select; may need to have imperfections filled and finished to be serviceable	$1^1/_4$' and up, with an average of $2^1/_4$'
Oak, prefinished Prime	Excellent appearance with few knots or flaws	$1^1/_4$' and up, with an average of $3^1/_2$'
Standard	Varying appearance, varying sound-wood characteristics	$1^1/_4$' and up, with average of 3'
Tavern	More markings, contains knots, burls, pinworm holes	$1^1/_4$' and up, with average of 3'
Hard maple, beech & birch, unfinished First	Best appearance, least color variation and character marks	2' and up, with 2' to 3' lengths 33% of footage
Second	Variegated appearance, varying sound-wood characteristics of species	2' and up, with 2' to 3' lengths 45% of footage
Third	More markings than either of the other two; may need to have imperfections filled and finished to be serviceable	$1^1/_4$' and up, with $1^1/_4$' to 3' lengths 65% of footage

Figure 4
Grades of common wood flooring

tough coatings to provide shine and protection for the flooring. They're also relatively easy to install with glue — no nailing. Just use the flooring, accessories and glue from the same manufacturer, and follow their detailed installation instructions.

Installing Wood Flooring

Installation procedures vary, so always follow the manufacturer's specific guidelines for the material you're using. But whether you're installing strips, planks or unit blocks, there are some general rules that you should know. Don't install wood floors on damp, rainy days. Make sure the building is heated, even at night, while you're laying the floor to keep the relative humidity low. Once the wood has even a single coat of finish, the moisture absorption slows considerably.

Precautions

You need to take precautions to prevent damage from moisture, heating systems or other forms of radiant heat in the building, as well as from more obvious sources during construction.

Heating Systems

Always find out if there's a radiant heating system in the concrete slab, especially if you're installing wood flooring in an older home. Old radiant heating systems run at around 120 to 150 degrees, while the new ones average 80 to 100 degrees. Some mastics aren't suitable even at this lower temperature, so make sure you check the manufacturer's specifications. Also, some flooring manufacturers don't recommend installing their products over any radiant-heated slab. Check it out before you commit to a job.

In new construction with radiant-heated slabs, turn on the heating system to dry out the concrete at least 48 hours prior to having the flooring delivered. Install plywood subfloor or sleepers, but don't use nails or power fasteners. They could accidentally puncture the pipes and damage the heating system.

Lay an extra layer of paper or felt over areas above a furnace or uninsulated heating ducts. Otherwise, the heat will dry out the floor finish.

Existing Wood Floors

Before laying a new floor over an existing wood floor, secure any loose boards, nail down raised heads, and replace cupped or crowned flooring. Remove all existing trim, including thresholds, which will interfere with laying the floor. (Use a pry bar and leverage it against a piece of scrap wood to protect the wall.) Clean the surface thoroughly, but don't wet it all. Cover the existing floor with asphalt felt or building paper. Install the new floor at a 45- or 90-degree angle to the old one.

Layout

Accuracy is essential here, which is why a good flooring installer may spend up to a third of his time planning the layout. Be absolutely meticulous in measuring and snapping the lines. Otherwise, small errors will grow as you lay the floor, causing glaring misalignments by the time you've finished the room.

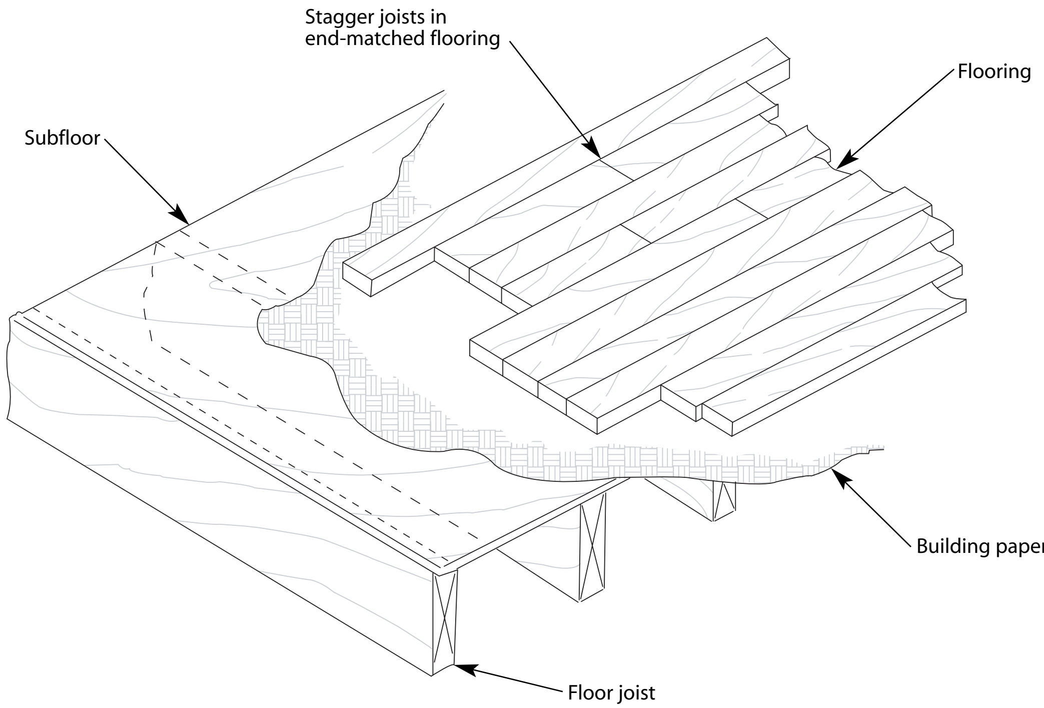


Figure 5
Applying strip floor

Planks and Strips

Plank and strip flooring will look and perform better if they're laid lengthwise with the room, which should be crosswise to the joists (Figure 5). If they're laid lengthwise with the joists, use a thicker subfloor.

Don't use the walls as a guide for your layout because they're rarely perfectly true. (Fortunately, though, you can camouflage small inaccuracies.) Instead, snap a chalk line from $^1/_2$ to $^5/_8$ inch from the starter wall (the longest, most visible wall), starting at least 3 to 6 inches away from corners. You'll use this space for expansion, covering it later with the shoe molding. End walls will also need a little space for expansion, about $^1/_2$ inch on each end. Snap a second chalk line $^1/_2$ to $^5/_8$ inch from the opposite wall in the same manner. Measure the distance between the two lines in several places. If the lines are more than $^1/_2$ inch out of parallel, you'll have to allow for this variation and distribute the error to both sides of the room.

If you use sleepers without plywood, you can't snap a trustworthy chalk line on the polyethylene. Instead, stretch lines between nails for the base line and test line.

Block Units

You can lay out block units square with the walls or at a 45-degree angle to the walls. For units square with the walls, begin by finding the center of the focal point of the room. The focal point is usually the entry door, but it could be something like a fireplace or window. Snap a chalk line exactly the length of four or five block units to the left or right of the focal point, still allowing a $^1/_2$- to $^5/_8$-inch expansion space at the walls. This is the base line. Find the center point of this line and snap a line that intersects it at a 90-degree angle. The second line is the test line. This intersection of lines is the base line for laying the blocks. To test for straightness, measure 3 feet in one direction from where the lines intersect and 4 feet in the other direction. The two points on the angled line should be exactly 5 feet.

The base line for blocks set at a 45-degree angle begins the same way. From the point where the lines intersect, measure 4 feet in each direction. Mark these points A, B, C, and D. Find the center points between each point, and draw lines that connect the center points, intersecting line A-C and line B-D, to form an X (Figure 6). Use these lines as the new base line.

Fitting Around Obstacles

To fit pieces around obstacles such as doorway or trim pieces, you can use a compass or a paper template. If you're using a compass, place the board you need to cut up against the obstacle. With the compass point against the obstacle and the pencil on the board, trace the line onto the board.

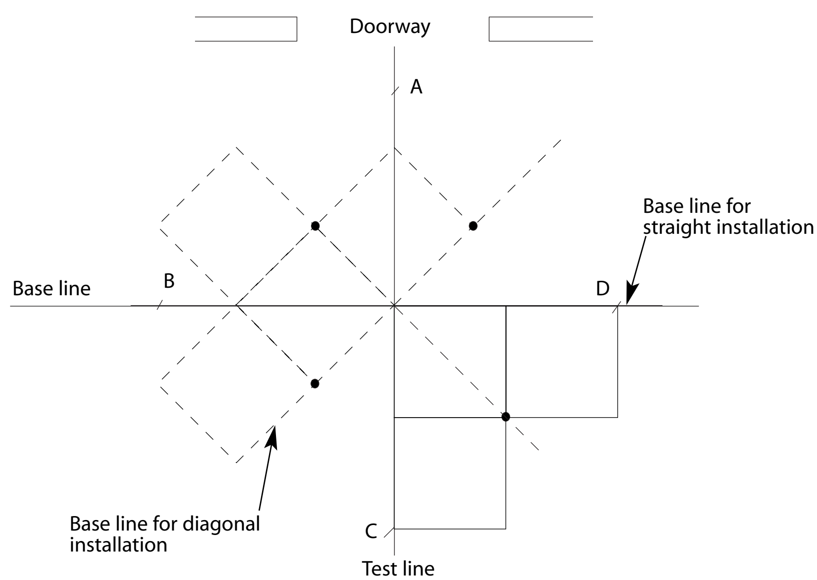


Figure 6
Laying out wood block flooring

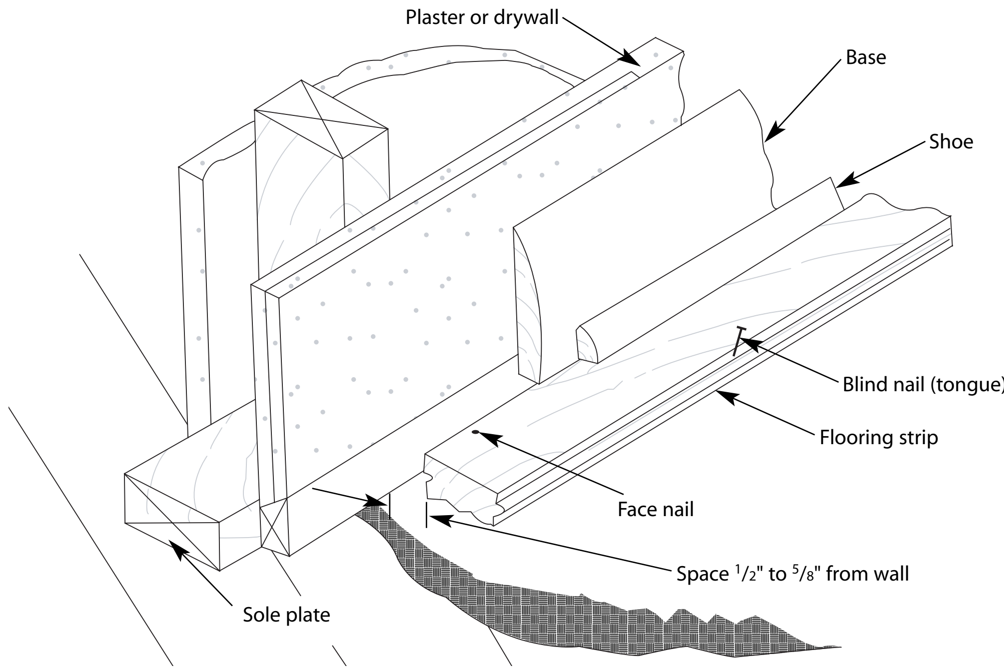


Figure 7
Installing the starting strip

You can accomplish the same thing with a paper template. Just tape paper to the floor, allowing the excess to fold up against the obstacle. Draw or cut with a utility knife where the floor meets the trim.

Where possible, simply cut away the bottom of the trim so you can slip the flooring in underneath it.

Installing Strip Flooring

Tools and Materials

- *Chalk line*
- *Hammer*
- *Power nailer*
- *Nail punch*
- *Fasteners*

Work from the same direction on each row, usually left to right (when you're standing with your back to the starting wall). For fireplace hearths, stairwells, or other areas, miter pieces of trim to frame the opening.

Thin laminated strip flooring may need both glue and nails to secure it firmly to the floor. However, nailing alone is adequate for most strip flooring.

Use the following as a guide for your installation:

1. Begin with the straightest pieces for the first and last two or three rows. Place the first course of flooring $^1/_2$ to $^5/_8$ inch from the wall, groove side to the wall, using spacers if necessary. See Figure 7. Nail 8d finishing nails along the edge next to the wall, working from the middle to the ends. Use an air-driven finish nailer for the first few rows, to protect the walls. If you're

nailing over joists, space your nails so every other nail hits the sleepers or joists. The shoe molding should cover the holes. If it doesn't, use a nail punch to countersink the nails, then fill. At the board ends, drill nail holes first to avoid splitting the wood. Blind nail the tongue side to the subfloor every 10 to 12 inches.

2. Lay out (or rack) the next seven or eight courses, staggering end joints by at least 6 inches. Scatter the shorter pieces evenly throughout, or save them for small or out-of-the-way places like closets or bathrooms. Cut pieces to within 1/2 inch of the walls. When a leftover cut piece is more than 8 inches long, start the next row with it. (Begin at the left end.)

3. Snugly fit groove to tongue, and blind nail through the tongue every 10 to 12 inches. Countersink the hand-driven nails. See Figure 8. After the first few rows, use a power nailer, which will secure the nails faster and better. Be careful that end joints don't meet over subfloor joints. Likewise, if you're nailing over sleepers, nail on both sides of the sleeper joints. Some flooring pieces will inevitably meet in the voids between sleepers, but don't let this happen to two pieces that are side by side.

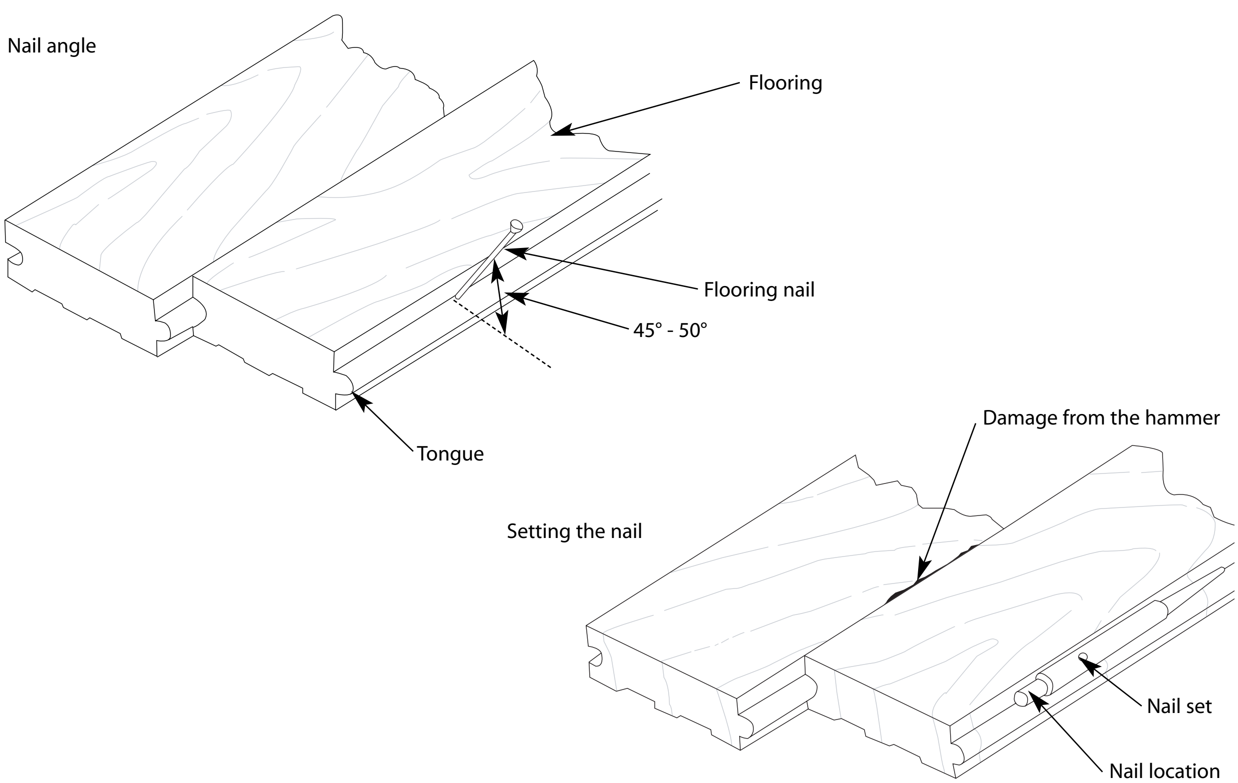


Figure 8
Nailing strip flooring

4. Continue working across the room. When you reach the opposite wall, leave a $^1/_2$- to $^5/_8$-inch expansion space. You may have to rip the tongue side of the last piece for a tight fit. Hand nail the last several rows. Tighten the final course against the previous one with a pry bar. Drill holes and nail close to the edge, just like you did the first course. Countersink the hand-driven nails. If the last row is too narrow to nail without splitting the wood, glue it in place with yellow carpenter's glue, securing it in place until it dries.
5. Warped boards can cause a problem during installation. You can wedge them into place with a job-made lever, or nail a scrap of wood to the subfloor, and wedge another T&G scrap between the two, forcing it down. But first, check to make sure the board is actually warped. Check for a nail or scrap that may be keeping it from lying flat.
6. Replace the baseboard and molding. Nail the shoe molding to the baseboard, not the flooring.

Installing Plank Flooring

To install plank flooring, you'll need the same materials that we listed under strip flooring plus a drill with a spade bit and plugs. The plugs may be packaged with the prefinished flooring or you can buy them in bulk.

Both strip and plank floors use the same system for installation, but plank flooring involves the additional step of placing the plugs for finishing. Some plank floors are glued to the plywood subfloor. As always, check the manufacturer's specifications. Also, some installers leave a thin crack, about the thickness of a putty knife, between boards.

Follow the installation guidelines for strip flooring, except that you blind nail the tongue every 6 to 8 inches instead of every 10 to 12 inches.

To finish the installation, drill one or two holes (depending on the plank's width), and countersink No. 9 or No. 12 screws at each end of the plank and in the middle, as necessary. Use a template to evenly space the holes. Be careful not to make too many holes, which will make it look too busy.

Installing Unit Block Flooring

Although some unit blocks come with tongue-and-groove edges, they're always glued, rather than nailed. Always install blocks in a pyramid or stair-step pattern and not in straight rows. Lay a quarter of the room at a time, but don't bother to trim the edges until you complete the whole room.

Tools and Materials

- *Adhesive*
- *Notched trowel ($^1/_4$" deep, $^1/_4$" wide, and $^1/_4$" apart)*
- *Chalk line*
- *Cork expansion strips*
- *100-pound roller*

Use the following steps as a guide for installing unit block flooring:

1. Snap chalk lines to find your starting point. (Refer back to Figure 6). Spread the adhesive in about a 6- by 12-foot triangular area on one side of the base line and both sides of the test line. Try not to cover the base or test lines. Follow the manufacturer's guidelines for letting the adhesive set; some require a waiting time of 30 to 60 minutes to increase tack, while others don't.
2. Place the first block at the point where the base and test lines intersect. Don't slide the block in place; rather, drop it lightly in its spot, twisting slightly.
3. Set the second block on the same side of the base line but on the other side of the test line. Put the third block on the same side of the base line but on the opposite side of the first block. The fourth block should go directly above the first. From there, build the pattern in a stair step, checking periodically to make sure the blocks are straight and even. As you work, use a scrap piece of flooring to help you place the blocks. Fit the groove of the scrap piece over the tongue of the piece you're laying and tap the block in place.
4. Periodically lift a block to make sure that the adhesive completely covers the back side. Also, follow the manufacturer's instructions carefully so that you spread the right amount of adhesive. If you use too little, the blocks may not bond adequately. Too much, and the excess will squeeze out of joints. Some manufacturers suggest pressing the floor down more securely using a 100-pound roller.
5. Cut the trim blocks by putting a full block directly on top of the last row of glued blocks. Leave a $^1/_2$- to $^5/_8$-inch gap between the loose block and the wall. Using a straightedge, draw a line where the secured tile ends. Cut and glue. Place cork expansion strips around the room in between the trim tiles and the wall.
6. Replace the trim and shoe molding. Follow the manufacturer's suggested amount of time before putting furniture on the floor and allowing regular traffic on it. It's usually about 24 hours.

Finishing and Refinishing Wood Flooring

Many kinds of flooring come already prefinished: Once you've laid them, you're finished with the job. This simplicity is attractive to most do-it-yourselfers and even some contractors. However, the total cost for prefinished flooring is higher than for laying and finishing unfinished flooring. And there's another disadvantage. Prefinished floors tend to have more cracks between strips and may be slightly different thicknesses when laid. To prevent noticeable differences between pieces, the manufacturer bevels each lengthwise edge very slightly. This beveling hides the height difference, but it also leaves a small V to catch dirt and grit. As a result, a prefinished floor may not wear quite as well as an unfinished one with a good finish.

All floors, regardless of how they come from the supplier, will occasionally need some rejuvenating. The method and extent of work involved will vary depending on the original finish.

Staining, sealing and finishing an unfinished floor takes more time, but when it's done correctly, it results in a more durable surface. You should finish a new floor within one to three weeks of installing it. Make it the last thing you do in the construction process, except for applying the final coat of paint to the base molding. This will prevent other workmen from scuffing or marring the finished floor.

The finishing process is divided into two important steps: sanding and finishing. If the first step is done poorly, there's little you can do to fix it except sand again.

Sanding a Wood Floor

The condition of the floor will determine how many times you'll need to sand it. It's common to sand three times, with increasingly fine sandpaper, for both new floors and for refinishing an existing floor. If you're working on a floor that's in good condition and doesn't have a wax buildup, you might be able to get by with a single pass with a disc sander and extra fine paper. For floors in poor condition, you may have to do one or two preliminary cuts (sandings) on the diagonal before you follow with the standard three sandings. Don't try to sand floors that have been painted rather than stained. Use a paint remover first, then follow with sanding.

Preparing to Sand

Most new flooring is at least $^3/_4$ inch thick, so there's not a problem with sanding it. But make sure older floors still have enough thickness to make sanding safe. As long as the existing floor is at least $^3/_8$ inch thick, you can sand and refinish it. Pull a floor register or remove a piece of shoe molding to check the thickness.

Prepare the floor by checking for loose nails or boards or cracks that need to be repaired first. Remove everything from the room that fine dust will damage, including drapes and electronic equipment. Take off shoe molding and cover vents. Seal off the room with polyurethane film.

Caution: Remember that fine sanding dust, some finishes, and fumes are a volatile combination. The three together are flammable, so put out all pilot lights and don't smoke. In addition, wear safety glasses, a dust mask and ear plugs.

Sanding

The standard sanding process includes three steps. Begin with coarse grit sandpaper and sand the entire room. Repeat the process with medium grit, and finish with fine grit. Sand strips and planks with the grain, overlapping cuts to avoid ridges. Block and parquet flooring are more confusing because the wood is laid in several different directions. Sand first with medium grit on the diagonal. Then use medium grit again, but on the opposite diagonal. Finally, finish with fine grit on a buffer and disc, sanding with the room's longest dimension.

It's easiest to sand large areas with a power drum sander. They're available for rent, and they're really the only efficient way to work. However, they're rather tricky to use. A novice can quickly eat into the flooring without realizing it, creating hollows and ridges along the way. Before you start using one, get a complete lesson from the rental place and practice if you can. Then when you start on the client's floor, begin your sanding in an inconspicuous place.

A drum sander can't get right up against the walls. So after you've made the first cut, sand the baseboard with an edger (also called a disc sander) or by hand scraping and sanding with the grain. Use the same grit sandpaper as the drum sander. The edger will, of course, be much faster, but the hand scraping and sanding will leave fewer marks. Some professionals always follow an edger with hand sanding for better blending. Vacuum up the loose sanding dust. After making the second cut with the drum sander, repeat the steps with the edger, again using the same grit sandpaper. Once more, clean up the dust.

If you've used an edger after the first two cuts, make the third cut with a screen disc on a buffer. Otherwise, use the drum sander with fine grit sandpaper and follow by hand sanding. After the final sanding, wipe down windows, sills, trim, and walls and vacuum the floors to pick up the loose dust. Do one final cleaning with a tack cloth. Make the room as clean as possible. You don't want dust falling onto the wet finish and marring your new surface.

Operating a Drum Sander —

1. Load the sandpaper onto the drum. (There are several standard types of drum sander you can rent; some hold the paper in place with a clamp, others in a slot. Be sure to have the rental agent demonstrate how to load the one you rent.)

2. Working the room lengthwise, begin along the right-hand wall with about two-thirds of the room in front of you. To operate the sander, pull the drum up off the floor and turn on the power. Ease the drum down level on the floor and walk forward slowly and evenly. When you near the end of the first lap, slowly lift the drum off the floor. Never just stop with the drum in motion, or you'll sand an irreparable dip into the floor.
3. Gently lower the drum down again and pull the drum backward along the same path. Move slowly and evenly, never stopping. When you reach the starting point, gradually raise the drum again. Move the machine over about 4 inches and begin the process again.
4. Repeat the forward and backward passes until you've finished the two-thirds section. Turn the machine 180 degrees and do the one-third section in the same way. Overlap the two-thirds and one-third sections by 2 to 3 feet.
5. After covering as much of the floor as possible with the drum sander, put the same grit sandpaper in the edger. Overlap the edger into the drum-sanded area to blend. Sand with the grain as much as possible. To sand corners and tight spots by hand, glue an old towel onto the top edge of a brick, leaving enough toweling loose to cover both sides of the brick. Wrap sandpaper over the opposite edge and hold it in place under the towel. Sand with the grain.
6. Repeat the entire process with a medium grit paper and again with a fine grit paper. Vacuum up dust from walls, sills, trim and floor. Follow with a tack cloth.
7. When the floor is completely sanded, check for nail holes, cracks between strips, or any other flaws that you need to repair. Fill these with matching putty and sand when dry.

Staining Wood Floors

If possible, apply the first coat of finish the same day you finish the sanding.

Sometimes the client prefers the wood left natural, or unstained. More often, though, they'll want to change the color of the wood. There are several ways to do this. The most common methods are penetrating stains or pigmented stains. Wood absorbs a penetrating stain, so the grain and markings are highlighted. In contrast, pigmented stains aren't absorbed. They color the wood, but also tend to hide the grain.

Tools and Materials

- *Paint brush*
- *Lamb's wool applicator*
- *Tray and liner for the stain*
- *Stain*

Applying a Stain

The amount of time you leave the stain on the wood determines the color of the wood. Usually, a stain takes about 15 minutes to color the wood. If in doubt, err on the light side. You can always apply more stain to darken it; it's harder to remove or lighten stain that's too dark. Test on scraps of the same kind of wood or apply to a small area in an inconspicuous place to see how long to leave the stain on. Once you know how long to leave the stain on, you can use this time frame to figure how large an area you should work on at one time.

Use the following guidelines for your application:

1. Use a paintbrush to cut in along the wall to avoid getting stain on the shoe molding. About 1 foot away from this strip, apply a heavy streak of stain along the grain, using the lamb's wool applicator.
2. Go back and brush across the grain of the wood between the two strips of stain. Don't allow the stain to puddle anywhere and don't redip the applicator.
3. Wipe up the excess stain with a clean, lint-free cloth and allow it to dry.

Remember that the stain only changes the color of the wood. While it provides a small degree of protection, don't depend on it to protect wood flooring from moisture or dirt. You'll need to follow the stain with a protective finish.

Pickling and Bleaching

Two other options for changing color are pickling and bleaching. You need to apply a protective finish after these as well.

Pickling

There are four steps for a pickled finish:

1. Apply thinned paint to the floor.
2. Wait 20 to 60 minutes for the paint to begin drying.
3. Scrub off most of the color, until you get the effect you want.
4. Finally, sand to smooth the surface. After sanding there will still be little flecks of paint left in the wood grain.

Bleaching

The purpose of bleaching is to reduce variations in the wood's color without hiding the grain. Use a special bleach designed for wood flooring, and follow the manufacturer's recommendations. Once it has reached the desired shade, you apply a neutralizing formula — either a commercial neutralizer or a 50/50 mix of white vinegar and water — to stop the bleaching action. Follow the neutralizer with a warm water rinse and then allow the floor to dry completely. Complete the bleaching in one process. Repeated bleachings would soften the wood and make it easier to dent.

Finishing the Floor with a Penetrating Seal

A penetrating seal does just what the name implies: it penetrates into the wood pores and hardens, in the process sealing and protecting the floor against dirt and stains. The real beauty of a penetrating seal is that it wears in the same way that the wood wears and won't chip or scratch. The floor is easily refinished without sanding by cleaning it and applying another coat of sealer or a reconditioning product made to rejuvenate old sealer. And you can spot-repair flooring because a penetrating seal won't show lap marks where the new finish overlaps the old. The drawback to a penetrating seal is that it may darken as it ages. Also, it's not as durable as a surface finish and requires waxing for better protection and higher gloss.

There are two general categories of penetrating seals, depending on their drying time. Normal (or slow drying) sealers are manageable even for a novice. Fast-drying sealers are more difficult to apply without lap marks or splotches. Both types are generally applied in two coats or a single coat and a special top dressing.

Tools and Materials

- *Vacuum cleaner*
- *Tack cloth (a trowel saturated in water for water-base sealers or in mineral spirits for oil-base sealers)*
- *Long-handled applicator with a lamb's wool pad, wide brush or squeegee*
- *Rags*
- *Abrasive screen (similar to sandpaper but looks like window screen. Avoid using steel wool.)*

Applying a Penetrating Seal

Use the following as a guide for your application:

1. Vacuum up all sanding dust; follow by cleaning the room with a tack cloth. Generously spread the sealer along the grain with a lamb's wool applicator, brush, squeegee or rags. Allow it to stand for the time recommended by the manufacturer, usually about 15 minutes.
2. Wipe up the excess sealer with clean rags or a squeegee.
3. Allow to dry 8 hours or overnight.
4. The penetrating sealer raises the grain slightly. You'll have to smooth the surface by buffing, either with a buffer or by hand. The buffer also levels out and smoothes imperfections. Wait until the surface is completely dry, or the buffer will gum up. Place the abrasive screen on the floor, and set the buffer on top of it. Friction will hold the screen to the scrub pad. Some sealers require buffing while the sealer is still wet. Even if the manufacturer recommends using steel wool, don't use it if

you're going to follow the sealer with a water-base polyurethane finish. The little filaments left behind will rust and leave speckles in the finish.

5. Fine sweep the surface, and remove any remaining residue with a tack cloth. Apply a second seal coat in the same manner.

6. Wax the floor.

Finishing the Floor with a Surface Finish

In contrast to a penetrating seal, a surface finish sits on the surface of the wood and doesn't penetrate, which gives the wood a protective coating. Although it's far more durable than a penetrating seal, it's also a lot more work to redo. At the very least, the old surface must be lightly sanded, or scuffed, before you can apply a new finish. If the floor has been waxed or it's severely worn, you'll have to resand and refinish the entire surface.

There are three kinds of surface finishes commonly used: polyurethane, moisture-cured urethanes, and urea-formaldehyde finishes. All of them are extremely durable and highly resistant to moisture. Polyurethane is the easiest to apply. Leave the other two to professionals because it takes experience to apply them correctly.

Tools and Materials

- *Sanding equipment*
- *Tack cloth (see penetrating sealer application)*
- *Long-handled lamb's wool applicator*
- *Abrasive screen*

Varnish and shellac used to be common as floor finishes. Both are rare today because the newer surface finishes are so much more durable. If you're asked to refinish a floor covered with varnish or shellac, sand it down and apply polyurethane.

To find out how an existing floor was finished, scratch an inconspicuous spot with a coin. If the finish doesn't flake or crumble off, the floor probably has a penetrating sealer on it. But before refinishing, do a small test sample in an out-of-the-way place.

Applying a Polyurethane Finish

Follow these guidelines for your application:

1. On a new floor, staining will raise the grain, which allows the finish to adhere with no further treatment. On an older floor that's in good condition and hasn't been waxed, you can use a screen disc to rough up the old finish. Otherwise, you'll need to sand off the old finish. Vacuum up all sanding dust and wipe surfaces with a tack cloth.

2. Stir, don't shake, the polyurethane container to mix according to the manufacturer's directions. Using a lamb's wool applicator, generously brush the polyurethane across and then with the grain. Allow it to dry as specified by the manufacturer.

3. Buff with an abrasive screen. Fine sweep the surface and then thoroughly wipe it with a tack cloth to remove all dust particles.
4. Apply a second coat in the same manner, and then a third if needed. Don't buff the final coat.

Protecting the Finish

After you've done all the work to finish, or refinish, a wood floor, take a little more time to let the clients know how to protect it.

Dirt and grit are the true enemies of a wood floor. So the first rule in maintaining a long-lasting finish is to put dirt-catching rugs or mats in entry areas. The second is to sweep or dust mop the floor daily to remove rough particles. Regular vacuuming is particularly important for prefinished floors because dirt can get trapped in the small beveled Vs between strips.

If you've used only a penetrating sealer, tell your clients to keep a coating of wax on the wood. Since liquid buffing wax is easier to use than paste wax, it's the most common choice. Make them aware of the following precautions regarding the type of wax they use: First, use only wax designated for wood floors; and second, don't use a liquid that has a water base, even though some water-base waxes are labeled as suitable for wood floors. Use only a solvent-base wax.

Usually waxing once or twice a year with a liquid buffing wax/cleaner combination is enough, although they may need to wax more often in heavy traffic areas. They should buff occasionally in between waxing to take scratches out of the wax.

Surface finishes should never be waxed, or all the old finish will have to be removed before a new coat will adhere.

Regardless of the finish, *never* wet-mop a wood floor — even if the manufacturer says it's OK. Surface finishes can tolerate a damp mop, but wax-coated finishes can't take even that much water.

Repairing Wood Floors

As durable as well-cared-for hardwood floors are, they're not problem-free. Most often, a change in moisture or humidity is the culprit. You can't do much when the variation is an unavoidable one, like normal weather or changing seasons. These tend to cause slow changes and don't do long-term damage. Usually when floors develop real flaws, such as cupping or crowning, it's a direct result of sudden moisture changes.

Flooring is more prone to cupping if the wood was plain-sawed. The grain of plain-sawed wood runs flat with the board. If it's exposed to moisture, it's likely to cup. Quarter-sawed wood has less area that can expand from moisture, and so it's less likely to cup.

Other situations can cause floor problems as well. A settling foundation, poor or inadequate subfloor material, or even the finish you use can all create problems. Whenever flooring starts to cup, crown, crack, or split, immediately begin looking for the cause and try to fix the problem. Otherwise, you'll be replacing the same flooring over and over again. Figure 9 shows common wood flooring problems and their solutions.

Repairing Cracks

If the cracks are just normal cracks resulting from seasonal changes, it's best to leave them alone. Closing cracks with filler will only create more problems when the weather changes. During the seasonal wet months, the wood will swell again, causing the cracks to disappear, forcing out the filler.

For cracks caused by other problems, repair them by troweling a matching filler into the spaces. Then scuff or screen the surface with a power buffer and apply a polyurethane finish.

Repairing Cupping

Because cupping is a direct result of moisture changes, the first step is to correct the problem. Invariably, the moisture comes up from below the flooring and can't evaporate through the surface because the surface is sealed. Use a meter to measure the moisture content of the floor surface, the subfloor, joists, crawl space, and so on. Fix all the drainage problems, place vapor barriers, and install cross-ventilation under the floor. In damp climates, you may also have to install a dehumidifier.

The drying process is a slow one. It may take several weeks or even months for the surface and below-surface humidity to balance out. Once they've reached an even point, allow another month for the wood to dry further. This may be all you need to do to fix the problem.

However, if other problems arise, repair those first. Then, if the cupping remains a problem, you'll have to sand the floor smooth and refinish it.

Replacing Damaged Floorboards

When major damage occurs, you may have to replace some of the floorboards. Here's how to do it with the least amount of damage to the neighboring floorboards.

Problem	Possible Causes	Determining the Cause	Solution
Cracks between floorboards	Normal changes in humidity	Hairline cracks from the thickness of a piece of paper to less than the width of a dime appear and disappear seasonally	This is normal fluctuation in wood; plank floors have a greater tendency than strip floors to crack; install a humidifier to add moisture
	Foundation settling, stretching the subfloor and causing cracks over the joints	Check the floor for levelness; check for settling in the foundation walls	Repair the foundation
	Excess drying due to heating and venting system	Cracks appear only over heating plant or ducts	Insulate between subfloor and ducts or furnace
	Poor quality or inadequate subfloor materials	Squeaks, cracks especially over subfloor joints	Replace the subfloor; may be able to remedy by nailing more fasteners over joists
	Vehicle traffic on floor not designed for it		Replace flooring to meet traffic needs
Cracks between and within floorboards	Bleached, white, or pastel finish	Small cracks more visible with the light finishes; cracks tend to be seasonal, appearing in dry seasons	This is the nature of the finish; use only a professional finisher; allow finish to dry completely (up to 10 days); clean often and use dirt-trapping mats
Cracks in parquet	No cork expansion joint filler	Cracks near the walls are larger than cracks near the center	Remove baseboard; cut a ¾" expansion space between flooring and walls; place cork expansion pieces in space
Cupped floor	Sealed top surface, exposed to moisture from below	Use a sling psychrometer or digital thermometer hygrometer to measure moisture of flooring surface and back of flooring, subfloor, joists, etc.	Solve excess moisture problem; if flooring dries out soon after cupping occurs, there may be no damage; otherwise, sand and refinish floor
Crowned floors	After a cupped floor is sanded and refinished, flooring may dry further, causing crowning and cracking	Check for excess moisture on surface	Solve excess moisture problem; wait until face and back moisture readings have been the same for 30 days before sanding and refinishing
Flaws within strip or plank	Excess moisture; lower grade of flooring	Flaws are isolated	Solve excess moisture problem; replace floorboard with unflawed board
Squeaky or loose flooring	Flooring has cupped and then dried out; or flooring has expanded in rainy weather and edges squeak from rubbing against each other	Boards will squeak or feel loose when walked on	Sift small amount of powdered soapstone, talcum powder, or powdered graphite between strips where squeak occurs; face nail flooring with headless steel pins or fasten from underneath with wood screws
Loose flooring	Flooring has cupped and then dried out, causing the adhesive to lose its holding ability	Flooring will pop or sound hollow when walked on or tapped	If asphalt cut-back mastic was used, pull up a few pieces of flooring at a time and spray kerosene on the mastic to reactivate it; press flooring back into place, or face nail with headless steel pins

Figure 9
Wood flooring problems and solutions

Tools and Materials

- *Drill with a spade bit and bit for finish nails*
- *Chisel*
- *Nail punch*
- *Replacement flooring*
- *Wooden mallet and wood block*
- *6d or 8d finish nails*
- *Yellow carpenter's glue*
- *Wood putty*

Use the following guidelines for replacing damaged floorboards:

1. Drill several holes across the width of the board. Go only as deep as the flooring itself, not through the subfloor.
2. Chisel out the board, starting at the drilled holes and working to the edges. Cut through the tongue on both sides of the floorboard, squaring up each edge as much as possible and removing the old tongue.
3. Carefully measure the opening. Cut the replacement board 1/32 inch longer, and sand the ends smooth. Chisel off the bottom part of the groove.
4. Apply glue to both side edges of the floorboard. Slip the tongue into the groove and push the board into place, using a mallet and wood block to force it in. Remove any excess glue.
5. Drill two holes in each end of the floorboard and nail. Set the nails with a nail punch and fill the holes with matching wood putty. Stain and refinish to match the surrounding wood.

Repairing the Finish

It's easier to blend in a spot finish on floors with a penetrating seal and wax than those with a surface finish such as polyurethane. To determine which finish was used on the floor originally, scratch an out-of-the-way spot with a coin. If the finish flakes, it's a surface finish. If not, it's a penetrating seal. If the finish "smudges," it's waxed, which means that a penetrating sealer was applied before the wax.

Repairing Penetrating Sealers

1. Pour sealer reconditioning or paint thinner into a small puddle and rub with fine steel wool. Wipe it clean as you work.
2. When the floor is dry, wax with either a liquid or paste wax and buff to blend with the rest of the floor.

Repairing Surface Finishes

1. Using steel wool or fine sandpaper, remove one or two complete layers of finish from the entire length of the affected board. Stain the wood and allow it to dry completely.
2. Tape the perimeter of the board or boards to be finished with a good quality masking tape so the finish doesn't seep under the tape and build up. Then, using the same finish as the original, apply the finish, letting it dry between coats. Remove the masking tape when the finish is completely dry.

Removing Stains

You can prevent most stains by simply cleaning up spills immediately. For floors with a surface finish such as polyurethane, liquids don't penetrate quickly if the finish is in good shape. Waxed floors are more vulnerable, even if the floor has a good coat on it. When removing stains from a waxed floor, avoid using more than a damp cloth. Otherwise, water may be absorbed into the wood and cause further damage.

Refer to the chart in Figure 10 for specific stain removal instructions. Work at the stain from the outside edges in toward the center so that it doesn't spread further. Once you've removed the stain, you may have to refinish the wood and reapply a penetrating sealer, but do it only after the wood had dried completely. Rewax the area when the finish dries. If a stain is too deep or stubborn for removal, you'll have to remove and replace the flooring piece or pieces.

Stain	Removal Procedure
Milk or food	Rub spot with damp cloth; rub dry and rewax.
Dark spot from standing water	Rub stain with No. 1 steel wool; or sand with fine sandpaper, then clean with No. 1 or 00 steel wood and mineral spirits.
Dark spot from ink or animal feces	Clean area with No. 2 steel wool and mineral spirits, and then wash with vinegar, allowing it to stand for 3 to 4 minutes. Repeat if necessary. If spot remains, sand with fine sandpaper. If vinegar doesn't work, bleach the spot with 1 part oxalic acid to 1 quart water (use rubber gloves with oxalic acid).
Black marks from heels or caster wheels	Rub vigorously with fine steel wood and good floor cleaner; wipe dry.
Mold or mildew from damp, stagnant air	Improve ventilation; clean area with cleaning fluid.
Chewing gum, crayon, candle wax	Apply ice until deposit is brittle enough to crumble off; pour cleaning fluid around (not on) area to soak under deposit and loosen it.
Cigarette burns	Moisten steel wool with soap and water and rub burn.
Alcohol	Rub with liquid or paste wax, silver polish, boiled linseed oil, or cloth barely dampened with ammonia.
Oil, grease	Rub with a kitchen soap that has a high lye content; or put cotton saturated with hydrogen peroxide on the stain, followed by a second layer of cotton with ammonia; repeat until the stain is removed.
Wax buildup	Strip old wax with mineral spirits or wood floor cleaner, using rags and fine steel wool as needed.

Figure 10
Stain removal chart for waxed floors

Manhours

Manhours to Install Wood Flooring, per 100 SF of Floor		
Type of Flooring	**Manhours**	**Suggested Crew**
T&G strip flooring, 2 1/4" strips	3.00	1 finish carpenter
Straight edge plank flooring, 6" to 12" wide, set with biscuit joiners	5.50	1 finish carpenter
Straight edge plank flooring, 6" to 12" wide, set with screws and butterfly plugs	6.50	1 finish carpenter
Wood block flooring, prefinished	6.00	1 finish carpenter
Filling and machine sanding	1.70	1 finish carpenter
Finishing, with filler and final coat	1.80	1 finish carpenter

For information on related topics, see:

Floor Framing, page 299

Flooring, page 359

Trim, page 673