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Volume 3. Concrete and Masonry

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IN THIS VOLUME, you will study all aspects of concrete construction. Unit 1, concrete, discusses site preparation, concrete form construction and reinforcement, mixing and placing concrete. Unit 2 covers masonry construction with lessons on mortar, concrete masonry units and clay masonry units. Unit 3 rounds off the volume with masonry wall and floor construction with topics on plaster, stucco, wall tile and floor tile.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Concrete

MANY OF YOU will have the opportunity to mix and place concrete. This is a very important task and must be done correctly. Imagine the consequences of what would happen if you poured columns and footings for a pre-engineered building, but your layout was off and the mix design wasn't strong enough. The project would be delayed and a lot of money would be wasted in time and materials. In this unit, we discuss the procedures taken for site preparation, concrete form construction, and concrete reinforcement. We also discuss concrete fundamentals including mixing, placing, and finishing. Take the knowledge gained here and build upon it through on-the-job training and self-study.

1–1. Forming and Reinforcing

As with most things we do, one task builds upon another—this section is no exception. In this section, we discuss the procedures involved to form and reinforce concrete placement. However, before you learn how to build and erect forms, you'll need to know how to properly layout the project and prepare the subgrade.

401. Site preparation

The first, and probably the most important task in any building construction, is a strong foundation; it starts with a properly laid out subgrade. On large projects with blueprints, the foundation plan has already been done. On small projects, you'll have to make sure the subgrade is planned properly before any other construction is done. Check the soil type to make sure that it allows water to drain away from the foundation. If possible, your subgrade should be on relatively high ground to minimize possible water seepage into the foundation.

Building layout

After the location and alignment have been determined, you're ready to layout and stake the building. Staking is nothing more than marking the corner locations to determine the exact boundaries (building lines). We must emphasize accuracy; a mistake in either the layout or staking can cause trouble as construction progresses. If, for example, the building layout isn't square, the roof frame won't be square, and you'll have problems when you align the roof sheathing with the rafters.

An engineer normally does the layout and staking on large buildings or structures, but sometimes you'll have to do it for smaller structures. In either case, it's equally important that you understand the layout process. There are many ways to layout a building; you must select the one that best fits your situation. Regardless of the method you choose, remember that the building lines drawn from batterboard to batterboard indicate the foundation walls' exact outside surface. These batterboards and building lines are usually located after the building stakeout.

Locating building corners

The blueprint indicates the building's size and specifies how far it should be from a stationary reference point or monument. NOTE: In this sense, a monument is any permanently located object. The monument can be manmade, such as a driven length of pipe; or it can be natural, such as a tree or large stone. We often call monuments horizontal control points. Monuments that reference a building's location are shown on the engineer's drawing, along with the necessary dimensions and other information to locate the building lines with precision.

Baselines

The first step in locating corner stakes for a building is to establish a baseline, sometimes called the *reference line*, based on the information that's available to you. For example, you may want to lay out a building so that its front wall is parallel to a street. If the street is curbed, you can simply use the curb as the baseline. From this baseline, you can make measurements to establish the building's front corners so that they are equally distant from and, therefore, parallel to the curb. If the street is not curbed, you can use the street centerline as the baseline. Figure 1–1 shows a baseline example. Notice that the straight line from monument "A" to monument "B" forms the baseline from which you can locate the first building corner. This reference line is your starting point to an engineer's drawing on a small project. Your supervisor will guide you to this point. You should be able to lay out the rest on your own.

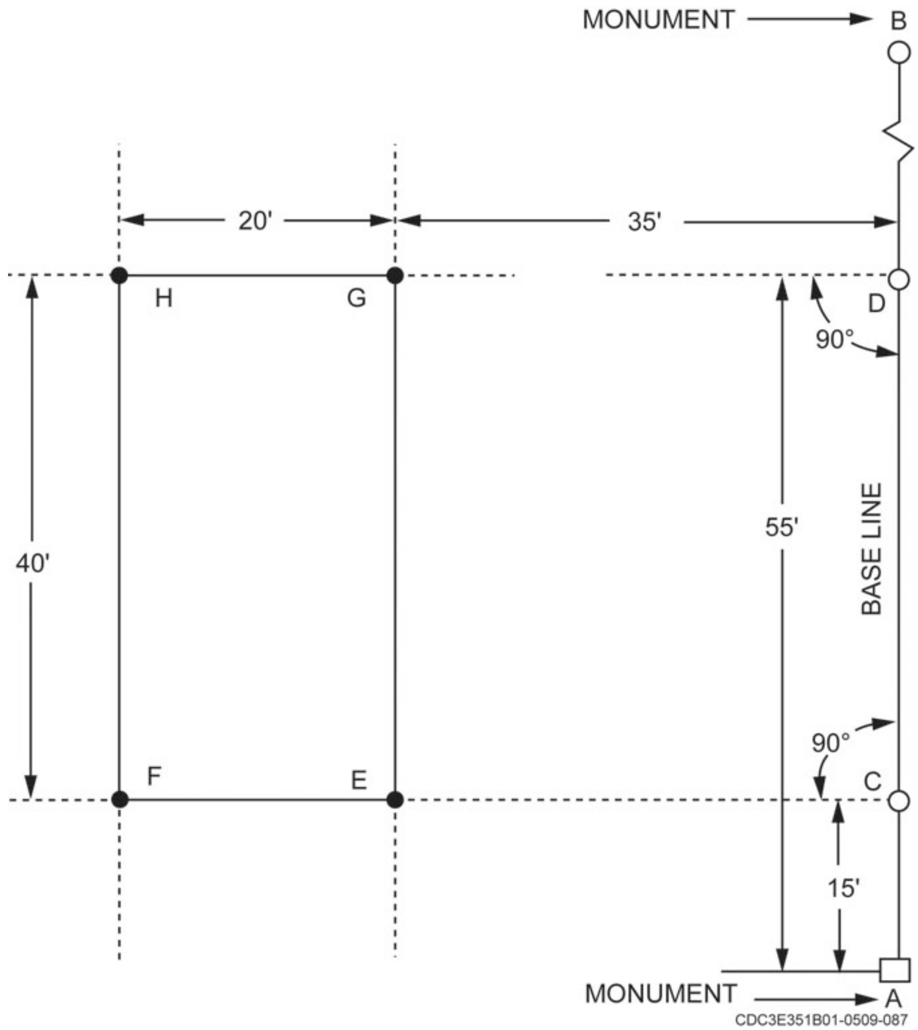

Figure 1–1. Locating building corners.

Locating the first building line

Refer again to figure 1–1 and find points “C” and “D.” These points mark the actual building length. You identify the location by measuring from monument “A” along the baseline and driving 2-inch by 2-inch stakes into the ground. Drive small finish nails or tacks into the stake tops to mark the exact reference points permanently. Pull the first building line from point “C” at a 90-degree angle from point “D” and parallel to the first building line approximately 70 feet out and tie it to a stake. Measure along this line and drive stakes into the ground, representing the third and fourth corners. Once you stake out all four corners and drive small nails into each stake top, it’s time to check the stakes for accuracy.

Squaring the building stakes

At this point, the building corners have been established and stakes driven to identify each corner. However, since there is a possibility that the corners aren’t square, check by measuring the diagonals of the building (fig. 1–2). If the diagonals aren’t the same length, the building layout isn’t square. In this case, move the third and fourth stakes (fig. 1–1, “G” and “H”) along the opposite side line until the diagonal measurements are equal. When you’re adjusting the diagonals, remember that the exact distance between each pair of stakes must not change.

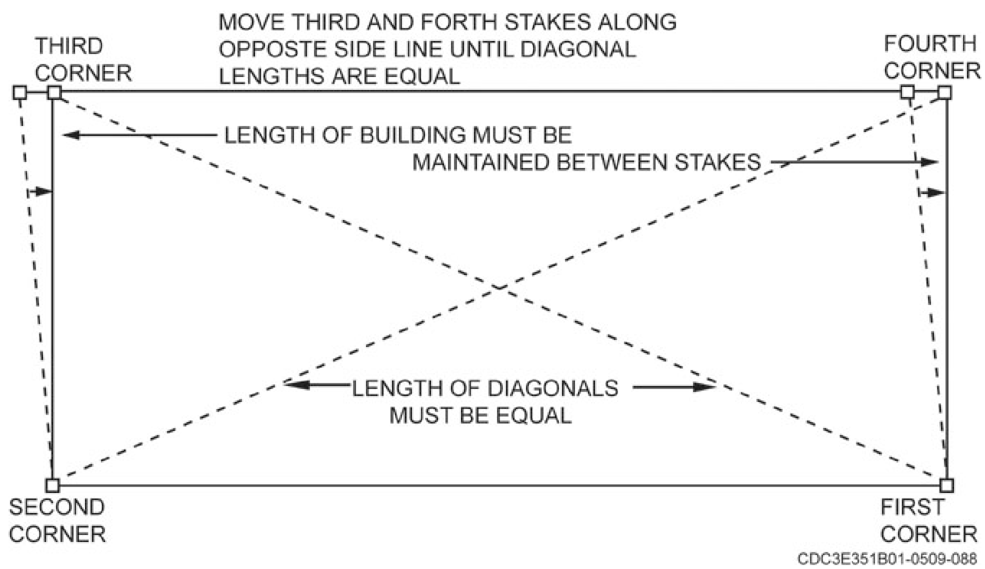

Figure 1–2. Squaring building stakes.

Pythagorean Theorem

The easiest and most accurate way to locate points on a line or to turn a given angle, such as 90 degrees, from one line to another is to use a surveying instrument called a transit. However, if you do not have a transit, you can locate the corner points with tape measurements by applying the Pythagorean Theorem ($A^2 + B^2 = C^2$). Below are the five steps to take to apply the theorem:

1. Stretch a cord from monument A to monument B, and locate points C and D by tape measurements from A.
2. In examining figure 1–1, you observe that straight lines connecting points C, D, and E form a right triangle with one side 40 feet long and the adjacent side 35 feet long. By the Pythagorean theorem, the length of the hypotenuse of this triangle (the line ED) is equal to the square root of $35^2 + 40^2$ (1225 + 1600 = 2825), which is approximately 53.15 feet. Because figure EG DC is a rectangle, the diagonals both ways (ED and CG) are equal. Therefore, the line from C to G should also measure 53.15 feet.

3. If you have one person hold the 53.15-foot mark of a tape on D, have another hold the 35-foot mark of another tape on C, and have a third person walk away with the joined 0-foot ends, when the tapes come taut, the joined 0-foot ends lie on the correct location for point E.
4. The same procedure, but this time with the 53.15-foot length of tape running from C and the 35-foot length running from D, will locate corner point G.
5. Corner points F and H can be located by the same process, or by extending CE and DG 20 feet.

The 3–4–5 triangle

If a transit isn't available, you can establish a right triangle (a square building corner) by carefully applying the basic 3–4–5 rule shown in figure 1–3. These numbers normally represent the ratio in feet and can be doubled any number of times to increase their accuracy. For example, you can use a larger triangle (6–8–10, 9–12–15, or 12–16–20) if the proposed building lines are long enough. In any case, select the largest combination that suits your needs and take these four steps:

1. Measure along the given reference lines from point "A" 4 feet and establish point "B" as illustrated in figure 1–3.
2. Measure along the opposite line from point "A" 3 feet and place a mark on the line to represent point "C." **NOTE:** After you make this mark, be careful not to stretch the line since that can make your mark inaccurate.
3. Measure from point "B" to point "C." If the two sides are 90 degrees to each other, the measurement will read 5 feet.
4. If any adjustments are needed, make them by moving side "A-C," not your reference line "A-B."

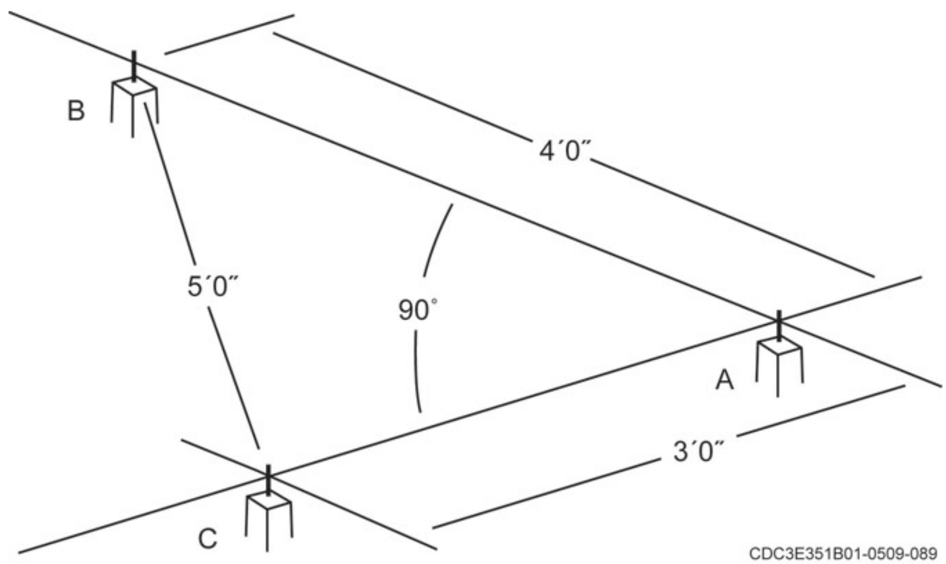

Figure 1–3. Squaring building corners.

Batterboards

Once the building corners are square, it's time to erect the batterboards and put the building lines in place. It's extremely important that these lines be marked permanently, yet be easy to remove when the excavation and foundation work begins (your batterboard arrangement does this). You must construct batterboards at each building corner to hold the building lines tightly in place (fig. 1–4). Batterboards are used extensively in construction because they stay in place throughout layout and excavation. The building location must be determined and the batterboards put in place before you can make an accurate layout. Place batterboards a minimum of four feet outside each corner location so that the equipment operators and builders can do their work. Make sure the ledger (crossbar) boards are long enough to extend beyond the corner stake (fig. 1–5).

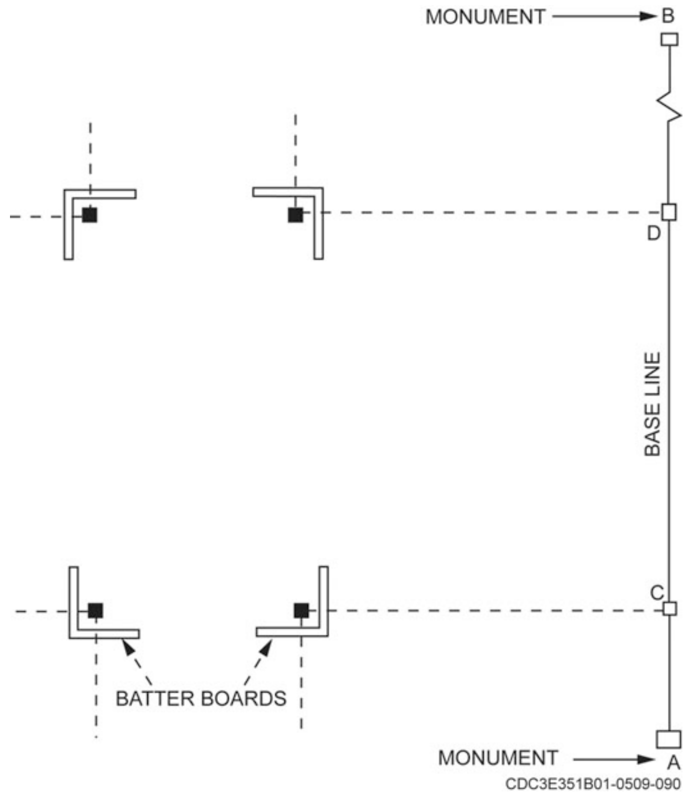

Figure 1–4. Batterboards at each corner location.

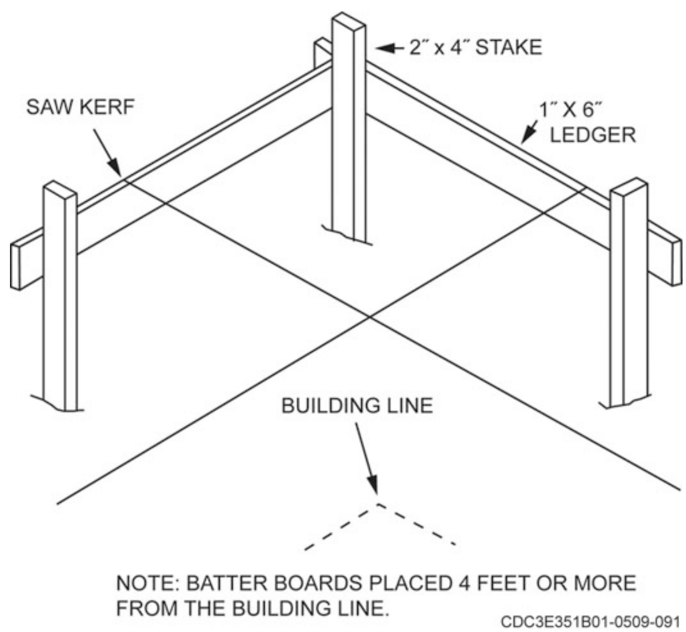

Figure 1–5. Batterboards in use.

The materials for batterboards should be strong enough to hold the tightly stretched cords and to absorb occasional accidental bumps without movement. You must brace them if the soil is loose or when the stakes are higher than three feet. Using 2 × 4 lumber for stakes and 1 × 6 lumber for the ledgers works for most construction projects. If the building site is relatively level, you can erect the first batterboard at any corner. When the site is sloped or on unleveled terrain, you should place the first batterboard at the highest corner. Regardless of which batterboard you place first, all batterboard ledgers must be level with each other.

Line level

A line level is a satisfactory method of leveling batterboard and building lines for small projects. This level consists of a bubble tube set into a metal (usually aluminum) case with a hook at each end so you can easily hang it on a builder's line. It's particularly useful for leveling between two points that are too far apart to use a 4-foot carpenter's level and straightedge. Store your line level in a small box packed with cotton or tissue to keep from bending the hooks or breaking the glass tube. A line level (fig. 1–6) is a delicate instrument; treat it accordingly.

How to use the line level is provided in the following bullets:

- Stretch a line between the two points to be checked for level.
- Hang the line level on the line as near the center as possible, and see if the bubble is in the middle of the tube. If not, lower or raise one end of the line until the bubble rests in the center of the tube.
- Check the level's accuracy by turning it end for end and rechecking the line. Sometimes the hooks will get bent causing the level to show an inaccurate reading.

There are times when the line level is unsuitable; for example, when outdoors during windy periods. The same holds true when the distance between the leveling points is so great that the line actually sags from its own weight creating an untrue reading with the level. In these situations, the water level is useful.

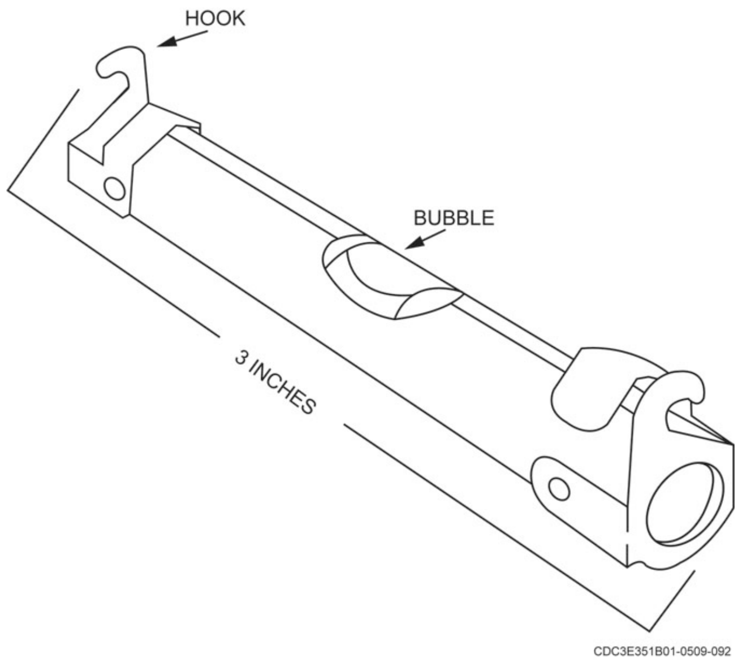

Figure 1–6. Line level.

Water level

Used right, the water level is an extremely accurate tool. A typical water level (fig. 1–7) uses a tube or hose, a funneling device, and water. In colder climates, you can use a water level kit with liquid antifreeze. Clear plastic tubing (half inch in diameter) with water or antifreeze also works with a great degree of accuracy. In either case, follow the four steps below:

1. Use a carpenter's level to level one right-angle batterboard at the highest building corner.
2. Drive stakes at the next batterboard location (fig. 1–7).
3. Fill hose with water until water level is up to the top of the batterboard "A," making sure the other end of the hose (at batterboard "B") is high enough to keep water from spilling over the top.

4. Mark the water level at the other end of the hose on the stake of batterboard "B." Use a carpenter's level to level ledger boards to this mark.

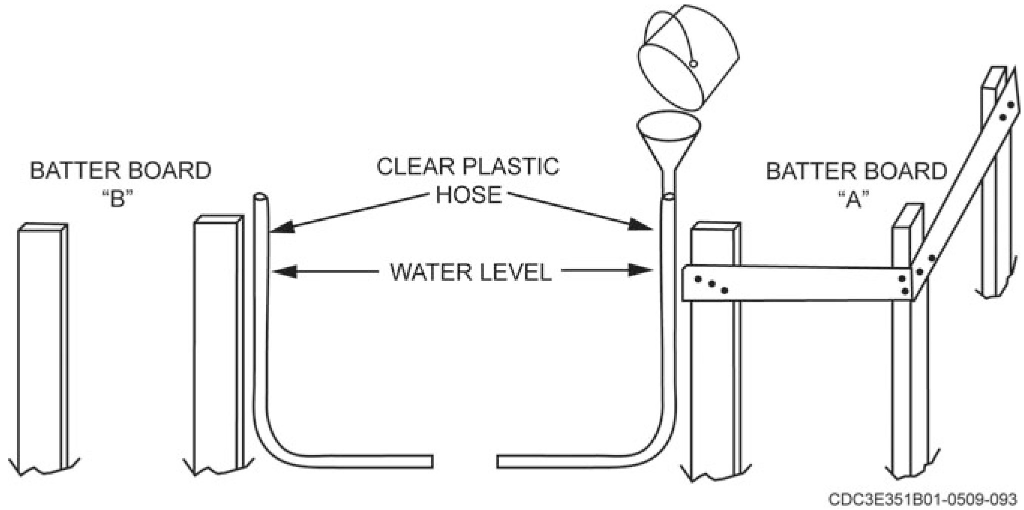

Figure 1–7. Water level.

Continue this process until all batterboards are in place. Once they're in place, the tops of the ledgers become marks from which you can measure the elevation.

Builder's level

The preferred method to sight the height of the ledger board is to use a builder's level. This is easily accomplished using the following five steps:

1. Setup the level in the approximate center of the building location.
2. Sight the benchmark (point of designated elevation) and record it.
3. Determine the difference between the benchmark and the ledger boards.
4. Sight and mark each outside batterboard corner stake at the required elevation.
5. Attach the ledgers to the stakes ensuring the top of the ledger is flush with the mark and level.

Marking and placing building and excavation lines

As soon as all batterboards are up, make reference marks on the top edge of the ledgers so that you can reestablish exact corner locations whenever you need to do so. You must do this before you disturb the corner stakes. By stretching a cord over the batterboards and using plumb bobs held over the corner stakes, you can transfer the building line locations to the batterboards (fig. 1–8).

Move the cord across each batterboard until it just touches the plumb bob string. Mark this position on top of each batterboard. You can place the third and fourth building lines and mark the batterboards by pulling the reference lines directly across the lines you've already established (fig. 1–9). Make a saw kerf (notch) in the outside edge of each marked ledger to hold the building lines securely in place. Then, you can easily remove these lines when excavation starts and replace them when you need the reference line.

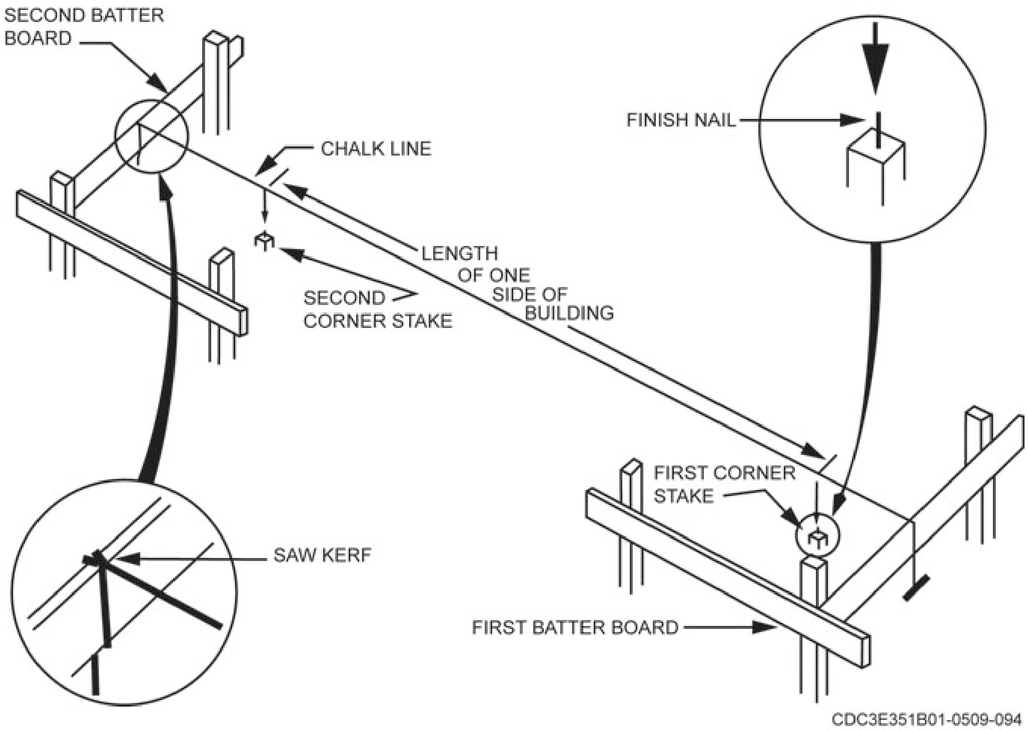

Figure 1–8. Placing the first building line.

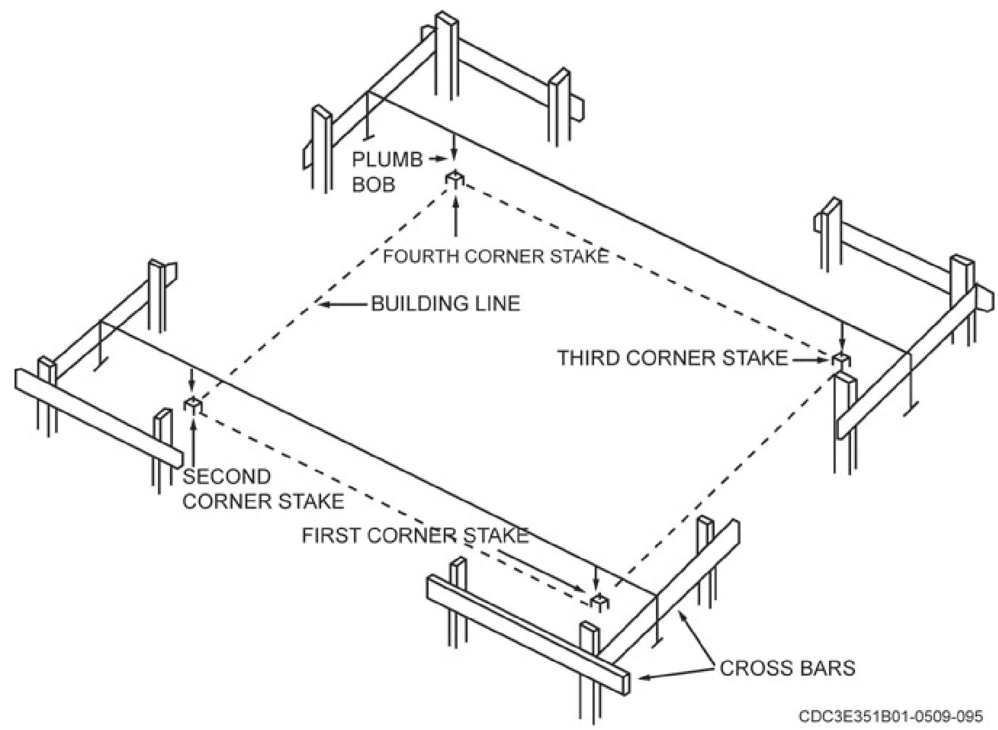

Figure 1–9. Placing building lines.

The building lines represent the foundation walls' outside surface. In most cases, forms must be set to pour these walls. Excavation must extend at least two feet outside the wall planes, unless you're using an earth form. A 2-foot space is the customary allowance for working space in constructing the forms. It's the space that must be backfilled after the concrete sets. When it's necessary, mark the excavation line location on the batterboards the same way you marked the building lines.

Finished grade

Making preparations for placing concrete is a very important factor for a quality concrete job. The *subgrade (bed)* must be prepared to receive the concrete, forms must be placed properly and steel must be placed in the concrete to get the required strength. After the *subgrade* is compacted you’re ready to make the concrete forms.

Subgrades

Concrete can be placed satisfactorily on rock, clay, earth, sand, or gravel subgrades. It can also be placed on old concrete surfaces.

Rock or concrete

When you place concrete on a rock or concrete surface, use stiff brooms to remove the debris from the surface, and then use high-pressure air or water to clean the surface thoroughly. After the area is completely clean and dry, coat the surface with a liquid bonding agent for complete adhesion between the rock and concrete and the newly placed concrete. When you’re placing new concrete over old, make sure the old concrete is in good shape (no cracking, heaving, or settling). Your base should be solid material. If at all possible keep at least a 2-inch concrete covering to minimize severe cracking from heavy loads. You may need to use a ⅜-inch pea gravel mix to cover the old concrete.

Clay

If you’re placing concrete on a clay subgrade, moisten it to help keep the subgrade from extracting moisture from the concrete. Sprinkle the subgrade intermittently so that it works into the clay without getting muddy. Compact a clay subgrade with a mechanical compactor (fig. 1–10) or hand tamper.

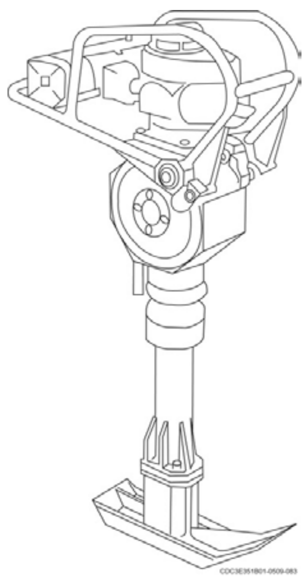

Figure 1–10. Mechanical compactor.

Earth

If you are to place concrete on earth, have an engineer check the earth for load carrying capacity. Next, dampen the earth subgrade but don’t saturate it. Dampening the earth helps cure the concrete at an even rate. If you don’t dampen the subgrade, the dry earth can extract moisture from the concrete causing an uneven cure rate and may not allow you enough time to finish the concrete properly.

Sand or gravel

Before you place concrete on sand or gravel subgrade, cover the subgrade with burlap, tarpaper, or polyethylene. Moisten the burlap with water before you place concrete on the concrete (overlapped). Lap the tarpaper at least one inch and staple it. Lap the polyethylene at least 12 inches. This helps keep the subgrade from extracting moisture and making the concrete set too soon.

Vapor barrier placement

In some cases, your project plans may call for a vapor barrier (moisture barrier) between the finish grade and the concrete. The vapor barrier stops vapor or moisture from passing from the finish grade through the concrete floor. This keeps condensation from damaging the finished flooring. The material used for a vapor barrier is usually a 6-mil polyethylene film that is decay and insect resistant. You must take care not to puncture it when you place reinforcement materials over it because that can cause numerous problems after you place the concrete. One problem that could develop is moisture trapped between the concrete and the barrier could make the concrete shift and/or crack or split. Major structural damage can occur if you puncture the vapor barrier. Most vapor barriers are used in basement floors, where the capillary action is such that not only is a vapor barrier necessary, but a sump pump may also be needed. After the subgrade is compacted you have a finish grade that's ready to receive concrete.

402. Concrete forms

Concrete forms are made for molding concrete. This construction is the reverse of other constructions because the form is inside the finished side. Since the dimensions are all inside measurements, you must create a different mental picture from that required in ordinary construction. The engineer's drawing shows foundation details, but the final features are determined by whoever is constructing them. Depending on their design and purpose, concrete forms may be very simple or very complex. To construct them, we use earth, metal, and/or wood.

Earth forms

Probably the simplest form constructed is the earth form. It can be used in subsurface construction if the soil is stable enough to retain the desired concrete shape. The earth form's advantage is it generally requires less excavation and has greater settling resistance. The obvious disadvantage is a rough surface finish that generally restricts its use to footings and foundations. If the excavation is wider than the footing or if the soil won't retain the trench sides until concrete can be poured, you can use wooden footing forms. These usually are simple, continuous forms anchored with stakes. We drive grade stakes between the forms (fig. 1–11), to assure proper thickness and easier leveling. **NOTE:** You must remove the stakes and fill the holes with concrete before the concrete sets.

Metal forms

The standard metal pavement form is very suitable for forming either square or rectangular floor slabs. Use metal forms when added strength is needed or where you will have to duplicate the construction many times. These 10-foot-long steel forms are held in position with pins wedged in pinholes and secured with end locks (usually three each). The standard pavement form is illustrated in figure 1–12. The weight of the form varies from up to 75 pounds for 8-inch forms to 95 pounds for 12–inch forms; however, new aluminum forms weigh substantially less.

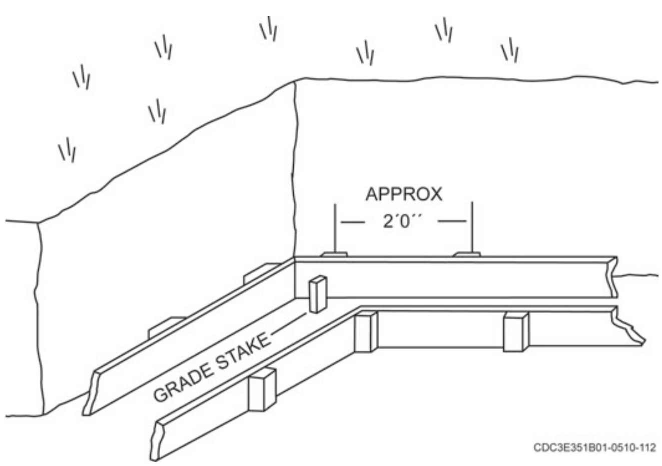

Figure 1–11. Wood form for concrete.

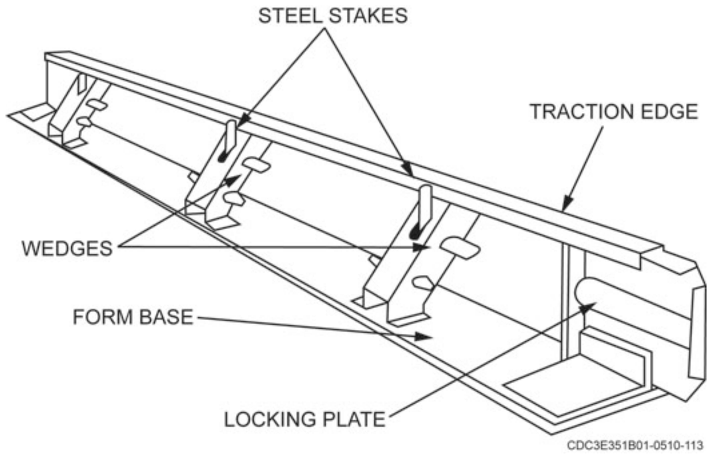

Figure 1–12. Metal form for concrete pavement.

You can use these forms for square or rectangular slabs of any dimension by letting one form end extend past each corner (fig. 1–13). By using this arrangement, you can form slabs even though they aren't in 10-foot multiples. The form end butts against the side of another form to make the corner but may not fit close enough to prevent leakage when the concrete is placed. In this case, you can place a sheet of thin-gauge metal folded to a 90-degree angle to seal the inside corner.

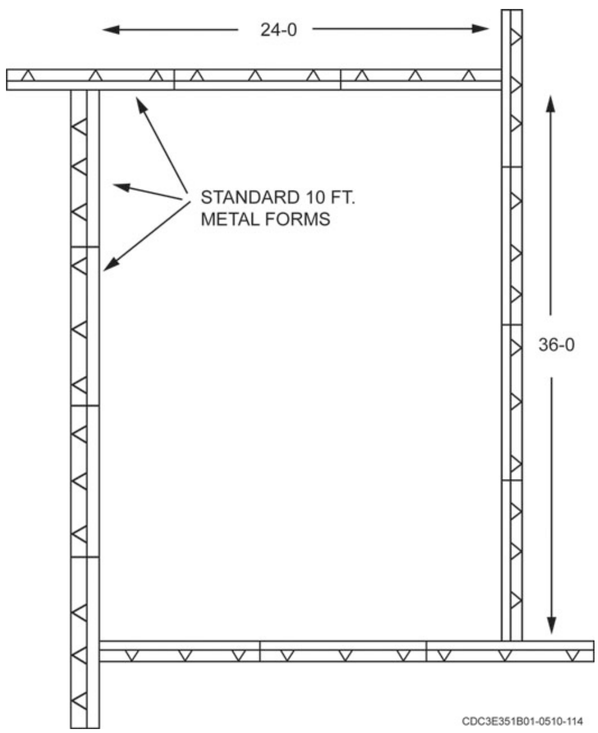

Figure 1–13. Metal forms for a concrete slab.

Wooden forms

Select your form style according to the strength required. Supporters and stakes are usually 2 × 4s and are the same kind and grade specified for wall framing. If you need greater strength, you can use 2 × 6s, 2 × 8s or larger lumber with 1 × 4s as bracing. You can sheath your forms with plywood or retaining boards of ordinary 1-inch finished lumber.

The lumber or plywood width for form construction must be strong enough to hold the concrete in a plastic state. For most formwork, we usually choose ¾-inch-thick exterior grade plywood over lumber. Plywood is economical and warp resistant and can be reused many times. In addition, it requires less backing (stakes and braces) and produces a smoother finished surface than lumber. Depending on your requirements, you can use thinner plywood. For example, plywood that's ¼- or ⅜-inch-thick is useful in forming curved surfaces.

To secure the forms, you normally use 8d nails to fasten 1-inch lumber and ¾-inch plywood. To nail 2-inch lumber, use 16d nails. If the forms are to be reused, use duplex nails. Both lumber and plywood are economical and can be adapted to make various concrete forms. If you maintain them well, you can use them over and over again. Place oil on wooden forms before use so that they'll resist water absorption and concrete adhesion.

Also put oil on wooden forms for columns and wall before installation. You can oil all other forms whenever it's convenient, but you must oil them before you place the reinforcing steel. Form oil spilled on reinforcing material reduces the bond between the steel and the concrete.

Fiber

Fiber forms are prefabricated from impregnated waterproofed cardboard and other fiber materials. Successive layers of fiber are first glued together and then molded in the desired shape. Fiber forms are ideal for round concrete columns and other applications where preformed shapes are feasible since they require no form fabrication at the job site. This saves considerable time and money.

Fabric

Fabric forming is made of two layers of nylon fabric. These layers are woven together, forming an envelope. Structural mortar is injected into these envelopes, forming nylon-encased concrete "pillows." These are used to protect the shorelines of waterways, lakes and reservoirs, and as drainage channel linings. Fabric forming offers exceptional advantages in the structural restoration of bearing piles under waterfront structures. A fabric sleeve with a zipper closure is suspended around the pile to be repaired and mortar is pumped into the sleeve. This forms a strong concrete jacket.

Form design

Forms for concrete construction must support the plastic concrete until it has hardened. Forms must be designed for all the weight to which they are likely to be subjected. This includes the dead load of the forms, the plastic concrete in the forms, the weight of the workmen, the weight of equipment and materials, and the impact due to vibration. These factors vary with each project, but none should be ignored. The ease of erection and removal is also an important factor in the economical design of forms. Platform and ramp structures independent of formwork are sometimes preferred to avoid displacement of forms due to loading and impact shock from workmen and equipment.

Form construction

Strictly speaking, it is only those parts of the formwork that directly mold the concrete that are correctly referred to as the "forms." The rest of the formwork consists of various bracing and tying members. In the below discussion, illustrations are provided to help you understand the names of all the formwork members. You should study these illustrations carefully to help you understand the material in the rest of this lesson.

Foundation forms

The portion of a structure that extends above the ground level is called the superstructure. The portion below the ground level is called the substructure. The parts of the substructure that distribute building loads to the ground are called foundations. Footings are installed at the base of foundations to spread the loads over a larger ground area. This prevents the structure from sinking into the ground. Forms for large footings, such as bearing wall footings, column footings, and pier footings, are called foundation forms.

NOTE: It's important to always place the footings of any foundation system with the bottom of the footing at or below the frost line.

Simple foundation

Whenever possible excavate the earth and use it as a mold for concrete footings. If this is not possible, you must construct a form. Because most footings are rectangular or square, you can build and erect the four sides of the form in panels (fig. 1–14). The following list provides the seven steps in building a simple foundation form:

1. Make the first pair of opposing panels to exact footing width (fig. 1–14a).
2. Then nail vertical cleats (studs) to the exterior sides of the sheathing. Use at least 1 × 2 inch lumber for the cleats, and space them 2½ inches from each end of the exterior sides of the panels and on 2-foot centers between the ends (fig. 1–14a).
3. Next nail two cleats (studs) to the ends of the interior sides of the second pair of panels. The space between these panels should equal the footing length plus twice the sheathing thickness (fig. 1–14b).
4. Then nail cleats on the exterior sides of the panels spaced on 2-foot centers (fig. 1–14b).
5. Erect the panels into either a rectangle or square and hold them in place with form nails. Make sure that all reinforcing bars are in place.
6. Now drill small holes on each side of the center cleat on each panel. These holes should be less than half inch in diameter to prevent paste leakage. Pass No. 8 or No. 9 black annealed iron wire through these holes and wrap it around the center cleats of the opposing panels to hold them together.
7. Mark the top of the footing on the interior side of the panels with grade nails.

For forms four feet square or larger, drive stakes against the sheathing, as shown in figure 1–14. Both the stakes and the 1 × 6 tie braces nailed across the top of the form keeps it from spreading apart. If a footing is less than l-foot deep and 2-feet square, you can construct the form from 1-inch sheathing without cleats. Simply make the side panels higher than the footing depth and mark the top of the footing on the interior sides of the panels with grade nails. Cut and nail the lumber for the sides of the form.

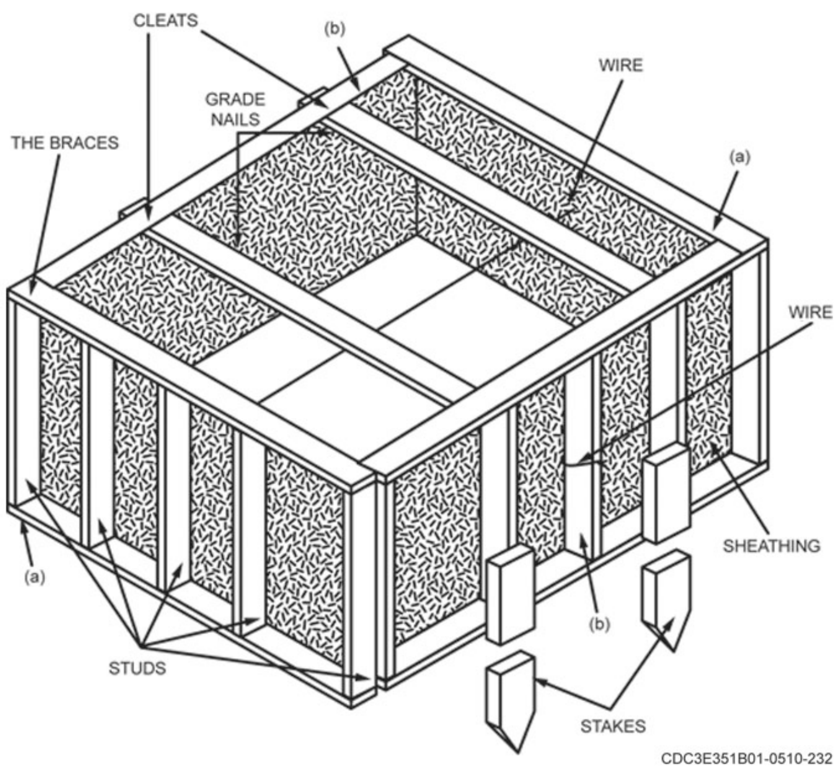

Figure 1–14. Simple foundation.

Foundation and pier forms combined

You can often place a footing and a small pier at the same time. A pier is a vertical member that supports the concentrated loads of an arch or bridge superstructure. It can be either rectangular or round. You build a pier form as shown in figure 1–15. You must provide support for the pier form while not interfering with concrete placement in the footing form. You can do this by first nailing 2 × 4s or 4 × 4s across the footing form (fig. 1–15). These serve as both supports and tie braces. Then nail the pier form to these support pieces.

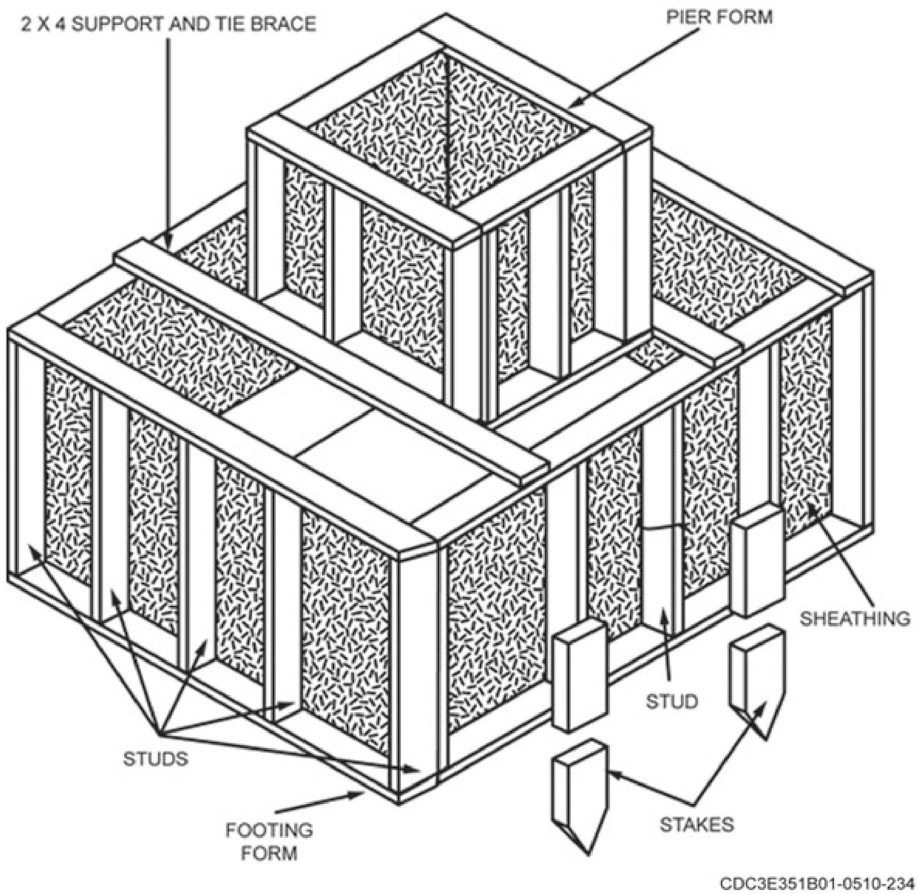

Figure 1–15. Combined foundation and pier form.

Bearing wall footings

Figure 1–16 shows a typical footing formwork for a bearing wall, and figure 1–17 shows bracing methods for a bearing wall footing. A bearing wall, also called a loadbearing wall, is an exterior wall that serves as an enclosure and also transmits structural loads to the foundation. The form sides are 2-inch lumber whose width equals the footing depth. Stakes hold the sides in place while spreaders maintain the correct distance between them. The short braces at each stake hold the form in line.

A keyway is made in the wet concrete by placing a 2 × 2-inch board along the center of the wall footing form. After the concrete is dry, the board is removed. This leaves an indentation, or key, in the concrete. When you pour the foundation wall, the key provides a tie between the footing and wall.

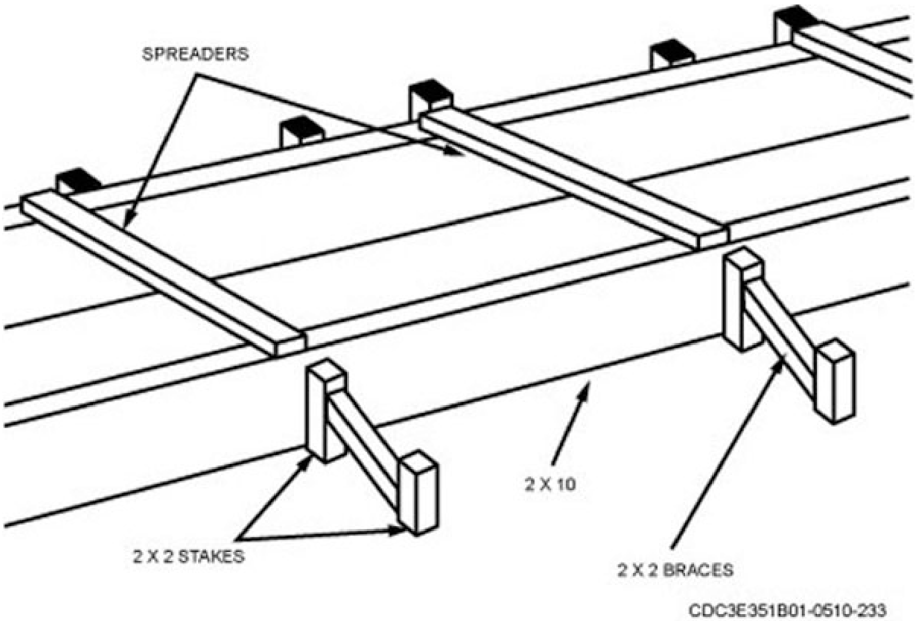

Figure 1–16. Bearing wall footing.

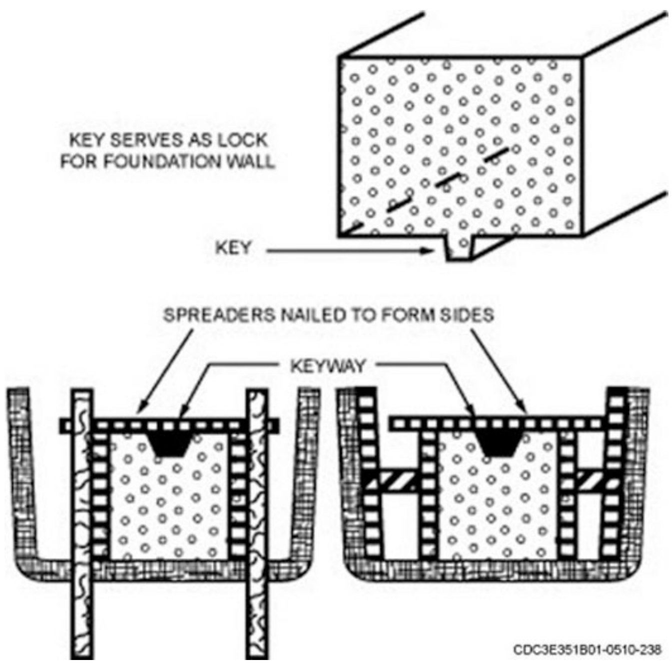

Figure 1–17. Bracing methods.

Pier and column forms

These boxlike forms open at the ends and are braced to prevent bulging or breaking. The two general types are continuous and sectional. A continuous form is suitable for short piers or columns and extends from the bottom to the top of a pier. It's slightly tapered so that it can be lifted from the hardened concrete. We use sectional forms to build columns that can be dismantled and reassembled with bolts and wedges. The sectional form operates on the same principle as the layer unit form for walls. The concrete is poured and left to set; then the form is dismantled and reset for the next section.

Columns

Square column forms are made of wood. Round column forms are made of steel or cardboard impregnated with waterproofing compound. Figure 1–18 shows an assembled column and footing form. After constructing the footing forms build the column form sides and then nail the yokes to them.

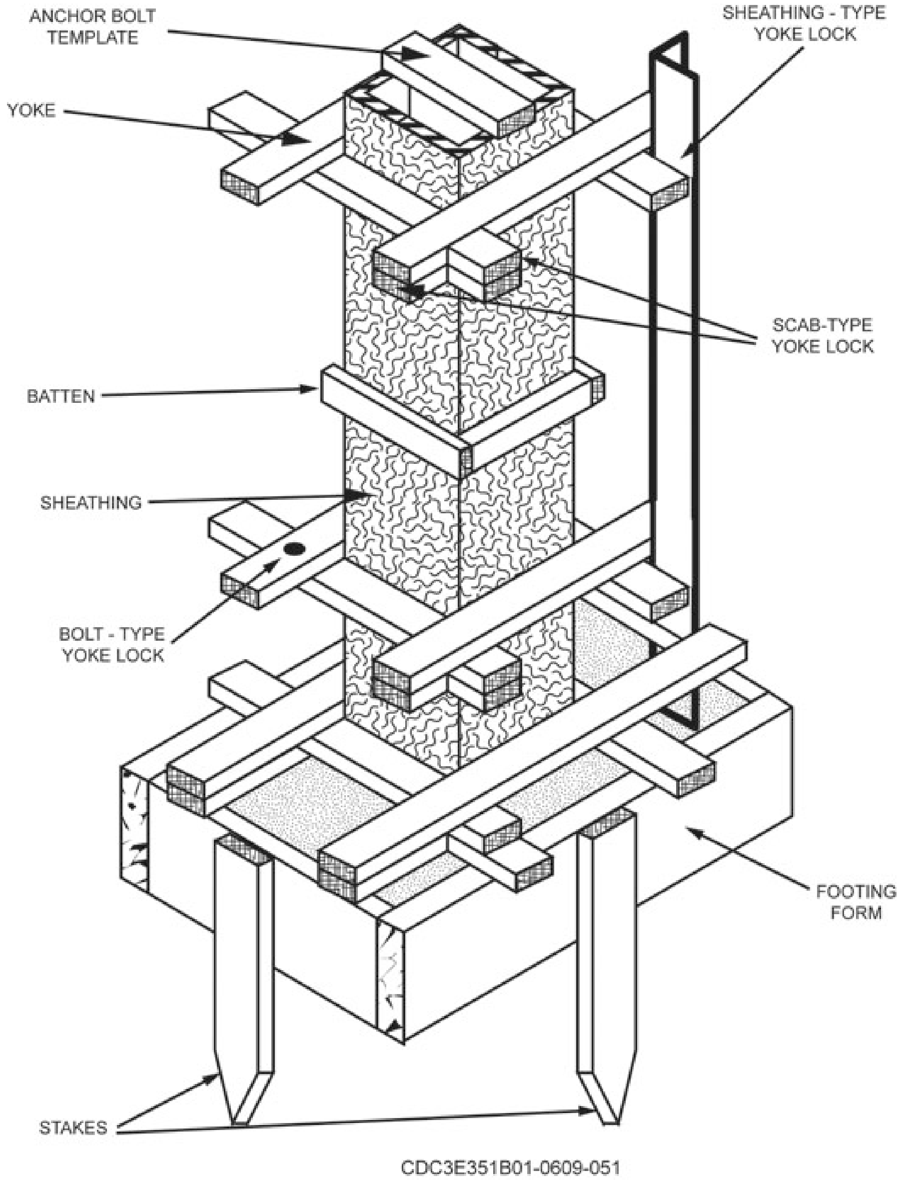

Figure 1–18. Column and footing form.

Figure 1–19 shows a column form with two styles of yokes. View A shows a commercial type, and view B shows yokes made of all-thread bolts and 2-by material. Since the rate of placing concrete in a column form is very high and the bursting pressure exerted on the form by the concrete increases directly with the rate of placing, a column form must be securely braced as shown by the yokes in the figure. Because the bursting pressure is greater at the bottom of the form than it is at the top, yokes are placed closer together at the bottom.

The column form should have a clean-out hole cut in the bottom from which to remove construction debris. Be sure to keep the pieces that you cut out to make the clean-out holes. This way, you can replace them before placing concrete in the column. The intention of the clean out is to make sure that the surface that bonds with the new concrete is clear of all debris.

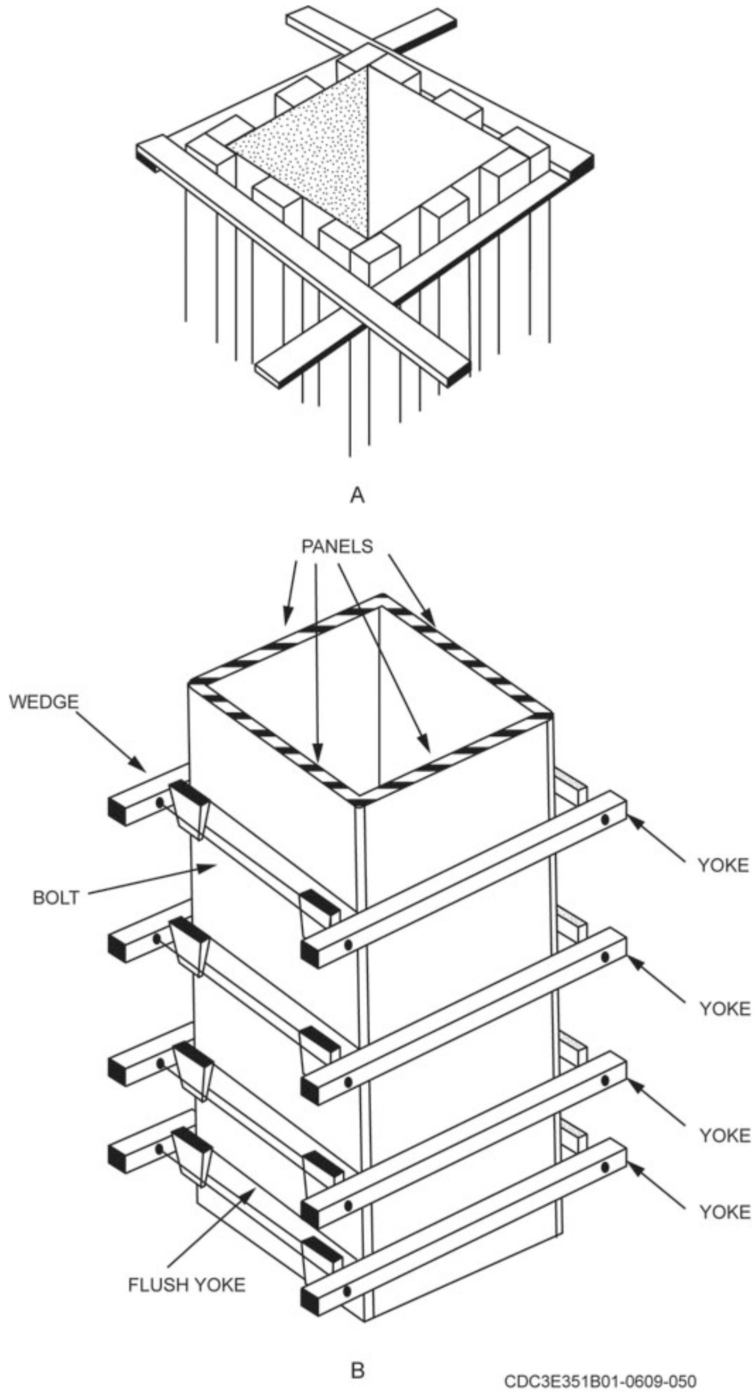

Figure 1–19. Column form.

Slab and sidewalk forms

Forms for slabs are similar to building forms for footings. The sides of the forms are secured in place with stakes. Obviously forms for floor slabs must be level; however, slabs for sidewalks and driveways are designed to shed water. The two most common building slabs are *slab-on-grade* and *monolithic slab*.

Slab-on-grade

This type slab was originally used mostly in warm climates; however with improved construction methods, it is now used in most climates to save money. The concrete slab is placed directly on the ground—as the name implies.

Monolithic slab

A monolithic slab is one where the slab and foundation are constructed during the same pour creating one unit. It consists of the slab with a footing placed around the entire perimeter of the building.

Installation procedures

You can use various methods to construct these forms to the desired elevation. The following method is one method used when batterboards are in place:

- Lay the form boards to the outside of the building lines. Make sure the top of the board is flush with the line.
- Drive stakes along the board at specified distances; approximately two feet apart when using 1–inch lumber and four feet apart when using 2-inch lumber. To aid in screeding, drive the stakes slightly below the top of the forms.
- Secure form boards to the stakes using appropriate fasteners (usually 8d duplex nails).
- Repeat steps for each side.

The only difference with monolithic slabs is that after the forms are in place, you'll need to excavate the earth around the perimeter of the building for the thickened edge. You'll also need to do the same for any interior areas that will hold load-bearing walls.

Wall forms

Wall forms (fig. 1–20) may be built in place or prefabricated depending on shape and desirability of form reuse. Some of the elements that make up wooden forms are wales, braces, sheathing, studs, shoe plates, spreaders, and tie wires.

Construction

Sheathing forms the surfaces of the concrete. It should be as smooth as possible, especially if the finished surfaces are to be exposed. Since the concrete is in a plastic state when placed in the form, the sheathing should be watertight. Tongue-and-groove sheathing gives a smooth, watertight surface; however, plywood is the most widely accepted sheathing material. The sheathing must be reinforced to resist the weight of the plastic concrete. The following is one construction method:

- Run 2 × 4 studs vertically to add rigidity to the sheathing. When the studs extend over four or five feet, reinforce them with double wales that run horizontally and are lapped at the corners. **NOTE:** Double wales also tie the panels together and keep them in a straight line.
- Nail a shoe plate into the foundation or footing. Carefully place it to maintain the correct wall dimension and alignment.
- Tie the studs into the shoe and space them according to the correct design.
- Cut small pieces of wood (spreaders) the same length as the thickness of the wall and place them between the forms to maintain proper distance between forms. **NOTE:** The spreaders are held in place by friction (no nails) and must be removed before the concrete covers them. You should attach a wire to each spreader so that the spreaders can be pulled out after the concrete has exerted enough pressure on the walls.
- Use a double strand of tie wire to hold the forms securely in place.

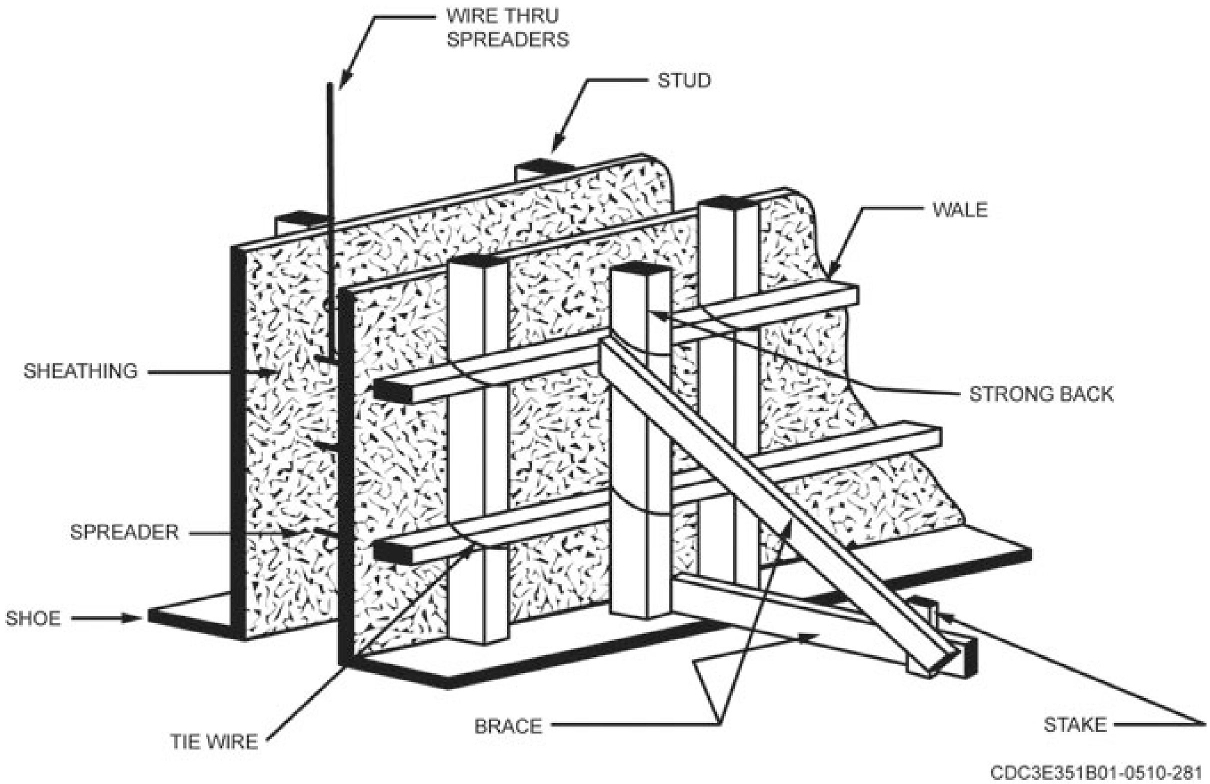

Figure 1–20. Wall form.

Bracing

You can use many different types of braces to add stability to the forms. The most common type you can make is to nail a diagonal member horizontal member to a stake and to a stud or wale (fig. 1–20). The diagonal member should make a 30-degree angle with the horizontal member. You can add additional bracing to the form by placing vertical members (strong backs) behind the wales or by placing vertical members in the corner formed by intersecting wales.

Reinforcement

There are many ways to reinforce wall forms. The three methods we'll discuss are with wire ties, snap ties, and tie rods.

Wire ties

Ties are often used on wall forms to reinforce against displacement. Two types of simple wire ties used with wood spreaders are shown in figure 1–21.

1. Pass the wire around the studs, the wales, and through small holes bored in the sheathing.
2. Place each spreader as close as possible to the studs, and set the tie taut with a wedge, as shown in view A (fig. 1–21), or twist with a small toggle, as shown in view B.
3. Knock out and remove each spreader as the concrete reaches it. Figure 1–22 shows you an easy way to remove the spreaders by drilling holes and placing a wire through them.

NOTE: The parts of the wire that are inside the forms remain in the concrete; the outside surplus is cut off after the forms are removed.

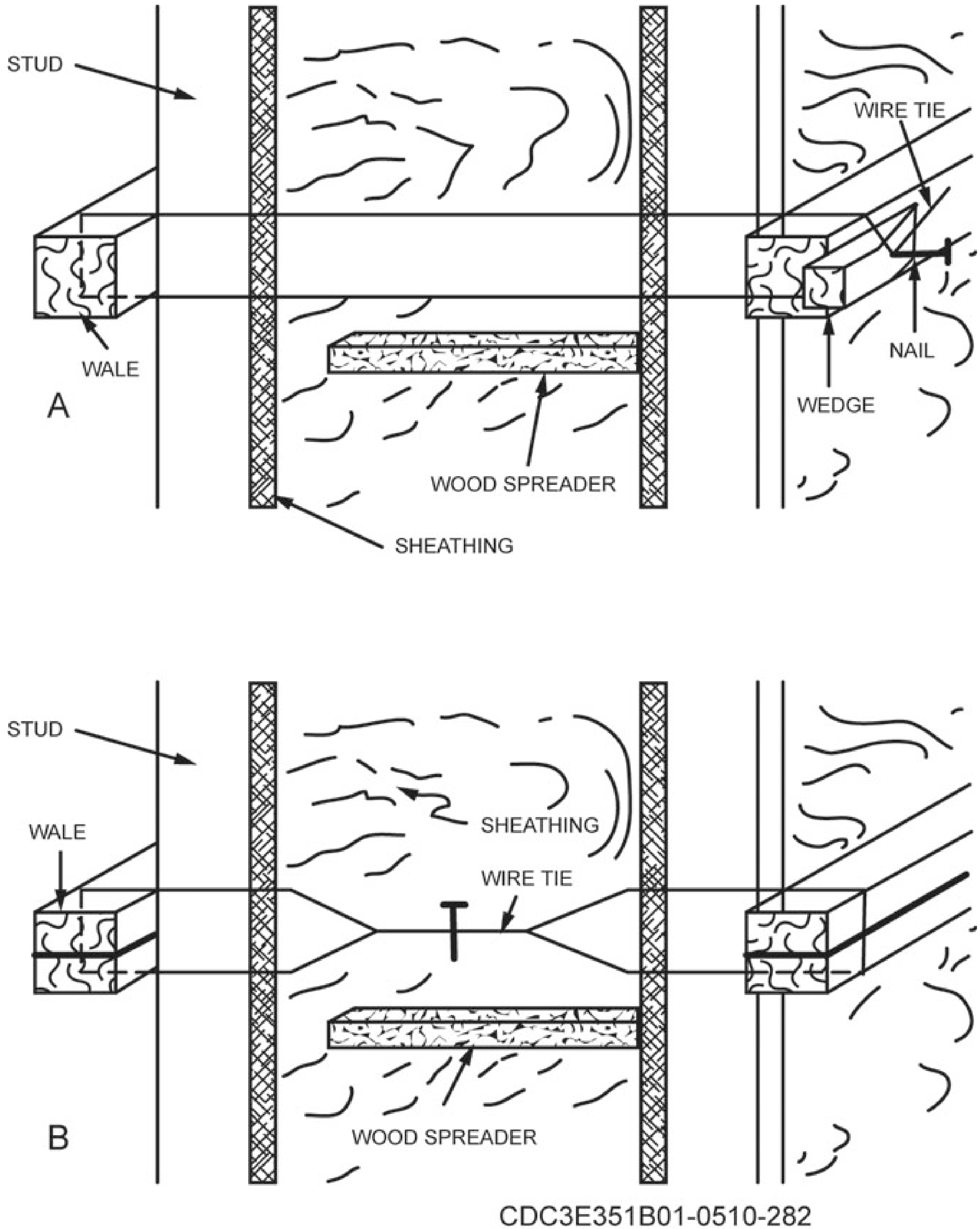

Figure 1–21. Wire ties for wall forms.

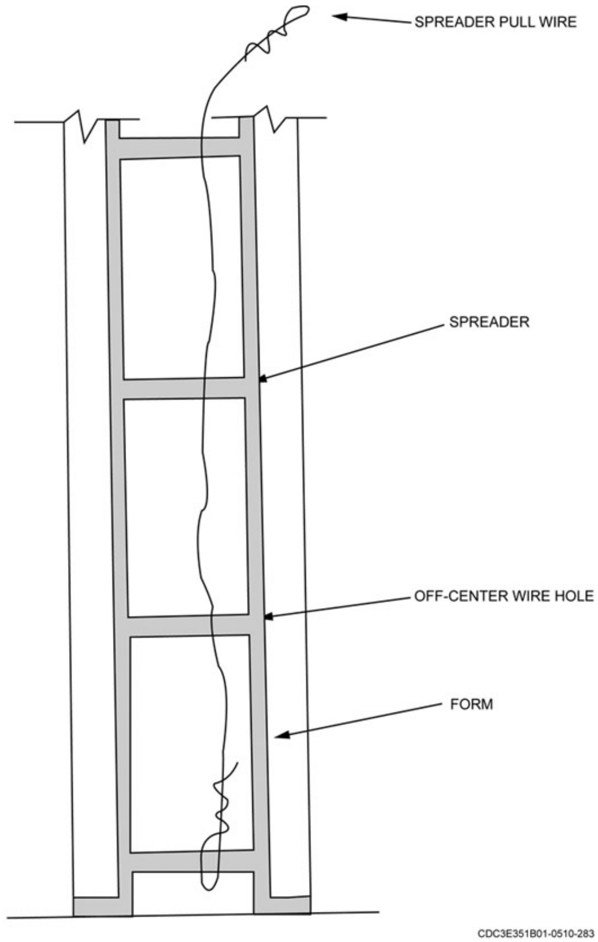

Figure 1–22. Removing wood spreaders.

Snap ties

There are many devices that serve the same function as the wire and spreader. One such device is the snap tie (fig. 1–23). These ties are made in various sizes to fit various wall thicknesses. Use the following six steps to use snap ties:

1. Remove the tie holders from the tie rod.
2. Pass the rod through small holes bored in the sheathing, and also through the wales (which are usually doubled for that purpose).
3. Tap the tie holders down on the ends of the rod to bring the sheathing solidly against the spreader washers.
4. After the concrete has hardened, detach the tie holders to strip the forms.
5. With the forms stripped, use a special wrench to break off the outer sections of rods. The rods break off at the breaking points, located about 1-inch inside the surface of the concrete.
6. Plug the small surface holes remaining with grout, if necessary.

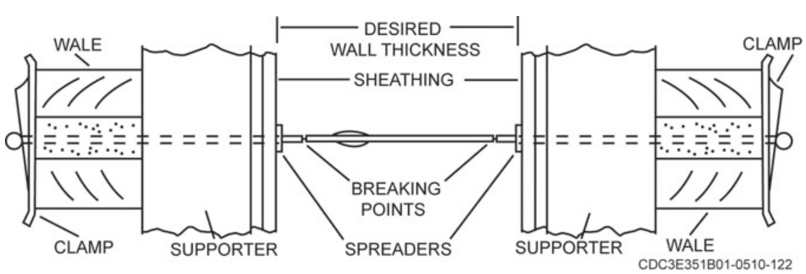

Figure 1–23. Snap tie.

Tie rods

Another type of wall-form tie is the tie rod (fig. 1–24). This rod consists of an inner section that is threaded on both ends and two threaded outer sections. If using tie rods follow the five steps below:

1. Set the inner section with the cone nuts to the thickness of the wall, and pass the outer sections through the wales and sheathing.
2. Secure the clamps (threaded on the outer sections) to bring the forms against the cone nuts.
3. After the concrete hardens, loosen the clamps and remove the outer sections of rod by threading them out of the cone nuts.
4. After the forms are stripped, remove the cone nuts from the concrete by threading them off the inner sections of the rod with a special wrench.
5. Plug the cone-shaped surface holes that remain with grout.

NOTE: The inner sections of the rod remain in the concrete. The outer sections and the cone nuts may be reused indefinitely.

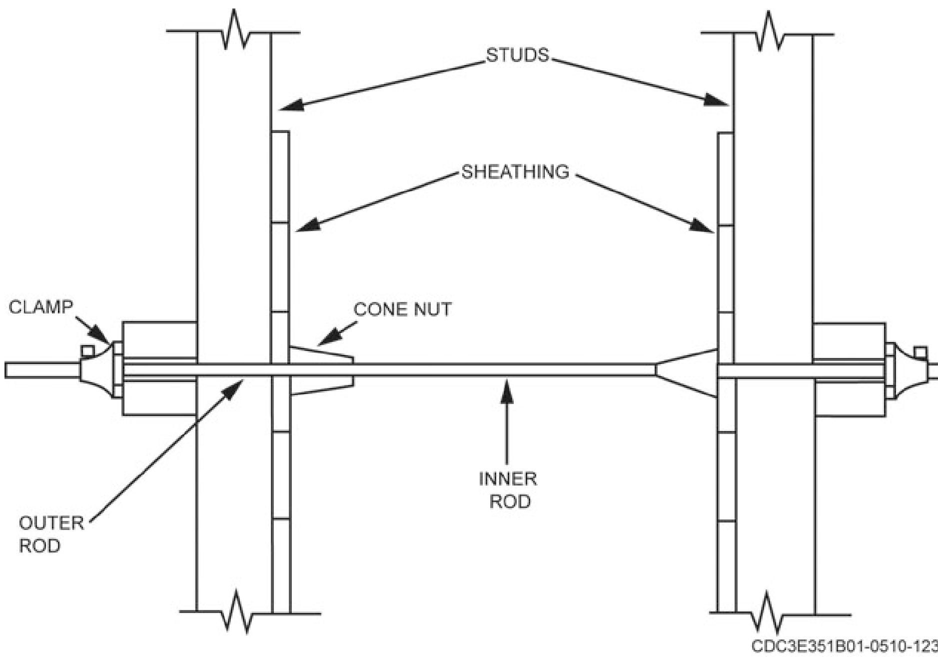

Figure 1–24. Tie rod.

Stair forms

Concrete stairway forms require accurate layout to ensure accurate finish dimensions for the stairway. You should always reinforce stairways with rebar (reinforcing bar) that tie into the floor and landing. Stairways are formed monolithically or formed after the concrete floor slab has set. You must anchor stairways formed after the slab has set to a wall or beam by tying the stairway rebar to rebar projecting from the walls or beams, or by providing a keyway in the beam or wall.

Stair form design

Figure 1–25 shows one way to construct forms for stairs up to three feet wide. The following are four steps to build stair forms:

1. Make the sloping wood platform that serves as the form for the underside of the steps from ¾-inch plywood. The platform should extend about 12 inches beyond each side of the stairs to support the stringer bracing blocks.
2. Shore up the back of the platform with 4 × 4 supports (fig. 1–25). The post supports should rest on wedges for easy adjustment and removal.

3. Cut 2 × 12 planks for the stringers to fit the treads and risers.
4. Bevel the bottom of the 2 × 12 risers for easy form removal and finishing.

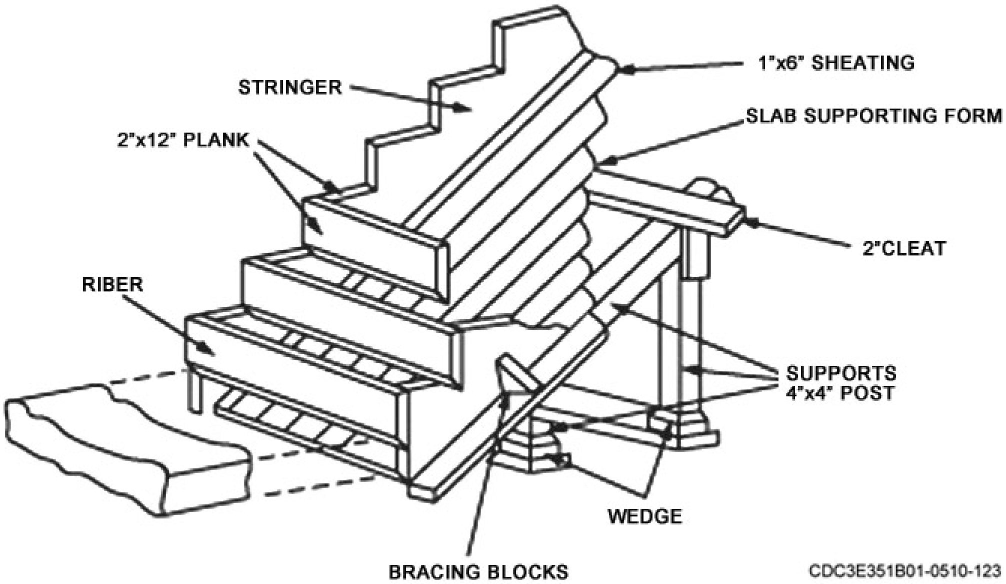

Figure 1–25. Stairway form.

Stairs form design between two existing walls

You should following these four steps when you form stairs between two existing walls (fig. 1–26).

1. Layout each step on the walls.
2. Rip the planks for the steps to width to correspond to the riser height.
3. Bevel the planks on the bottom edge so that you can trowel the whole tread surface (fig. 1–27).
4. Wedge the planks securely in position to the layout lines and brace them between the ends to keep them from bowing outward due to the wet concrete pressure.

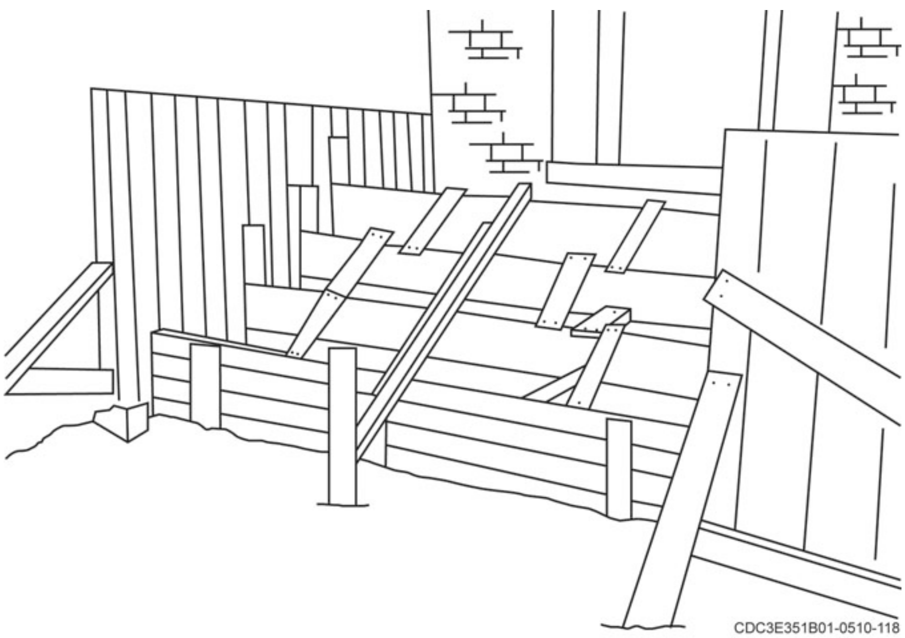

Figure 1–26. Stairway form design between two existing walls.

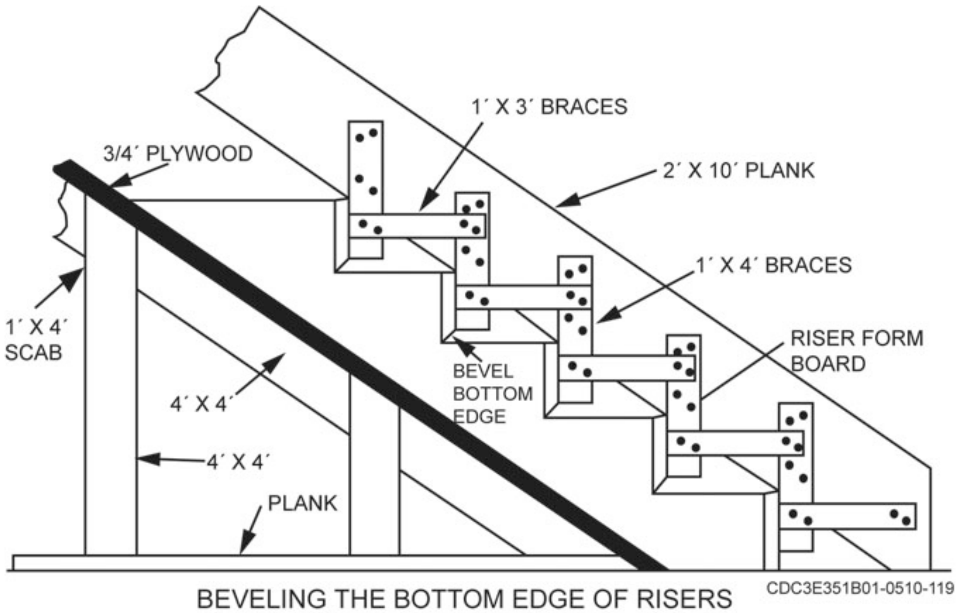

Figure 1–27. Beveling the bottom edge of risers.

Plywood stairs

Plywood may be an easier way to erect forms for concrete stairs. Follow the same procedure you would use when laying out wooden stairs, which are:

1. Cut out the material and space the forms the distance you will need for the step width.
2. Nail 2 × 4 material across it to form the riser.
3. Support and brace the forms to withstand the pressure from the plastic concrete.

Ramps

Ramps let us roll heavy objects up an incline and make elevated areas accessible for handicapped people. The basic form for concrete ramps is fairly easy to construct. You simply measure *up* from the subgrade or a solid surface (such as concrete or asphalt) to the higher level and measure *out* for the ramp length. The Americans with Disabilities Act of 1990 provides the following criteria:

- Ramps for new construction must not slope more than one inch for every 12 inches of run (1:12).
- The ramp's width must not be less than 36 inches with a maximum rise of 30 inches for any run.
- Each ramp must have a level landing at the top and bottom.

NOTE: You'll need to refer the Americans with Disabilities Act for special provisions for alterations to existing buildings. If your angle is too steep, it may be unsafe to use.

Plywood is a popular material to use in constructing small ramps. Use the following five steps below to begin:

1. Mark and cut the plywood and place it in position. With one or two cuts, you'll have both sides formed.
2. Now you can start installing the studs, wales (if necessary), stakes, diagonal bracing, and whatever you need to ensure stability.
3. Install a half-inch-thick bituminous expansion board between any existing concrete to help prevent the freshly poured concrete from cracking due to the expansion and contraction.

4. To make sure the concrete ramp doesn't separate from an existing concrete or asphalt surface, you may install No. 4 rebar (½ inch). Drill the holes to size with a hammer drill and pound the rebar in.
5. Cut more rebar for the ramp's length and width and install them horizontally. You will have to tie all intersecting rebar securely.

NOTE: Where the ramp starts to incline, you should have at least a 2-inch concrete layer for light traffic and a 4-inch layer for heavy traffic. If needed cut and dig out the area to accommodate the extra concrete. If you do it right, this should keep the ramp from cracking under load.

Concrete form removal

The time to remove forms varies from job to job. When possible, leave the forms in place throughout the curing period, but you may have to strip them (i.e., remove them) earlier so you can use them again. Below are a few rules to follow:

- *Never* remove forms before the concrete can support its own weight.
- Before placing any load on the concrete, make sure that it can support the load.
- When you remove (strip) forms, take care to avoid damaging the concrete or the forms.
- When you have to wedge against the concrete, avoid unnecessary damage by using wood wedges rather than a pry bar or other metal tool.
- *Never* rip the forms off. Not only could this damage the concrete and the form, but you could also injure yourself.

Oiling and wetting forms

You should never use oils or other form coatings that may soften or stain the concrete surface, prevent the wet surfaces from water curing, or hinder the proper functioning of sealing compounds used for curing. If you cannot obtain standard form oil or other form coating, you can wet the forms to prevent sticking in an emergency.

Oil for wood forms

Before placing concrete in wood forms, treat the forms with suitable form oil or other coating material to prevent the concrete from sticking to them. The oil should penetrate the wood and prevent water absorption. Almost any light-bodied petroleum oil meets these specifications. On plywood, shellac works better than oil in preventing moisture from raising the grain and detracting from the finished concrete surface. Several commercial lacquers and similar products are also available for this purpose. If you plan to reuse wood forms repeatedly, a coat of paint or sealing compound will help preserve the wood.

Oil for steel forms

Oil wall and steel column forms before erecting them. You can oil all other steel forms when convenient, but they should be oiled before the reinforcing steel is placed. Use specially compounded petroleum oils, not oils intended for wood forms. Synthetic castor oil and some marine engine oils are examples of compound oils that give good results on steel forms.

Applying oil

The successful use of form oil depends on how you apply it and the condition of the forms. The forms should be clean and have smooth surfaces. You should not clean forms with wire brushes because the brushes can mar the form surfaces and cause concrete to stick. Although you can apply the oil or coating with a brush, spray or swab. Cover the form surfaces evenly but do not allow the oil or coating to contact construction joint surfaces or any reinforcing steel in the formwork. Remove all excess oil.

Other coating materials

Fuel oil, asphalt paint, varnish, and boiled linseed oil are also suitable coatings for forms.

NOTE: Be sure to follow the material safety data sheets and all environmental laws when using these products. Some products may not be allowed for use in your area.

403. Concrete reinforcement

You have probably seen modern football stadiums with cantilevered concrete roofs; or you have seen concrete-built hospitals, aircraft hangars, auditoriums, or skyscrapers. Have you ever wondered how these structures were built to withstand the elements and loads that are imposed upon them? The answer is simple—with the help of steel. Concrete is strong under compression but relatively weak under tension. The reverse is true for steel (high tensile strength). Therefore when the two are combined, one makes up for the deficiency of the other. When steel is embedded in concrete in a manner that assists it in carrying imposed loads, the combination is known as reinforced concrete. The steel may consist of welded wire fabric or expanded metal mesh, but more often it consists of reinforcing bars or more commonly "rebar." In this lesson, we will discuss reinforcing bars.

Reinforcement bond

To keep from defeating the reinforcement purposes, there must be a good bond between the steel and the concrete. Bonds are created by natural means and are improved by mechanical means. The natural bonding of concrete to steel is brought about by concrete adhesion and shrinkage during hydration. This makes the concrete grip the metal tightly. To get a mechanical bonding between concrete and steel, the steel is twisted or deformed. There are many steel shapes and sizes available that are designed to fit various requirements.

Reinforcing steel

Reinforcing steel rods or bars (rebar) are available in various sizes. Rolling or stamping a rough pattern on the outside of the rods (deforming) lets the concrete adhere to them better. Rebar is available in diameters ranging from ¼ to 1⅜ inches. You may be asked to find a No. 4 rebar. Rebar is graded with numbers, starting with No. 2 and ending with No. 11. The number equals the total number of eighth inches in the bar. As an example, a No. 3 rebar equals ⅜ inch in diameter. The rebar is usually round in sizes two through eight. The rebar length can range from 20 to 60 feet; local suppliers commonly carry the 20-foot lengths. The individual rods are often woven, welded, or tied together to construct reinforcement units. These units are built and placed together according to a predetermined system or pattern. When used for concrete floors, columns, and slabs, reinforcing steel rods are assembled at the job's beginning so that they are ready for installation when the formwork is completed. Deformed rebar is shown in figure 1–28. A chart showing standard rebar sizes is shown in figure 1–29.

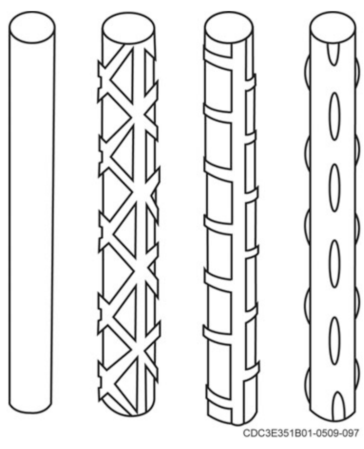

Figure 1–28. Rebar types.

Bar No.	Diameter (in)	Area (sq in)	Weight (lb per ft)
--	* 1/4	0.05	0.17
3	3/8	.11	.38
4	1/2	.20	.67
5	5/8	.31	1.04
6	3/4	.44	1.50
7	7/8	.60	2.04
8	1	.79	2.67
9	** 1 1/8	1.00	3.40
10	** 1 1/4	1.27	4.30
11	** 1 3/8	1.56	5.31

*The 1/4-inch round bar can be obtained only as a plain bar.
**Approximate diameter.

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Figure 1–29. Rebar sizes.

Welded wire fabric

Welded wire fabric (WWF), often referred to as “wire mesh,” or “WWF” comes in rolls and sheets. You must cut them to fit your individual application and lap-tie (splice) the individual fabric sections together to form a continuous fabric sheet. Refer to the project specifications when you must lap WWF; otherwise, the normal splice is made lapping one full square plus two inches.

Cutting WWF

When you work with rolled wire, use extreme caution. For safety, it takes two people to cut a wire section.

NOTE: Remember to use extreme caution and wear gloves and goggles.

When cutting WWF the next six steps is a suggested cutting method.

1. Place the wire roll on the ground.
2. Use two people to unroll the wire just enough for both to stand on the end.
3. The first person remains standing on the end. The second person rolls out the wire to the desired length.
4. The second person remains standing on the unrolled wire and cuts it with bolt cutters.
5. Both people grip the wire and step off of it.
6. In unison, both people flip the wire over and bend it back to allow it to lay flat.

Supports and spacers

Tie wires support and space steel reinforcement units in vertical forms; however, we use anchors and manufactured units, such as precast concrete blocks, chairs, bolsters, and stirrups, to support steel reinforcements for concrete slabs.

Anchors

Anchors (fig. 1–30) secure the steel reinforcing rod ends.

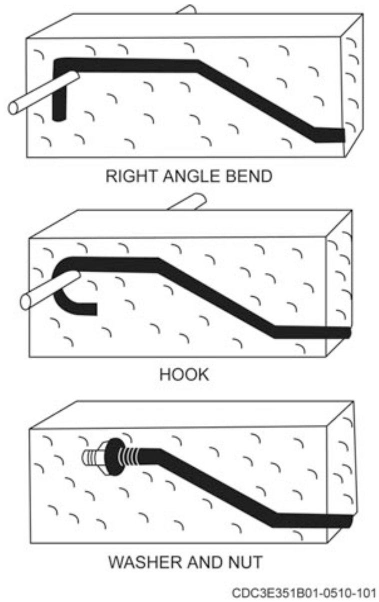


Figure 1–30. Securing rebar ends.

Chairs, bolsters, and stirrups

We use different manufactured devices to support and space reinforcing steel. The steel rods must be spaced correctly in relation to each other and to the formwork sides. Normally we use supports and spacers, called *chairs* and *bolsters*, in forms to support and space the reinforcing material in a concrete slab. We normally use *stirrups* to support and space reinforcing material placed in concrete columns, girders, and beams. Refer to figure 1–31 for examples of several chairs, bolsters, and stirrups in.

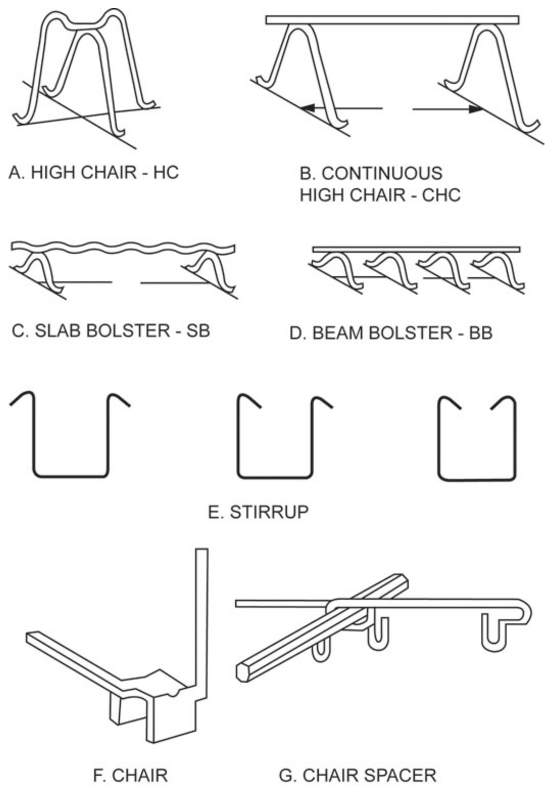


Figure 1–31. Supports and spacers for concrete.

Manufacturing reinforcement units

To build reinforcement units for various structures, you must cut and bend the individual rods to form these units.

Bending reinforcement materials

The following list provides you bending and cutting methods.

- When numerous reinforcing rods with various lengths and shapes are required, bend them on a *bar-bending table* (fig. 1–32).
- Another way is to use a *rebar bender/cutter*. This manually operated tool can cut up to a No. 5 rebar and bend it from zero to 90 degree.
- When you need to cut rebar larger than ⅝-inch, use an oxyacetylene cutting torch. **NOTE:** Heating rebar until it is cherry red and bending it is not recommended because it makes the rebar lose its temper and tensile strength. You must fully understand how to operate an oxyacetylene torch before you use it.
- You can also use shears to cut even the largest size rods. **NOTE**: Allow extra length for the bend radius before you cut.
- For small jobs, you can use a hand hacksaw or a power-driven hacksaw with a carborundum metal blade.

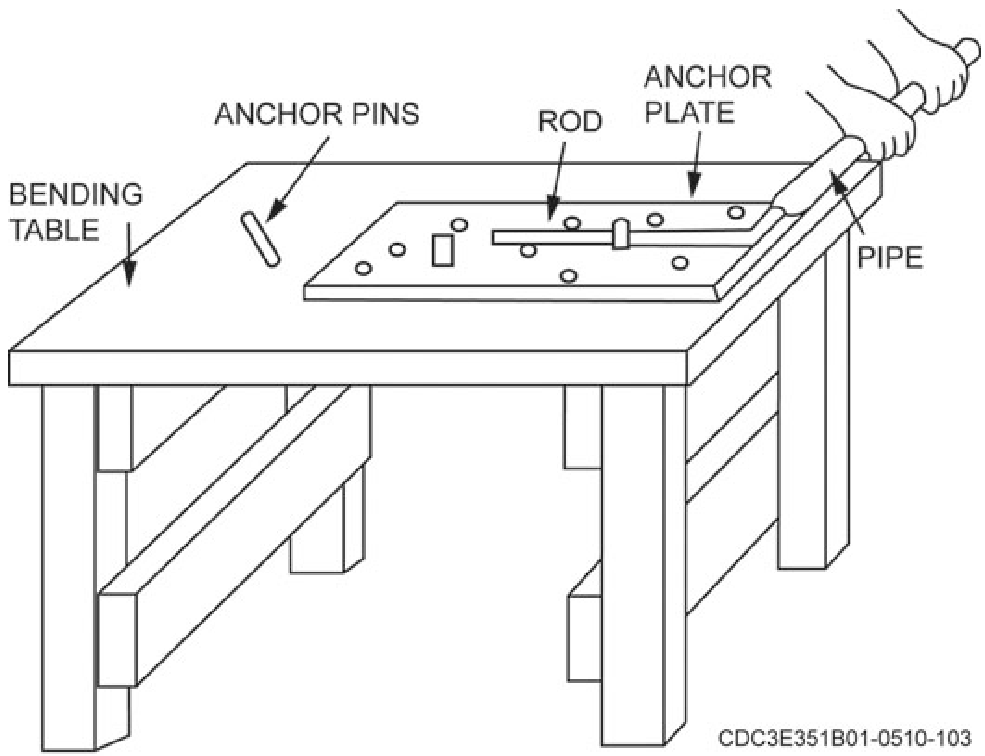


Figure 1–32. Bar-bending table.

When you make joints in reinforcement units, overlap them and tie them with a wire (fig. 1–33). Preassemble this unit before you place it into the form. Figure 1–34 shows an assembled steel-reinforcing column. Tie each wire where it intersects the steel rods. All rebar used in concrete should be rust free and primed before concrete placement. Rebar with rust causes poor bonding with the concrete.

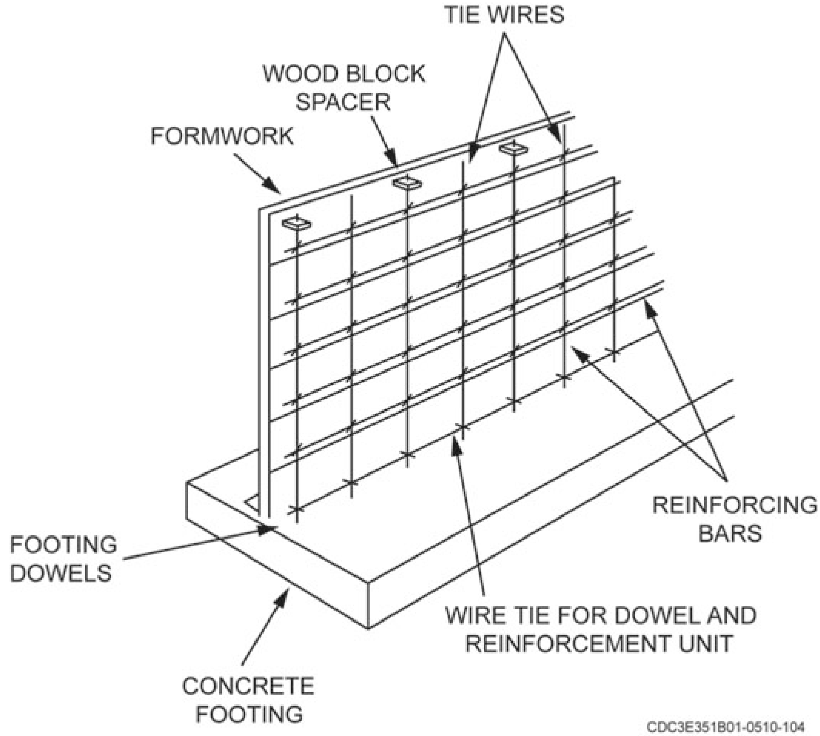


Figure 1–33. Tying rebar.

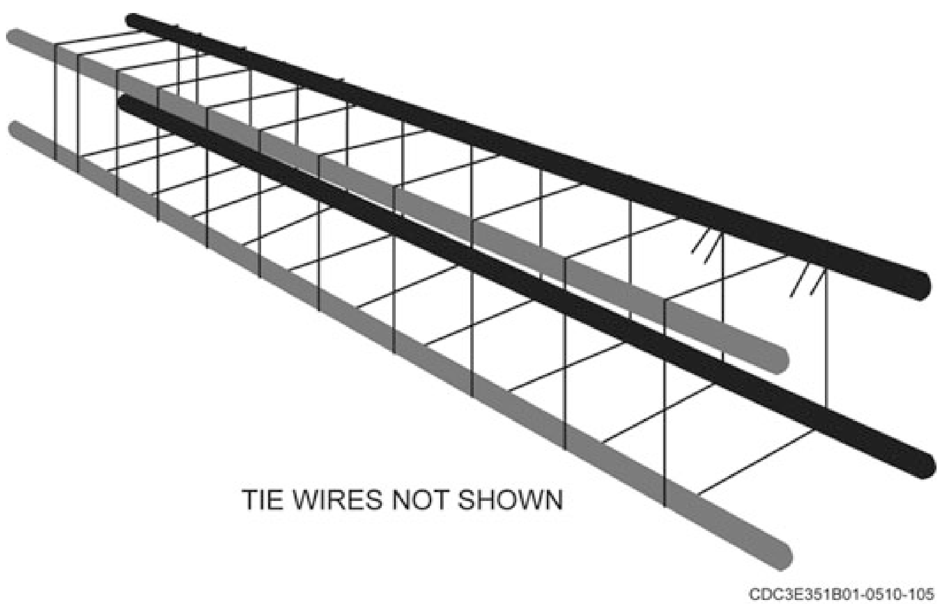


Figure 1–34. Reinforced steel column.

Location for reinforcing steel

The proper location for reinforcing bars is given on the drawings. To make sure that the structure can withstand the loads it must carry, place the steel in exactly the position shown. Secure the bars in position so that they will not move when the concrete is placed. This can be accomplished by using the reinforcing bar supports shown in figures 1–31 and 1–35.

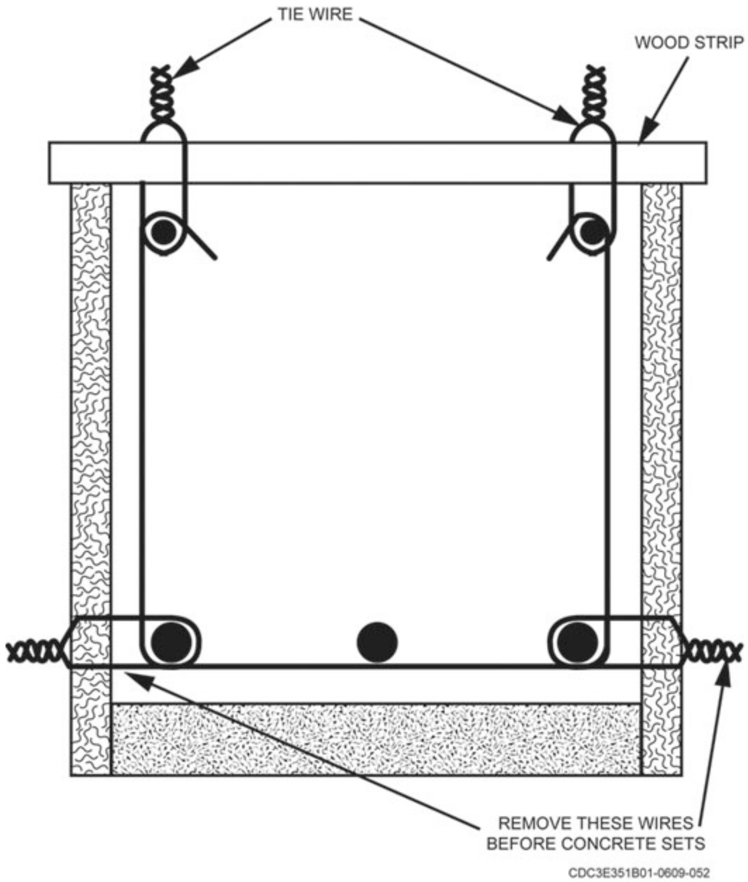


Figure 1–35. Beam reinforcing steel hung in place.

Footings and other principal structural members

Footings and other principal structural members that are against the ground should have at least three inches of concrete between steel and ground.

If the concrete surface is to be in contact with the ground or exposed to the weather after removal of the forms, the protective covering of concrete over the steel should be two inches for bars larger than No. 5 and 1½ inches for No. 5 or smaller.

The protective covering may be reduced to 1½ inch for beams and columns and ¾-inch for slabs and interior wall surfaces, but it should be two inches for all exterior wall surfaces.

Distance from bars

The clear distance between parallel bars in beams, footings, walls, and floor slabs should be a minimum of one inch, or 1⅓ times the largest size aggregate particle in the concrete.

In columns, the clear distance between parallel bars should be a minimum of 1½ times the bar diameter, 1½ times the maximum size of the coarse aggregate, or not less than 1½ inches.

Reinforcing floor slabs

The support for reinforcing steel in floor slabs is shown in figure 1–36. Determine the slab bolster height by the protective cover required over the concrete. You can use concrete blocks in place of slab bolsters; however, *never* use wooden blocks. Bar chairs, like those shown in figure 1–36, are available from commercial sources in heights up to and over 20 inches in height. Tie the bars together at frequent intervals with wire ties to hold them firmly in position.

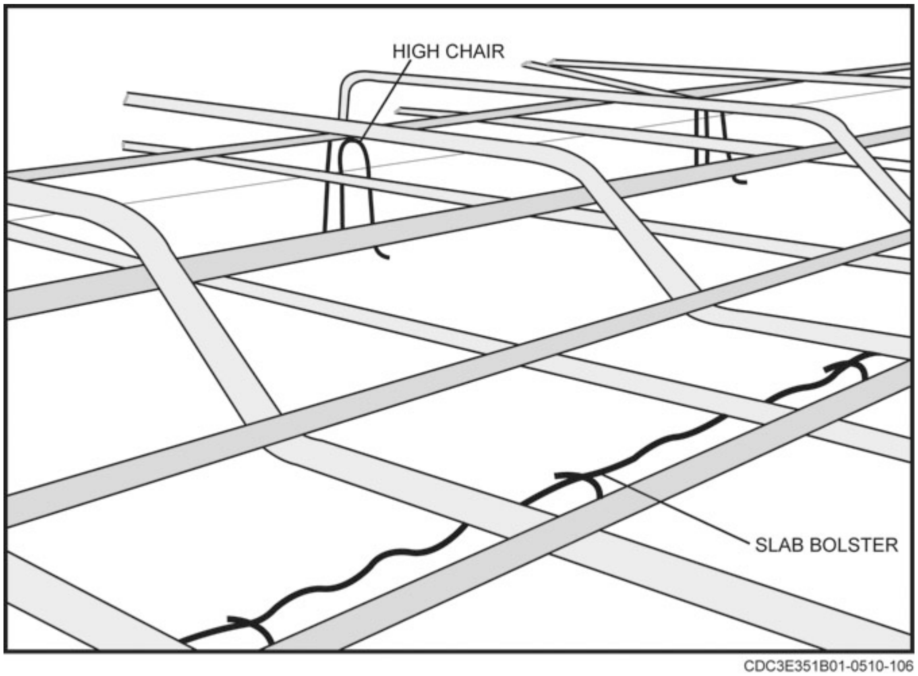


Figure 1–36. Reinforcing steel for a floor slab.

Reinforcing columns

To assemble steel cages for column ties follow the four steps in this list.

1. Lay the vertical bars for one side of the column horizontally across a couple of sawhorses.
2. Slip the proper number of ties over the bars, add the remaining vertical bars, and then space the ties out per the job specifications. You can now hoist and set it as a unit.
3. After the column form is raised, tie it to the dowels or reinforcing steel carried up from below. This holds it firmly in position at the base.
4. Erect the column form and tie the reinforcing steel to the column form at 5-foot intervals, as shown in figure 1–37.

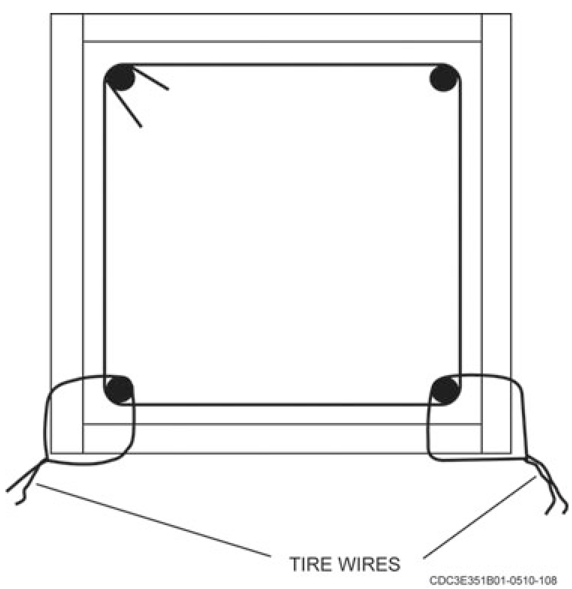


Figure 1–37. Column reinforcement.

Reinforcing beams

Figure 1–38 shows metal supports holding the beam-reinforcing steel in position. Note the position of the beam bolster. Tie the stirrups to the main reinforcing steel per the job specifications. Whenever possible, you should assemble the stirrups and main reinforcing steel outside the form and then place the assembled unit in position.

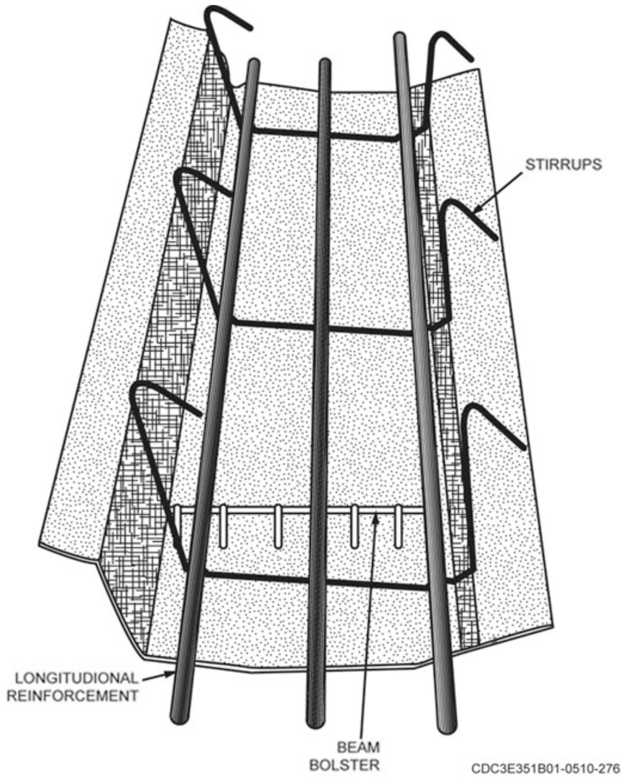


Figure 1–38. Beam reinforcement.

Reinforcing walls

Place steel in walls in the same fashion as for columns, except erect the steel in place. Horizontal steel is tied to vertical steel at least three times in any bar length.

Reinforcing footings

Steel is placed in footings very much as it is placed in floor slabs. Stones, rather than steel supports, may be used to support the steel at the proper distance above the subgrade. Steel mats are generally preassembled and placed in small footings after the forms have been set. A typical arrangement is shown in figure 1–39. Steel mats in large footings are generally constructed in place.

WWF use

WWF is also used as limited reinforcement for concrete footings, walls, and slabs, but its primary use is to control crack widths due to temperature changes.

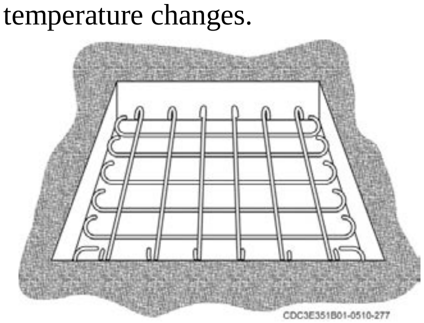


Figure 1–39. Footing reinforcement.

Splicing reinforcing bar

Because rebar is available only in certain lengths, you must sometimes splice it together for longer runs. Where splices are not dimensioned on the drawings, the bars should be lapped not less than 30 times the bar diameter or not less than 12 inches. Tie the bars together with tie wires (fig. 1–40).

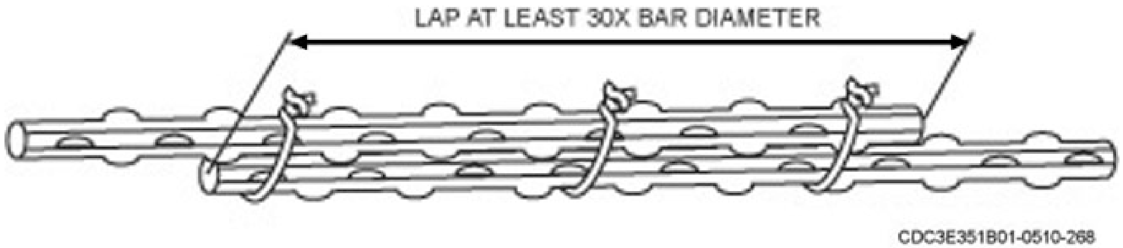


Figure 1–40. Spliced rebar.

Installing anchor bolts

Figure 1–41 shows two popular anchor bolts—the *pipe sleeve* and the *hooked anchor bolt*.

The *sleeve* on the pipe sleeve anchor should be at least one inch larger in diameter than the bolt. This lets the bolt be shifted for exact positioning. Set the sleeve level with the top of the floor when you're finished. Pack it with a rag or newspaper to keep concrete from entering. The anchor bolt and pipe sleeve are good anchors to use in anchoring machinery.

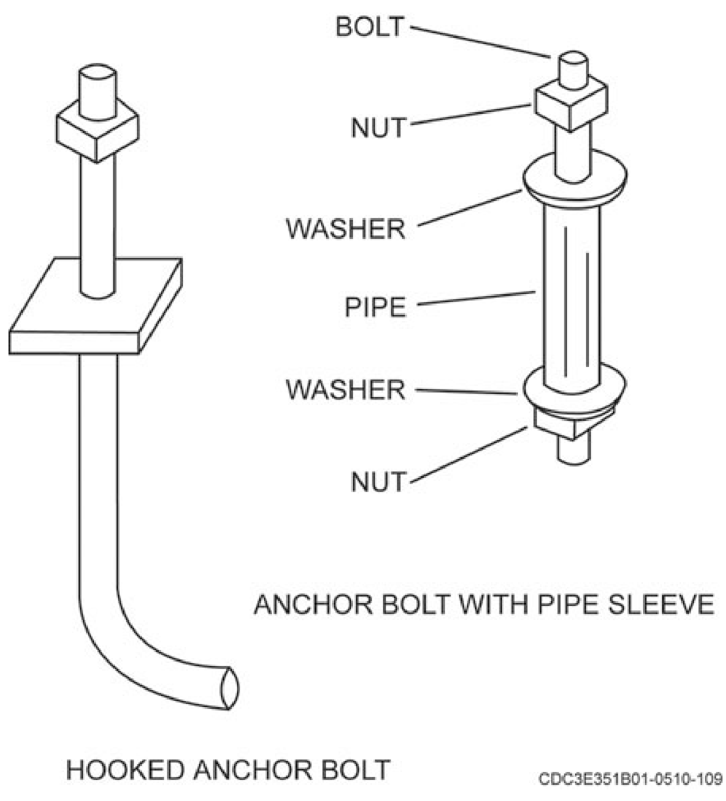


Figure 1–41. Anchor bolt details.

Use the *hooked-type anchor bolt* (J-bolt) to anchor a wood sill to a concrete slab or masonry wall. You can also use the bolt shown in figure 1–42 for this purpose. Take care when you place concrete around these bolts so you don't disturb their alignment.

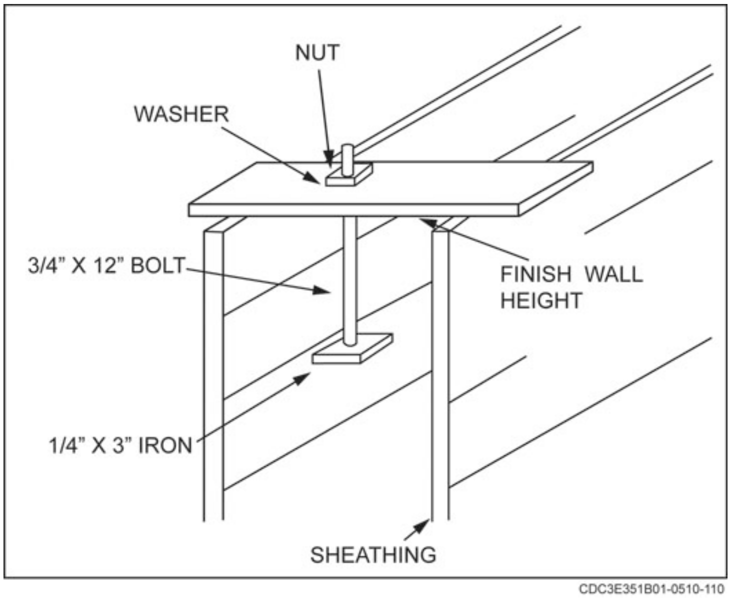


Figure 1–42. Suspended anchor bolt in a wall form.

A template (fig. 1–43) is useful for aligning the anchor bolts. It's a good idea to drill holes $^{1}/_{16}$-inch larger than the bolt to permit minor adjustments.

Always refer to the job specifications for the exact placement. For most concrete construction projects (*not* masonry), one bolt is required 12 inches from each end and six feet on center for one-story homes and four feet on center for two story homes.

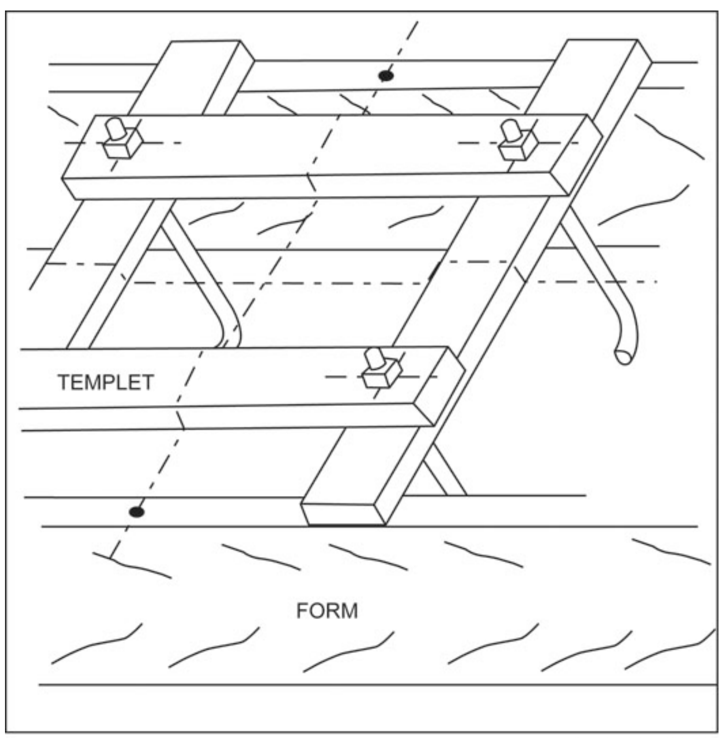


Figure 1–43. Template used to place anchor bolts.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Site preparation

1. What is the first step in locating corner stakes for a building?

2. How do you use the 3–4–5 rule to establish a 90-degree corner?

3. Roughly how far from the building's outside corners do you place the batterboards and why?

4. Match the descriptions in column A with the leveling methods in column B. Column B items are used more than once.

Column A	*Column B*
____ (1) This is a bubble tube set in a metal case.	a. Water level.
____ (2) You must recheck it end-to-end for accuracy.	b. Line level.
____ (3) You must store it carefully to avoid breaking the bubble tube.	
____ (4) When used right this is an extremely accurate tool.	
____ (5) This becomes distorted at great distances.	
____ (6) This may be affected in colder climates.	

5. What is the customary allowance for a working space for constructing forms?

6. What do you use to clean rock or concrete surfaces before you place fresh concrete on them?

7. Why do you moisten a clay subgrade before you place fresh concrete on it?

8. Before you place concrete on a sand or gravel subgrade, what do you use to keep from extracting moisture from the mix and making the concrete set too fast?

9. What problems could a puncture in the vapor barrier cause?

402. Concrete forms

1. What advantages does earth form construction have?

2. How are metal forms held firmly in position?

3. What type and size material is useful for forming curves?

4. When constructing simple foundation forms four feet square or larger, what is used to keep the form from spreading apart?

5. When installing slab forms, how are the form boards laid in relation to the building lines?

6. How are the stakes driven when forming slabs with 1-inch and 2-inch lumber, respectively?

7. When constructing wall forms, how should you reinforce studs that extend over four or five feet?

8. When constructing stairways, how should you always reinforce them?

9. What action should you take when constructing stair forms to allow troweling of the whole tread surface?

10. What is the maximum ramp slope for new construction?

11. What can you do to help prevent cracking due to concrete expansion and contraction when new ramps adjoin existing concrete?

12. When removing forms, what should you use if you must wedge against the concrete?

403. Concrete reinforcement

1. How does concrete bond to steel?

2. What size reinforcement is required if plans call for No. 3 rebar?

3. Why should you *not* heat rebar cherry red for bending?

4. Why would you *not* want to use rusty rebar?

5. For footings and other structural members that are against the ground, how much concrete should be between the steel and the ground?

6. When splicing rebar, what lap distance should you use?

7. For most concrete construction projects (*not* masonry), what is the normal anchor bolt spacing for one and two story homes?

1–2. Concrete Fundamentals

Concrete is one of the most important construction materials. It is comparatively economical, easy to make, offers continuity and solidity, and will bond with other materials. The keys to good-quality concrete are the raw materials required to make concrete and the mix design as specified in the project specifications. In this section, we'll discuss the concrete ingredients and mix designs, mixing and placing techniques, consolidating and finishing procedures, and concrete inspecting and repairing methods.

404. Concrete ingredients and mix designs

Concrete is a synthetic construction material. It is a mixture of cement, fine aggregate (usually sand), coarse aggregate (usually gravel or crushed stone), and water in the proper proportions. The product is not concrete unless all four of these ingredients are present.

Constituents of concrete

The fine and coarse aggregates in a concrete mix are the inert (inactive) ingredients. Cement and water are the active ingredients. You must first thoroughly mix the inert ingredients and the cement together, and then add water. Water causes a chemical reaction (hydration) with the cement that causes the concrete to harden. The hardening process occurs through hydration not by drying out of the mix. Instead of being dried out, concrete must be kept as moist as possible during the initial hydration process. Drying out causes a drop in water content below what's required for satisfactory cement hydration. In fact concrete hardens just as well underwater as it does in air.

Watertightness of concrete

The ideal concrete mix is one with just enough water required for complete cement hydration. However, this results in a mix too stiff to pour in the forms; therefore, a mix fluid enough to be poured in forms always contains more water than needed. This water eventually evaporates leaving voids in the concrete. The larger and more numerous these voids are, the less the watertightness of the concrete. To keep the concrete as watertight as possible, to attain the necessary degree of workability, you must not use more water than the minimum amount required.

General requirements for good concrete

Some general requirements for good concrete are provided in the list below:

1. Use a cement type suitable for the work at hand.
2. Carefully weigh or measure the amount of cement, sand, coarse aggregate, and water required according to project specifications.
3. Make sure it is workable enough to fill the form spaces thoroughly but not too fluid resulting in defects.
4. Handle it properly to prevent segregation.
5. Make sure the concrete is properly cured.

Concrete ingredients

The essential ingredients of concrete are cement, aggregate, and water. A mixture of only cement and water is called cement paste. In large quantities however, cement paste is prohibitively expensive for most construction purposes.

Portland cement

Most cement used today is Portland cement. This is a carefully proportioned and specially processed combination of lime, silica, iron oxide, and alumina. There are five types of Portland cement. The type of construction, chemical composition of the soil, economy, and the finished concrete requirements influence which kind to use.

Type I

Type I cement is general-purpose cement for concrete that does not require any of the special properties of the other types. In general, use type I cement for areas that are not subjected to sulfate attack. Type I Portland cement is for pavement and sidewalk construction, reinforced concrete buildings and bridges, railways, tanks, reservoirs, sewers, culverts, water pipes, masonry units, and soil-cement mixtures. Type I cement reaches its design strength in about 28 days.

Type II

Type II cement is modified to resist moderate sulfate attack. It also usually generates less heat of hydration and at a slower rate than type I. A typical application is for drainage structures where the sulfate concentrations in either the soil or groundwater are higher than normal but not severe. Type II cement is also used in large structures where its moderate heat of hydration produces only a slight temperature rise in the concrete. Type II cement reaches its design strength in about 45 days.

Type III

Type III cement is high-early strength cement that produces design strengths at an early age, usually seven days or less. It has a higher heat of hydration and is more finely ground than type I. Type III permits fast form removal and, in cold weather construction, reduces the period of protection against low temperatures. Richer mixtures of type I can obtain high-early strength, but type III produces it more satisfactorily and economically. However, use it cautiously in concrete structures having a minimum dimension of 2½ feet or more—the high heat of hydration can cause shrinkage and cracking.

Type IV

Type IV cement has a low heat of hydration and is intended for applications requiring a minimal rate and amount of heat of hydration. Its strength also develops at a slower rate than the other types. Type IV is used primarily in very large concrete structures, such as gravity dams, where the temperature rise from the heat of hydration might damage the structure. Type IV cement reaches its design strength in about 90 days.

Type V

Type V cement is sulfate-resistant and should be used where concrete is subjected to severe sulfate action, such as when the soil or groundwater contacting the concrete has a high sulfate content. Type V cement reaches its design strength in about 60 days.

Aggregates

The material combined with cement and water to make concrete is called aggregate. Aggregate makes up 60 to 80 percent of concrete volume. It increases the strength of concrete, reduces the shrinking tendencies of the cement, and is used as economical filler.

Types

Aggregates are divided into fine (usually consisting of sand) and coarse categories. For most building concrete, the coarse aggregate consists of gravel or crushed stone up to 1½ inch in size. However in massive structures, such as dams, the coarse aggregate may include natural stones or rocks ranging up to six inches or more in size.

Purpose of aggregates

The large, solid coarse aggregate particles form the basic structural members of the concrete. The voids between the larger coarse aggregate particles are filled by smaller particles. The cement and water form a paste that binds the aggregate particles solidly together when it hardens.

Aggregate sieves

When determining aggregate size (course or fine), the higher the number, the finer the sieve. Aggregates larger than No. 4 are all course; those smaller are all fines. No. 4 aggregates are the dividing point (considered either course or fine). **NOTE:** Any material that passes through the No. 200 sieve is too fine to be used in making concrete.

Quality standards

Since 60 to 80 percent of the volume of the finished concrete consists of aggregate, it is imperative that the aggregate meet certain minimum quality standards. It should consist of clean, hard, strong, durable particles free of chemicals that might interfere with hydration. The aggregate should also be free of any superfine material, which might prevent a bond between the aggregate and the cement-water paste. The undesirable substances most frequently found in aggregate are dirt, silt, clay, coal, mica, salts, and organic matter.

Handling and storage

Aggregate has a natural tendency towards segregation. *Segregation* is when particles of the same size gather together during loading, transporting or otherwise disturbing the material. Always handle and store aggregate stored in a method that minimizes segregation.

Do not build stockpiles up in cone shapes (i.e., dropping successive loads at the same spot). This procedure causes segregation. Instead build them up in layers of uniform thickness dumping successive loads alongside each other (fig. 1–44).

Water

The two principal functions of water in a concrete mix are to effect hydration and improve workability. Water used in mixing concrete must be clean and free from acids, alkalis, oils, and organic materials. Most specifications recommend that the water used in mixing concrete be suitable for drinking (potable).

Seawater can be used for mixing unreinforced concrete if there is a limited supply of fresh water. Tests show that the compressive strength of concrete made with seawater is 10 to 30 percent less than that obtained using fresh water. Seawater is not suitable for use in making steel-reinforced concrete because of the risk of corrosion of the reinforcement, particularly in warm and humid environments.

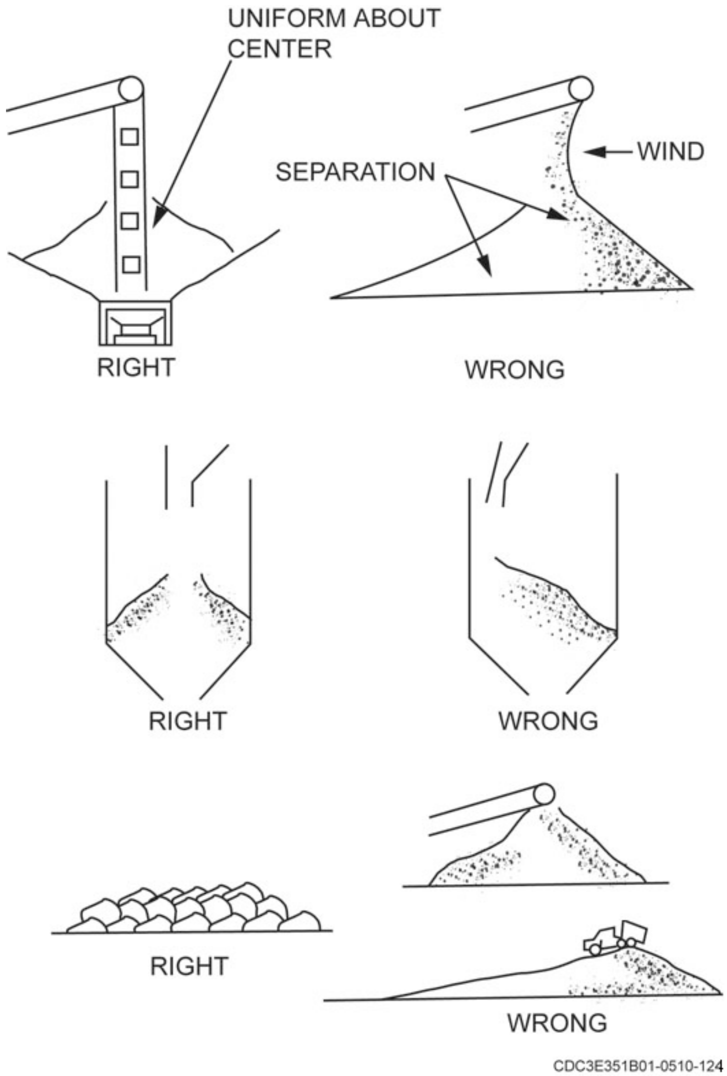


Figure 1–44. Handling aggregates.

Admixtures

Admixtures include all materials added to a mix other than Portland cement, water, and aggregates. Admixtures are sometimes used in concrete mixtures to improve certain qualities, such as workability, strength, durability, watertightness, and wear resistance. They may also be added to reduce segregation, reduce the heat of hydration, entrain air and accelerate, or retard setting and hardening. **NOTE:** You can often achieve the same results by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures (except air-entraining admixtures when necessary).

Workability agents

Materials, such as hydrated lime and bentonite, are used to improve workability.

Air-entraining agents

Air-entraining agents add millions of minute disconnected air bubbles to cement paste to change the basic concrete mix and increases durability, workability, and strength. The acceptable amount of entrained air in a concrete mix, by volume, is three to seven percent. Most air-entraining agents are in liquid form for use in the mixing water—just make sure you choose a type compatible with the cement you are using.

Accelerator

The only accepted accelerator for general concrete work is calcium chloride with not more than two percent by weight of the cement being used. Add this accelerator to the mix water to speed up the strength gain. Although the final strength is not affected, the strength gain for the first 7 days is greatly affected. The strength gain for the first 7 days can be as high as 1,000 pounds per square inch (psi) over that of normal concrete mixes.

Retarders

The accepted use for retarders is to reduce the rate of hydration. This permits the placement and consolidation of concrete before initial set.

Cement storage

Portland cement is packed in cloth or paper sacks, each weighing 94 pounds. A 94-pound sack of cement amounts to about one cubic foot by loose volume. Cement will retain its quality indefinitely if it does not come in contact with moisture. If it absorbs an appreciable amount of moisture in storage; it sets more slowly and strength is reduced. Store sacked cement in warehouses or sheds made as watertight and airtight as possible. Close all cracks in the roof and make sure there are not any openings between the walls and roof. Keep all doors and windows closed.

Stack the sacks against each other to prevent air circulation between them, but do not be stack them against the outside walls. Cover the stacks with tarpaulins if they are to stand undisturbed for long intervals (fig. 1–45).

If you must store sacks in the open, place them on raised platforms and cover them with waterproof tarps. The tarps should extend beyond the edges of the platform to deflect water away from the platform and the cement.

Cement sacks stacked in storage for long periods sometimes acquire a hardness called warehouse pack. You can usually loosen this by rolling the sack around. However, do not use cement that has lumps or is not free flowing.

Concrete mix design

Before proportioning a concrete mix, you need information concerning the job, such as size and shapes of structural members, required strength of the concrete and exposure conditions. The end use of the concrete and conditions at time of placement are additional factors to consider.

Ingredient proportions

The ingredient proportions for the concrete on a particular job are usually set forth in the specifications. The table below shows examples of normal concrete-mix design.

Ingredient Proportions						
CLASS OF CONCRETE (FIGURES DENOTE SIZE OF COURSE AGGREGATE IN INCHES.	ESTIMATED 28-DAY COMPRESSIVE STRENGTH (POUNDS PER SQUARE INCH).	CEMENT FACTOR BAGS (94 POUNDS) OF CEMENT PER CUBIC YARD OF CONCRETE FRESHLY MIXED.	MAXIMUM WATER (GALLONS) PER BAG (94 POUNDS) OF CEMENT.	FINE AGGREGATE RANGE IN PERCENT OF TOTAL AGGREGATE BY WEIGHT.	APPROXIMATE WEIGHTS OF SATURATED SURFACE-DRY AGGREGATES PER BAG (94 POUNDS) OF CEMENT.	
					FINE AGGREGATE POUNDS.	COURSE AGGREGAT E POUNDS.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
E–0.5	3,000	6.50	6.75	50–58	238	203
E–0.75	3,000	6.10	6.75	45–53	240	249
E–1	3,000	5.80	6.75	40–48	233	297
E–1.5	3,000	5.35	6.75	36–44	239	359
E–2	3,000	5.05	6.75	33–41	241	410
E–2.5	3,000	4.90	6.75	31–39	238	441
E–3.5	3,000	4.60	6.75	28–36	237	503

You can see in the above table, the formula for 3,000 psi concrete is 5.80 bags of cement per cubic yard, 233 pounds of sand (per bag of cement), 297 pounds of coarse aggregate (per bag of cement) and a water-cement ratio of 6.75 gallons of water to each bag of cement. These proportions are based on the assumption that the inert ingredients are in a saturated surface-dry condition. Meaning that they contain all the water they are capable of absorbing, but no additional free water over and above this amount.

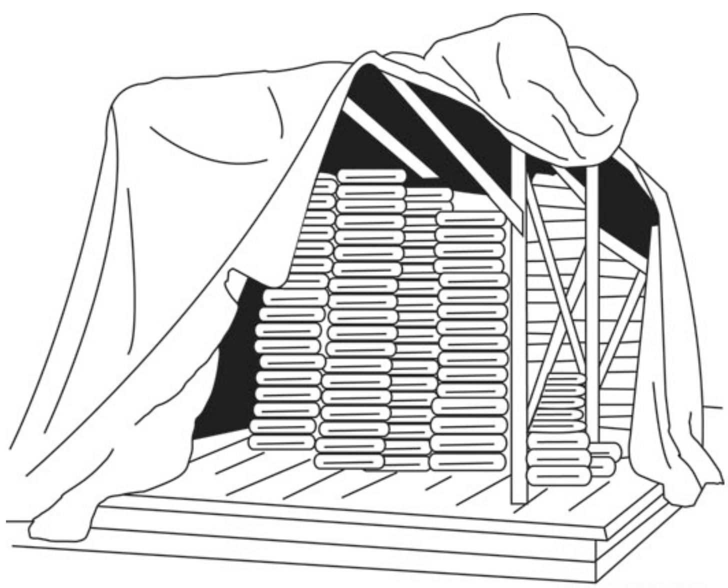


Figure 1–45. Cement storage.

Out in the field, the saturated surface-dry condition almost never exists. The amount of free water in the coarse aggregate is usually small enough to be ignored, but you must usually adjust the ingredient proportions for the fine aggregate. The following are some suggested actions to take if an adjustment is needed for fine aggregate:

- Since free water in the fine aggregate increases its measured volume or weight over that of the sand itself, the specified volume or weight of sand must be increased to offset the volume or weight of the water in the sand.
- Reduce the number of gallons of water used per sack of cement to allow for the free water in the sand. The amount of water actually added at the mixer must be the specified amount per sack less the amount of free water that is already in the ingredients in the mixer.

Material estimates

When tables are not available for determining material quantities required for one cubic yard of concrete, you can use rule 41 or 42 for a rough estimation. According to this rule, it takes either 41 or 42 cubic feet of the combined dry amounts of cement, sand, and aggregates to produce one cubic yard of mixed concrete. Use rule 41 to calculate the quantities of material for concrete when the size of the coarse aggregate is one inch or less. Use rule 42 when the size of the coarse aggregate is more than one inch but not over 2½ inches.

For estimating the amount of dry materials needed to mix one cubic yard of concrete, rules 41 and 42 work in the same manner. The decision on which rule to use depends upon the size of the aggregate. Let’s say your specifications call for a 1:2:4 mix (1 = cement; 2 = sand, 4 = course aggregates) with 2-inch coarse aggregates, which means you use rule 42. First, add 1:2:4, which gives you 7 (your factor). Then compute your material requirements below.

Divide your rule (42) by the factor (7) obtained by adding the numbers used in the mix (42 ÷ 7 = 6). This gives you 6 as the prime factor. You then multiply 6 times each ingredient in the mix.

1 x 6 = 6 bags, or 6 cubic feet of cement;

2 x 6 = 12 cubic feet of sand;

4 x 6 = 24 cubic feet of course aggregates.

Add your total dry materials, 6 + 12 + 24 = 42, to determine if your calculations are correct.

Slump testing

Slump testing is a means of measuring the consistency of concrete using a slump cone (fig. 1–46). The cone is made of galvanized metal with an 8-inch diameter base, a 4-inch diameter top and a 12-inch height. A ⅝-inch by 24-inch tamping rod is also needed. The tamping rod should be smooth and bullet-pointed. **NOTE:** Do not use a piece of rebar.

When you perform a slump test adhere to this list of procedures.

1. Dampen the cone and place it on a flat, moist, nonabsorbent surface.
2. Fill the cone in three layers, each approximately one-third the *volume* of the cone. When placing each scoop in the cone, move the scoop around the edge of the cone as the concrete slides from it, distributing the concrete symmetrically within the cone.
3. Rod each layer with 25 strokes. Distribute the strokes uniformly over the cross section of the cone and penetrate into the underlying layer. Rod the bottom layer throughout its depth.
4. If the cone becomes overfilled, use a straightedge to strike off the excess concrete flush with the top. Immediately remove the cone from the concrete by raising the cone carefully in a vertical direction.
5. Measure the slump immediately after removing the cone. You determine the slump by measuring the difference between the height of the cone and the height of the specimen (figure 1–46).
6. Record the slump in terms of inches—the difference in the height of the cone (12 inches) versus the height of the free standing concrete.

NOTE: To determine the concrete's cohesiveness, workability, and placability, gently tap the side of the mix with the tamping rod after completing the slump measurement. In a well-proportioned mix, tapping only causes it to slump lower; it doesn't crumble apart or segregate. If the concrete crumbles apart, it is over sanded. If it segregates, it is under sanded.

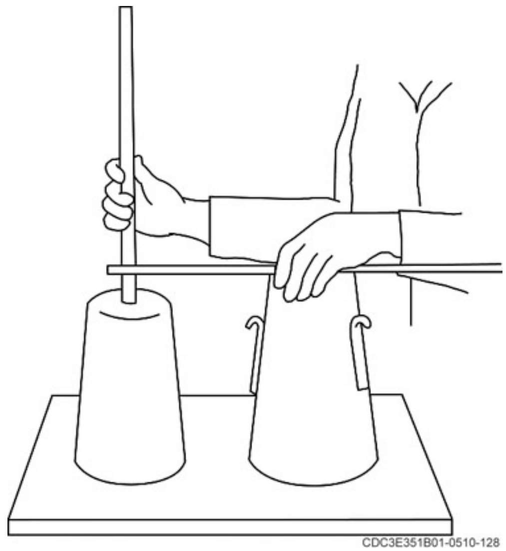


Figure 1–46. Measurement of slump.

Workability

A mix must be workable enough to fill the form spaces completely, with the assistance of a reasonable amount of shoveling, spading and vibrating. Workability varies directly with fluidity, since a fluid or "runny" mix fills the form spaces more readily than a dry or "stiff' mix. The workability of a mix is determined by the slump test. The amount of the slump, in inches, is the measure of the concrete's workability—the more the slump, the higher the workability.

The slump can be controlled by a change in anyone or all of the following: amount of aggregates, proportion of aggregates, or moisture content. If the moisture content is too high, you should add more cement to maintain the proper water-cement ratio. If the water proportion were changed, the water-cement ratio would be upset.

Never add more water without making the corresponding adjustment in the cement content. As you gain experience, you will discover that making very minor changes in the amount of fine or coarse aggregate can make adjustments in workability. Generally everything else remaining equal, an increase in the proportion of fine aggregates stiffens a mix, whereas an increase in the proportion of coarse aggregates loosens a mix.

NOTE: Never alter the proportions set forth in a specification without proper authorization.

405. Mixing and placing concrete

Concrete is mixed either by hand or machine. No matter which method is used, you must follow well-established procedures if you expect finished concrete of good quality. An oversight in proper concrete mixing, whether through lack of competence or inattention to detail, cannot be corrected later. In this lesson, we discuss methods used for mixing and placing concrete. Let's begin with hand mixing.

Hand mixing

There are many ways to hand-mix concrete. **NOTE:** You should not try to hand-mix a batch of concrete much larger than one cubic yard. The list below provides the equipment needed to hand mix concrete.

- Watertight metal or wooden platform or mortar boat.
- Two shovels or two mortar hoes.
- Metal-lined measuring box (fig. 1–47).
- Graduated bucket for measuring the water.

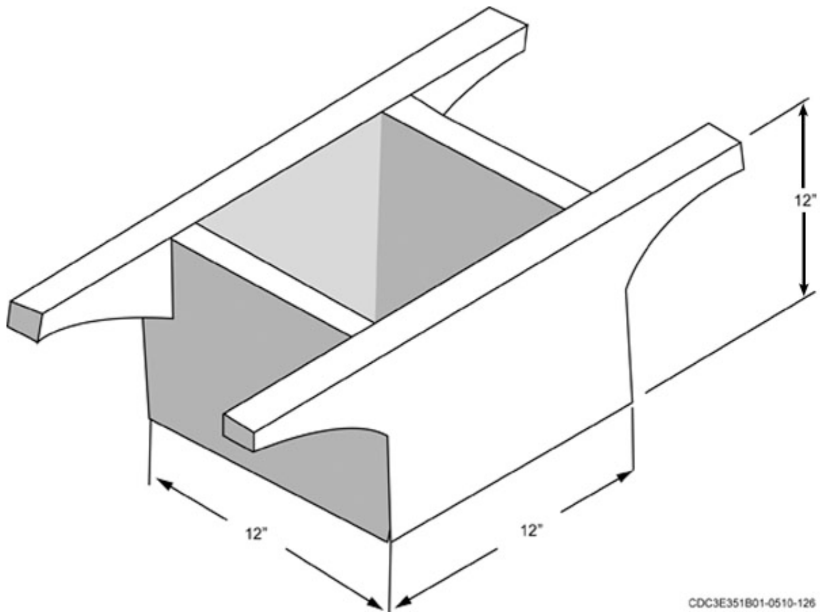


Figure 1–47. Measuring box.

You should make sure your mortar boat (or platform) is level and cleaned before use. Let's say your batch consists of two bags of cement, 5.5 cubic feet of sand, and 6.4 cubic feet of coarse aggregate. Mix the sand and cement together first, using the following procedure:

1. Dump 3 cubic feet of sand on the platform first, spread it out in a layer, and dump a bag of cement over it.
2. Spread out the cement and dump the rest of the sand (2.5 cubic feet) over it.
3. Dump the second sack of cement on top.

This use of alternate layers of sand and cement reduces the amount of mixing required.

The follow steps provide you guidance when there are two people completing the hand mixing.

1. Face each other from opposite sides of the pile and work from the outside to the center.
2. Turn the mixture as many times as necessary to produce a uniform gray color throughout. When the cement and sand are completely mixed, level the pile off and add the coarse material. Mix with the same turning method.
3. Trough the pile in the center. Pour the mixing water into the trough.
4. Turn the dry materials into the water and take care that none of the water splashes out.

When all the water has been absorbed, continue the mixing until the mix is of a uniform consistency—usually four complete turnings are required.

Machine mixing

There are various makes and models of concrete mixers. You'll have to refer to the manufacturer's instructions for the mixer you are using. The material presented here is based on the 16–S mixer; however, the basic mixing procedures should be the same for most mixers.

NOTE: The 16–S mixer has a capacity of 16 cubic feet (plus a 10-percent overload). Damage of this type of mixer will occur if the aggregate is larger than three inches.

Charging the mixer

You may charge most concrete mixers by hand or with the mechanical skip. Before loading the mechanical skip, remove the towing tongue. Place the dry ingredients into the skip with the coarse aggregate first, the cement next, and with the sand on top to prevent excessive loss of cement as the batch enters the mixer.

Mixing time

It takes a mixing machine having a capacity of 27 cubic feet or larger 1½ minutes to mix a one-cubic yard batch. Allow another 15 seconds for each additional half cubic yard or fraction thereof. Start the water into the drum a few seconds before the skip begins to dump, so that the inside of the drum gets a washout before the batched ingredients go in. Measure the mixing period from the time all the batched ingredients are in, provided all the water is in before one-fourth of the mixing time has elapsed. **NOTE:** Make sure the concrete is placed into the forms within 1½ hours from the time the mixing water is added to the batched ingredients.

Discharging the mixer

When the concrete is ready for discharge, move the discharge chute into place. In some cases, stiff concrete will carry up to the top of the drum and not drop down to the chute. On the other hand, very wet concrete may not carry up high enough to be caught by the chute. To correct these conditions, adjust the speed of the drum. For very wet concrete, increase the drum speed. For stiff concrete, slow down the drum speed.

Cleaning and maintaining the mixer

To properly clean and maintain the mixer you should ensure these steps are followed.

- Keep the outside of the mixer coated with oil to speed the cleaning process up.
- Wash the outside of the mixer with a hose and knock all accumulated concrete off.
- If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient; replace badly worn blades.
- Do not allow hardened concrete to accumulate in the mixer drum. Clean out the mixer drum whenever it is necessary to shut down for more than 1½ hours. Place a volume of coarse aggregate in the drum equal to one-half of the capacity of the mixer and allow it to revolve for about five minutes. Discharge the aggregate and flush out the drum with water.

NOTE: Do not pound the discharge chute, drum shell, or the skip to remove aggregate or hardened concrete. Concrete will readily adhere to the dents and bumps created.

Mixer Maintenance

Ensure all gears, chains, and rollers are properly guarded. Clean all moving parts and properly service them to permit safe performance. When the mixer drum is being cleaned, open the switches, close the throttles, and lock the control mechanism in the OFF position. Keep the area around the mixer clear.

Inspect the skip loader cables and brakes frequently to prevent injuries caused by falling skips. When working under an elevated skip, you must shore up the skip to prevent it from falling in the event that the brake fails or is accidentally released. The mixer operator must never lower the skip without first making sure that there is no one underneath.

Handling and transporting concrete

When you carry ready-mixed concrete with an ordinary type of carrier (such as a wheelbarrow or buggy), jolting of the carrier increases the natural tendency of the concrete to segregate. In an ideal situation, you should use carriers equipped with pneumatic tires (whenever possible) and keep the surface over which they travel as smooth as possible.

A long free fall also causes concrete to segregate. If you must discharge the concrete more than four feet above the level of placement, you should use specially designed buckets or chutes to keep the concrete from freefalling. **NOTE:** Segregation also occurs when discharged concrete glances off a surface, such as the side of a form or chute. Wheelbarrows, buggies, and conveyors should discharge so that the concrete falls clear.

You should only transport concrete by chute for short distances to decreases segregation and drying out. For a mix of average workability, the best slope for a chute is about one foot of rise to two or three feet of run. A steeper slope causes segregation, whereas a flatter slope causes the concrete to run slowly or not at all. The stiffer the mix, the steeper the slope required.

Ready-mixed concrete

Many projects today involve using a batch plant that contains its own mixer. A plant of this type discharges ready-mixed concrete into transit mixers, which haul it to the construction site. The truck carries the mix in a revolving chamber keeping the mix agitated in route to prevent segregation. **NOTE:** Discharge of the concrete from the drum should be completed within 1½ hours.

Transit-mixed concrete

With transit mixing, we refer to concrete that is mixed (either wet or dry) en route to a job site. A transit-mix truck carries a mixer and a water tank. The truck picks up the dry ingredients at the batch plant and adds the required amount of water upon arrival at the site. The mixer drum is kept revolving in route and at the job site so that the dry ingredients do not segregate.

Concrete construction joints

Shrinkage and differential movement places concrete structures under a variety of stresses. These stresses are the result of shrinkage that occurs during hydration and temperature changes and different loading conditions causing differential movement. These stresses can cause cracking, spalling, and scaling of concrete surfaces and, in extreme cases, can result in structure failure.

Types of joints

Properly placed joints can control stresses in concrete. We'll discuss three basic types of joints: isolation joints, control joints, and construction joints.

Isolation joints

Isolation joints separate (isolate) adjacent structural members. The joint that separates the floor slab from a column is one example. An isolation joint (fig. 1–48) allows for differential movement in the vertical plane due to loading conditions or uneven settlement. Isolation joints are sometimes called expansion or contraction joints. In this context, they allow for differential movement as a result of temperature changes (as in two adjacent slabs). All isolation joints (expansion or contraction) extend completely through the member and have no load transfer devices built into them.

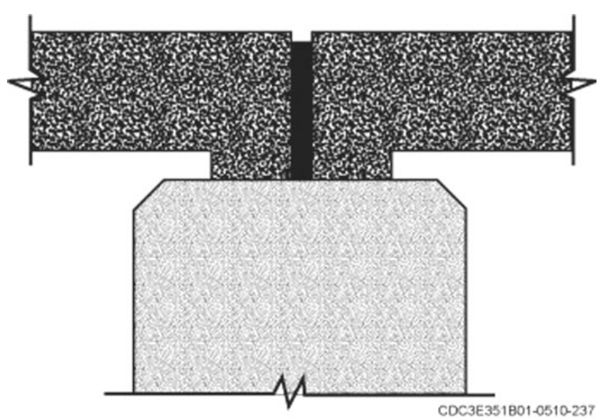


Figure 1–48. Isolation joint.

Control joints

Drying shrinkage and thermal contraction causes movement in the plane of a concrete slab. In a slab, shrinkage occurs more rapidly at the exposed surfaces and causes upward curling at the edges. If the slab is restrained from curling, cracks will occur. Cut control joints (fig. 1–49) into the concrete slab to create a plane of weakness, which forces cracking (if it happens) to occur at the control joints. Control joints run in both directions at right angles to each other. For interior slabs, cut them ⅓ to ¼ of the slab thickness and then fill with joint filler (fig. 1–50). For sidewalks and driveways, you can tool the joints ¾ to 1 inch deep, spaced at intervals equal to the width of the slab but not more than 20 feet apart in when the concrete is still plastic.

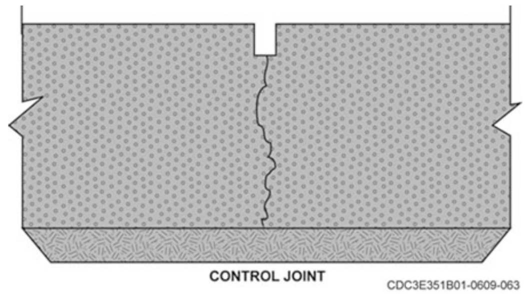


Figure 1–49. Control joints.

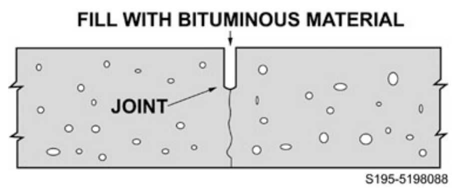


Figure 1–50. Area to be filled with bituminous material.

Construction joints

Make construction joints (figs. 1–51, 1–52, 1–53, and 1–54) where the concrete placement operations end for the day or where casting one structural element against previously placed concrete. These joints allow some load transfer from one structural element to another through the use of keys or (for some slabs and pavement) dowels. The construction joint extends entirely through the concrete element.

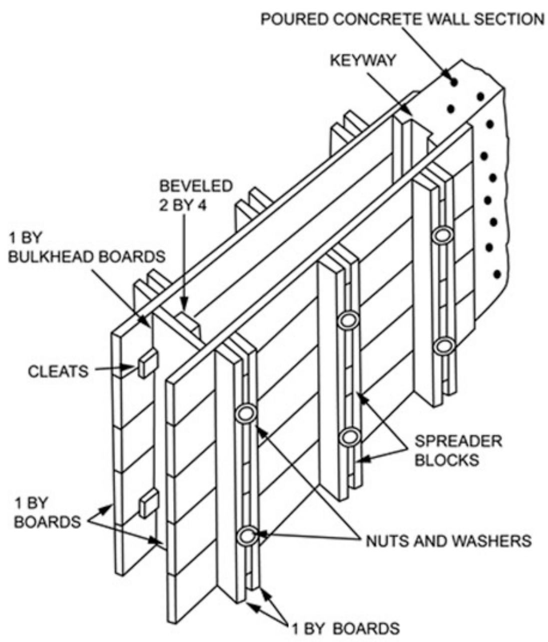


Figure 1–51. Vertical wall using keyway.

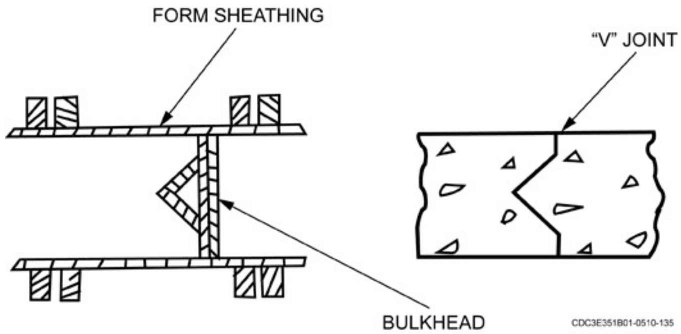


Figure 1–52. Keyed wall construction joint.

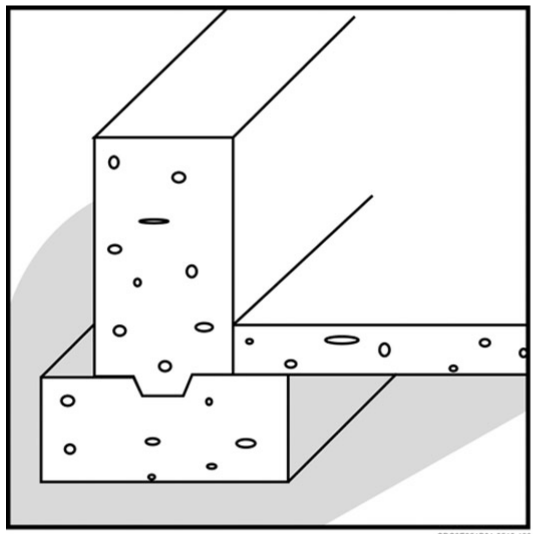


Figure 1–53. Construction joint between wall and footing with a keyway.

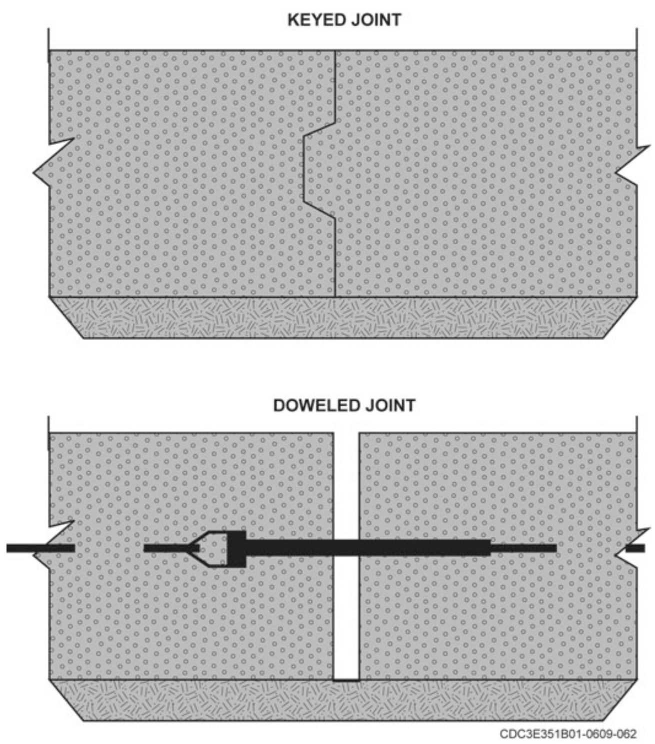


Figure 1–54. Types of construction joints.

Placing concrete

You cannot obtain the full value of well-designed concrete without using proper placing procedures. Below are some of the principles of concrete placement.

Segregation

Avoid segregation during all operations from the mixer to the point of placement including final consolidation and finishing.

Consolidation

Thoroughly consolidate the concrete working solidly around all embedded reinforcement and filling all form angles and corners.

Bonding

When placing fresh concrete against or upon hardened concrete, make sure that a good bond develops.

Maximum drop

Unless the free fall into the form is less than four feet, use vertical pipes, suitable drop chutes, or baffles. Good control prevents honeycombing and other undesirable results.

Layer thickness

Try to place concrete in even horizontal layers. Do not attempt to puddle or vibrate it into the form. Place each layer in one operation and consolidate it before placing the next layer to prevent honeycombing and voids. This is particularly critical in wall forms containing considerable reinforcement. Use a mechanical vibrator or a hand-spading tool for consolidation. Take care not to over vibrate. This can cause segregation and a weak surface. Do not allow the first layer to take its initial set before adding the next layer. Layer thickness depends on the type of construction, the width of the space between forms, and the amount of reinforcement.

Compacting

First, place concrete into its final position as nearly as possible. Then, work the concrete thoroughly around reinforcement and imbedded fixtures into the corners and against the sides of the forms. Because paste tends to flow ahead of aggregate, avoid horizontal movements that result in segregation.

Placing rate

To avoid excessive pressure on large project forms, do not exceed a filling rate of four vertical feet per hour except for columns. Coordinate the placing and compacting so that you do not deposit the concrete faster than it can be properly compacted. To avoid cracking during settlement, allow at least 4 hours (preferably 24 hours) between placing slabs, beams or girders, and placing the columns and walls they support.

Wall construction

When constructing walls, beams or girders, place the first batch of each layer at the ends of the section, and then work towards the center. This prevents water from collecting at the ends and corners.

For walls, fill the form to the construction level. Then, overfill the form about two inches and remove the excess just before the concrete sets. This ensures a rough, clean surface. Before placing the next lift of concrete, deposit a ½- to 1-inch-thick layer of sand-cement mortar. Make the mortar with the same water content ratio as the concrete and with a 6-inch slump to prevent stone pockets and to help produce a watertight joint.

When depositing concrete into high walls, place concrete through port openings and into the lower portion of the wall. Space the port openings at about 10-foot intervals up the wall. Be sure to remove spreaders (if any) as you fill the forms.

Slab construction

When constructing slabs, place the concrete at the far end of the slab first and then place subsequent batches against previously placed concrete. Do not place the concrete in separate piles and then level the piles and work them together. Also, don't deposit the concrete in piles and then move them horizontally to their final position. These methods can result in segregation.

Placing concrete on slopes

When placing concrete on slopes, always deposit the concrete at the bottom of the slope first, and then proceed up the slope placing each new batch against the previous one.

Temperature control

Take appropriate steps to control the temperature of fresh concrete from mixing through final placement, and protect the concrete from temperature extremes after placement.

Cold-weather concrete placing

Concrete placed when the air temperature is below 40°F is classified as cold-weather concrete. Cement hydration and strength development stop at temperatures below 40°F. If you must place in cold weather, here are some protective measures that should be taken.

- Reduce the amount of water in the mix used for slabs and flatwork (i.e. driveways and sidewalks) to allow for a four inch or less slump. This reduces the amount of water that bleeds to the surface and allows the concrete's initial set to happen faster.
- Use air-entrained cement or an air-entraining admixture.
- Modify the mix and use either an extra bag of cement per cubic yard of concrete; substitute ordinary cement with Type III (high-early strength) cement; or use a nonchloride set accelerator to develop strength faster.
- *Never* place concrete on a frozen subgrade because the concrete can crack when the subgrade thaws. If placing new concrete on a cold and hardened concrete surface, warm and moisten the surface before you deposit the new concrete.
- Before placing concrete in forms, be sure you remove all ice, snow, and frost from the forms and reinforcing material. You can do this efficiently with live steam.
- If protective covering is required, install it as completely as possible before you place the concrete. After you place the concrete, install a covering to enclose the freshly placed concrete to minimize heat loss.
- Raise the fresh concrete's temperature so that it's between 60 and 70°F when pouring and placing. Heat the water and aggregate between 70 and 80°F before putting it in the mixer. Always make sure the water temperature is below 80°F before you put in the cement and make sure the concrete mixing temperature *never* exceeds 80°F because higher temperatures reduce its strength. *Never* let the water temperatures exceed 165°F because that may cause a possible quick flash set of the cement.
- Delay removing the forms for as long as possible to reduce evaporation.

If you have a choice, you shouldn't pour concrete in temperatures below 0°F because of the expense involved to keep it from freezing while it is curing. **NOTE:** Concrete that freezes during the first few days of curing does not develop as much strength and durability as fully protected concrete. You can build a heated enclosure around the forms to provide protection against freezing. You can make these enclosures from lumber and plastic with a forced air heater. If concrete freezes before it sets (cures), the water expands and disrupts the bond between the cement and aggregate particles. After the concrete cures, freezing temperatures have little effect on it.

Hot-weather concrete placing

When the temperature is 90°F or more, you should take protective actions when placing concrete. Conditions are worsened when it is windy or the relative humidity is below 25 percent. You need to take precautions to maintain concrete temperature during curing at not more than 85 to 90°F.

You can lower concrete's temperature in the following several ways:

- Use the largest size aggregate possible and a water-reducing admixture.
- Place control joints at intervals slightly closer than usual.
- Use cold mixing water (in extreme cases, use slush ice to cool the water).
- Spray forms and subgrade before placing concrete.
- Sprinkle the coarse aggregate with water to cool it.
- Spray mixer drums with water to keep them cool.
- Insulate water supply lines and tanks.
- Shade materials and facilities not otherwise protected from the heat.
- Work only at night.
- Cure concrete for at least three days.

406. Consolidating and finishing concrete

Except for concrete placed underwater, you must consolidate and finish all concrete after placement. In this lesson, we will discuss ways that you can use to consolidate and finish concrete.

Purpose of consolidation

Consolidation eliminates rock pockets and air bubbles and brings enough fine material to the surface and against the forms to produce the desired finish. You can use such hand tools as spades, puddling sticks, or tampers, but mechanical vibrators are best. Any compacting device must reach the bottom of the form and be small enough to pass between reinforcing bars. The process involves carefully working around all reinforcing steel with the compacting device to assure proper embedding of reinforcing steel in the concrete. Since the strength of the concrete member depends on proper reinforcement location, be careful not to displace the reinforcing steel.

Consolidating walls

Use vibrators and spades to consolidate concrete in walls and similar type forms. Vibrators consolidate concrete by pushing the coarse aggregate downward, away from the point of vibration. Vibrators allow placement of mixtures that are too stiff to place any other way, such as those having a 1- or 2-inch slump.

Mechanical vibrators

The best compacting tool is a mechanical vibrator (fig. 1–55). The best vibrators are called internal vibrators because the vibrating element is inserted into the concrete. When using an internal vibrator follow the steps below:

- Insert it at approximately 18-inch intervals into air-entrained concrete for 5 to 10 seconds and into nonair-entrained concrete for 10 to 15 seconds. The exact period of time that you should leave a vibrator in the concrete depends on its slump (fig. 1–56).
- Overlap the vibrated areas somewhat at each insertion.

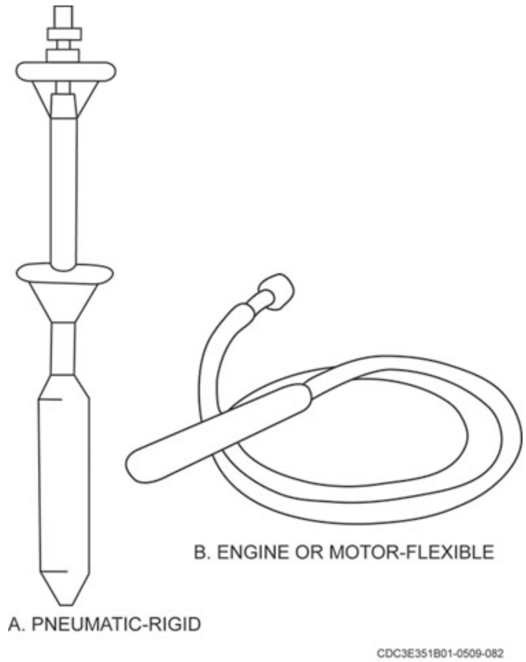


Figure 1–55. Mechanical vibrator.

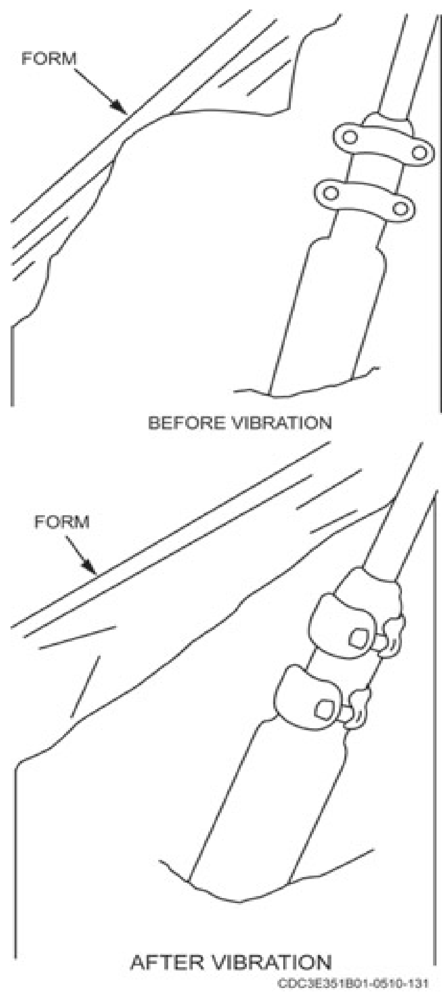


Figure 1–56. Using a vibrator to consolidate concrete.

- Whenever possible, lower the vibrator into the concrete vertically and allow it to descend by gravity (fig. 1–57). The vibrator should not only pass through the layer just placed but penetrate several inches into the layer underneath to ensure a good bond between the layers.

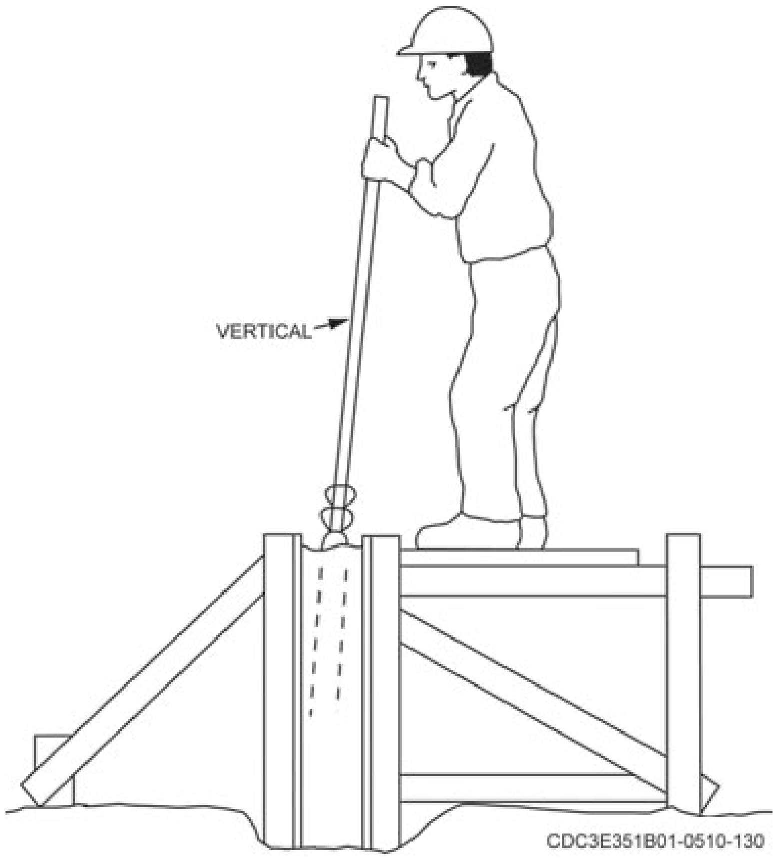


Figure 1–57. Using a mechanical vibrator.

You know that you have consolidated the concrete properly when a thin line of mortar appears along the form near the vibrator, the coarse aggregate disappears into the concrete or the paste begins to appear near the vibrator head. Withdraw the vibrator vertically at about the same gravity rate that it descended.

Some hand spading or puddling should accompany all vibration. To avoid the possibility of segregation, *do not* do the following:

- Vibrate mixes that you can consolidate easily by spading.
- Vibrate concrete that has a slump of five inches or more.
- Use vibrators to move concrete in the form.

Hand methods

Manual consolidation methods require spades, puddling sticks, or various types of tampers. Here is the procedure to consolidate concrete by spading; insert the spade along the inside surface of the forms (fig. 1–58) through the layer just placed and several inches into the layer underneath. Continue spading or puddling until the coarse aggregate disappears into the concrete.

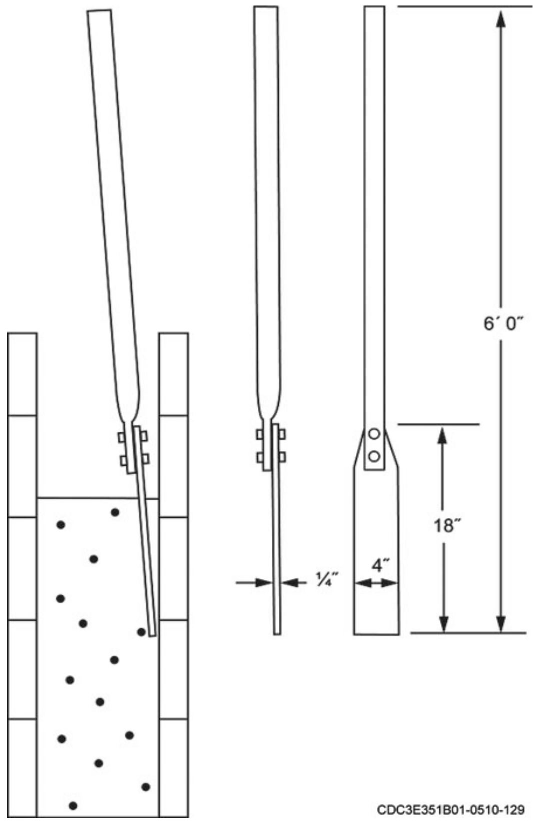


Figure 1–58. Hand spading concrete.

Finishing concrete

The finishing process provides the final concrete surface. There are many ways to finish concrete surfaces depending on the effect required.

Screeding

Screeding is the first step in finishing concrete. We do it just after we place a floor slab, sidewalk, and so forth because the top surface is rarely at the exact elevation we desire. *Screeding* is the *striking off* process that moves excess concrete to bring the surface to its proper elevation. You simply move a two-by board (screed) back and forth across the concrete with a sawing motion (fig. 1–59). The screed rides on the top of the forms. With each sawing motion, move the screed forward a short distance. While screeding, keep small concrete amounts ahead of the screed to fill in low spots and maintain a level surface as the screed moves forward. If there's a tendency for the screed to tear the concrete surface, slow down your forward movement.

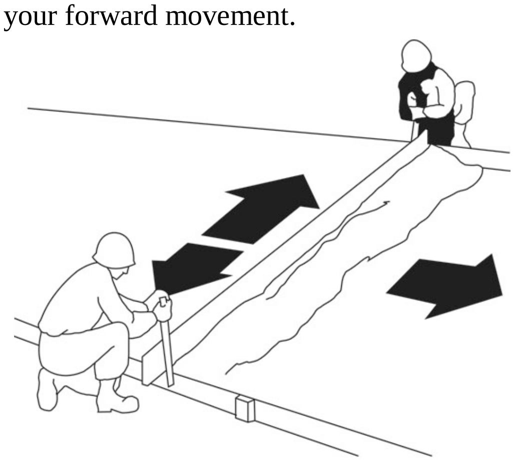


Figure 1–59. Screeding concrete.

You may encounter tearing problems when you use air-entrained or fiber impregnated concrete because the concrete tends to stick to the screed board. Depending on the project size, you should have at least one person on each side and one in the middle when screeding. The two people on the sides use a back and forth sawing motion while moving forward. The middle person uses a shovel to place and remove concrete during screeding. In some cases, you'll need to screed the surface a second time to remove the excess concrete surge caused by the first screeding. Power screeding on large projects saves time, effort, and money.

Hand tamping

Hand tamping, or jitterbugging, is done after the concrete has been screeded. Hand tamping is used to compact the concrete into a dense mass and to force the larger particles of coarse aggregate slightly below the surface. The tamping tool (jitterbug) (fig. 1–60), should be used only with a low-slump concrete, and bring only just enough mortar to the surface for proper finish. Insert the jitterbug at a right angle to the screeding operation. After using the jitterbug, you can go directly to using the bull float.

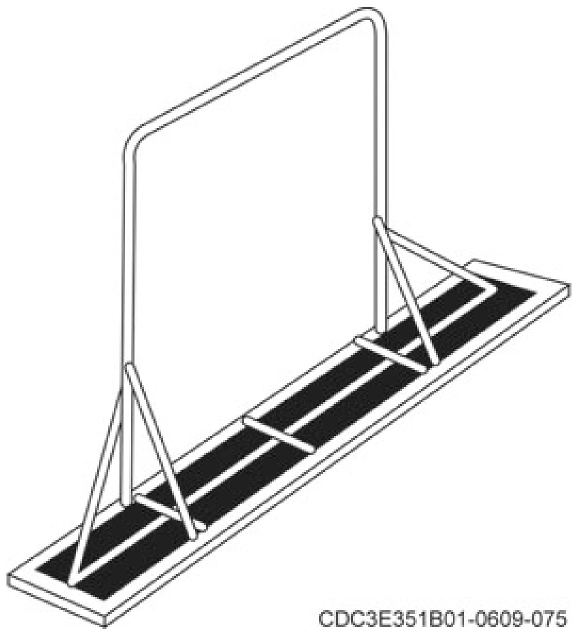


Figure 1–60. Hand tamp (jitterbug).

Rollerbug

An alternate to jitterbugging is using a rollerbug (fig. 1–61). As it rolls over the surface, it levels the concrete and pushes the large aggregate about $^{1}/_{16}$ inch below the surface. You can roll a slab in much less time than hand tamping. Also rollerbugging does not disturb the aggregate below the surface making the slab stronger and allowing it to resist weathering, spalling, and dusting better than tamped slabs. **NOTE:** The rolls of the rollerbug shown in figure 1–61 would actually resemble hollow rolls made of diamond mesh not solid rolls as depicted.

Figure 1–61. Rollerbug.

Floating

If you require a smoother surface than the one obtained by screeding, then work the surface sparingly with a wood or aluminum magnesium float or with a finishing machine. A long-handled float (bull float), (fig. 1–62), is used for slab construction. An aluminum float gives the finished concrete a smoother surface than a wood float. **NOTE:** Do not use cement or water as an aid in finishing the surface.

Floating has three purposes:

1. To embed aggregate particles just beneath the surface.
2. To remove slight imperfections (high and low spots).
3. To compact the concrete at the surface in preparation for other finishing operations.

Begin floating immediately after screeding (or tamping) while the concrete is still plastic and workable. However, do not overwork the concrete while it is still plastic because you may bring an excess of water and paste to the surface. This fine material forms a thin, weak layer that will scale or quickly wear off under use. It’s usually necessary to float the surface a second time after it partially hardens to remove the coarse texture (if this is the final finish).

Figure 1–62. Bull float.

Edging and joining

You should begin edging as the sheen of water begins to leave the surface. You should finish all edges of a slab that do not abut another structure with an edger (fig. 1–63). An edger dresses corners and rounds or bevels the concrete edges. Edging the slab helps prevent chipping at the corners and helps give the slab a finished appearance.

If you place control joints into a small slab or sidewalk before the concrete sets, you can use a jointer. This operation begins at the same time as edging.

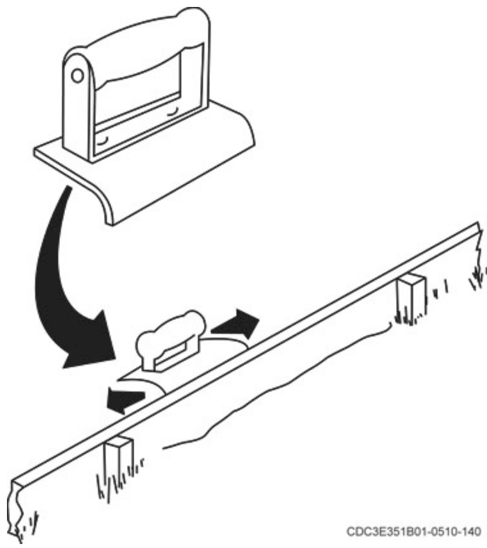


Figure 1–63. Edging with edger.

Surfacing

There are various ways to surface concrete. The methods discussed here are steel troweled, broomed, grinding, and exposed aggregate surfaces.

Troweling

To achieve a dense smooth finish, you must steel trowel the concrete after floating (fig. 1–64). Troweling should begin after the moisture film or sheen disappears from the floated surface and when the concrete has hardened enough to prevent working fine material and water to the surface. You should delay this step as long as possible. Troweling too early tends to produce crazing and lack of durability; however, troweling too late results in a surface too hard to finish properly. Troweling should leave the surface smooth, even, and free of marks and ripples. **NOTE:** Never spread dry cement on a wet surface to take up excess water.

Steel trowel

You can obtain a non-slippery, fine-textured surface by troweling lightly over the surface with a circular motion immediately after the first regular troweling. In this process, keep the trowel flat on the surface of the concrete.

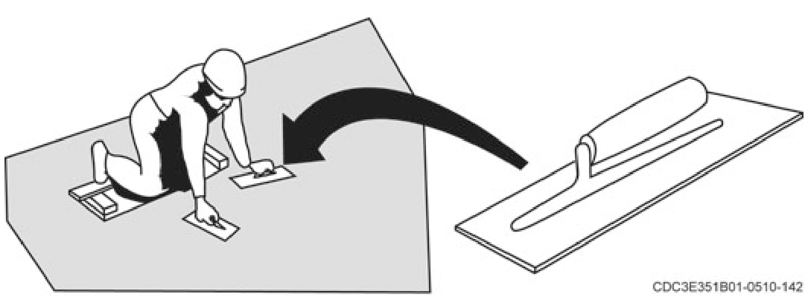


Figure 1–64. Steel finishing tools and troweling operations.

Where you require a hard steel-troweled finish, follow the first regular troweling with a second troweling. Begin the second troweling after the concrete has become hard enough so that no mortar adheres to the trowel, and you hear a ringing sound as the trowel passes over the surface. During this final troweling, tilt the trowel slightly and exert heavy pressure to thoroughly compact the surface.

NOTE: Hairline cracks (checks) are usually due to a concentration of water and extremely fine aggregates at the surface. This results from overworking the concrete during finishing operations. Such cracking is aggravated with the concrete drying and cooling too rapidly. Pounding the concrete with a hand float can usually close checks that develop before troweling.

Mechanical troweling machine

Use the mechanical troweling machine (fig. 1–65) on flat slabs with a stiff consistency. Mechanical trowels come with a set of float blades that slip over the steel blades. With these blades, you can float a slab with the mechanical trowels. The concrete must be set enough to support the weight of the machine and the operator. Machine finishing is faster than hand finishing; however, you cannot use it with all types of construction.

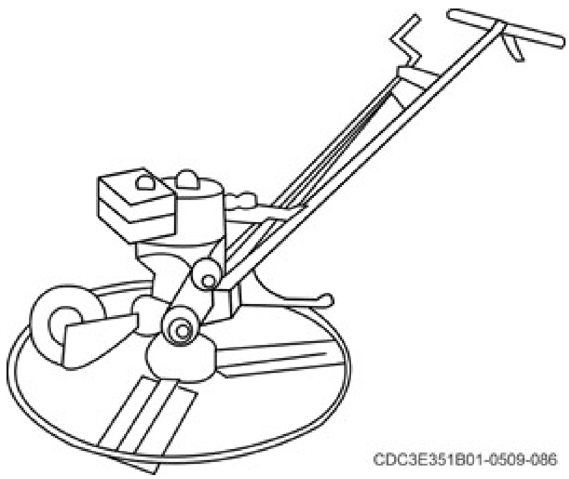


Figure 1–65. Mechanical troweling machine.

Brooming

Brooming the concrete before it has thoroughly hardened produces a nonskid surface. You should carry brooming out after the floating operation. For some floors and sidewalks where scoring is not desirable, you can produce a similar finish with a hairbrush after you trowel the surface once. Where you require rough scoring, use a stiff broom made of steel wire or coarse fiber. You should broom at right angles to the direction of the traffic.

Grinding

When specifications call for grinding, you should start it after the surface has hardened sufficiently to prevent dislodging the aggregate particles and continue it until the coarse aggregate is exposed. Keep the floor wet during the grinding process.

After the surface is ground, fill air holes, pits, and other blemishes with a thin grout. Spread this grout over the floor and work it into the pits with a straightedge. Next rub the grout into the floor with the grinding machine. When the filings have hardened for 17 days, give the floor a final grinding to remove the film and to give the finish a polish. Remove all surplus material by washing thoroughly.

Exposed aggregate finish

An exposed aggregate finish provides a nonskid surface. To obtain this, you must allow the concrete to harden sufficiently to support the finisher. To expose the aggregate, apply a retarder over the surface and then brush and flush the concrete surface with water. Since timing is important, use test panels to determine the correct time to expose the aggregate.

407. Curing, inspecting, and repairing concrete

After the concrete has been placed and finished, you need to make sure that it is properly cured and finished to the designed specifications. This lesson will discuss the curing methods, along with inspection and repair procedures.

Curing concrete

Both the rate and degree of hydration and the concrete's final strength depend on the curing process. Hydration continues indefinitely at a decreasing rate as long as the mixture contains water and the temperature conditions are favorable. Once the water is removed, hydration stops and cannot be restarted.

Curing is the period of time from consolidation to the point where the concrete reaches its design strength. During this period, you must take certain steps to keep the concrete moist and as near 73°F as practical. The properties of concrete (freeze and thaw resistance, strength, watertightness, wear resistance, and volume stability) improve with age as long as you maintain the moisture and temperature conditions to continue hydration.

The length of time that you must protect concrete against moisture loss depends on the type of cement, mix proportions, required strength, size and shape of the concrete mass, weather, and future exposure conditions. The period can vary from a few days to a month or longer. For most structural use, the curing period for cast-in-place concrete is usually three days to two weeks depending on the factors just mentioned.

When the temperature is at or above 50°F, curing should take place for at least five days, and three days when the temperature is at or above 70°F. If you use high-early-strength cement, reduce the curing period to two days at 70°F or three days at 50°F.

Curing methods

Several curing methods are available. They fall into two categories: those that supply additional moisture and those that prevent moisture loss. The table below lists several of these methods and their advantages and disadvantages.

METHOD	ADVANTAGES	DISADVANTAGES
Sprinkling with water or covering with burlap	Provides excellent results if kept constantly wet.	Likelihood of drying between sprinklings; difficult on vertical walls.
Straw	Provides insulation in winter.	Can dry out, blow away, or burn.
Moist earth	Cheap.	Messy, stains concrete, can dry out, hard to remove.
Ponding on flat surfaces	Provides excellent results, maintains uniform temperature.	Requires considerable labor; undesirable in freezing weather.
Curing compounds	Easy to apply and inexpensive.	Sprayer needed; inadequate coverage allows drying out; film can be broken or tacked off before curing is complete; unless pigmented, may allow concrete to get too hot.
Waterproof paper	Provides excellent protection, prevents drying.	Heavy cost can be excessive; must be kept in rolls; storage and handling problems.
Plastic film	Absolutely watertight, excellent protection. Light and easy to handle.	Should be pigmented for heat protection; requires reasonable care and tears must be patched; must be weighed down to prevent blowing away.

Methods that supply additional moisture

Methods that supply additional moisture include sprinkling and wet covers. Both these methods add moisture to the concrete surface during the early hardening or curing period. They also provide some cooling through evaporation. This is especially important in hot weather.

Sprinkling continually with water is an excellent way to cure concrete. However if you sprinkle at intervals, do not allow the concrete to dry out between applications. The disadvantages of this method are the expense involved and volume of water required.

Wet covers, such as straw, earth, burlap, cotton mats, and other moisture-retaining fabrics are used extensively in curing concrete. Lay the wet coverings as soon as the concrete hardens enough to prevent surface damage. Leave them in place and keep them moist during the entire curing period.

If practical, you can create an earthen dam around the edges and submerge the entire concrete structure in water.

Methods that prevent moisture loss

Methods that prevent moisture loss include laying waterproof paper, plastic film, or liquid membrane-forming compounds and simply leaving forms in place. All prevent moisture loss by sealing the surface.

Waterproof paper

You can use waterproof paper to cure horizontal surfaces and structural concrete having relatively simple shapes (fig. 1–66). The paper should be large enough to cover both the surfaces and the edges of the concrete. Wet the surface with a fine water spray before covering. Lap adjacent sheets at least 12 inches and weigh their edges down to form a continuous cover with closed joints. Leave the coverings in place during the entire curing period.

Plastic film

Plastic film materials provide lightweight, effective moisture barriers that are easy to apply to either simple or complex shapes. However, some thin plastic sheets may discolor hardened concrete, especially if the surface was steel-troweled to a hard finish. The coverage, overlap, weighing down of edges and surface wetting requirements of plastic film are similar to those of waterproof paper.

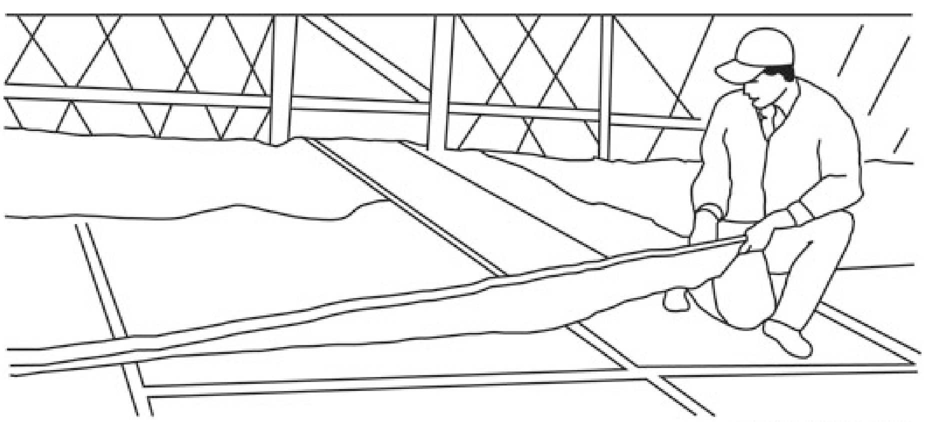


Figure 1–66. Covering a concrete slab.

Curing compounds

You can apply curing compounds with spray equipment, such as hand-operated pressure sprayers. If there is heavy rain within three hours of application, you must respray the surface. You can use brushes to apply curing compound to formed surfaces. These compounds permit curing to continue for long periods while the concrete is in use. Because curing compounds can prevent a bond from forming between hardened and fresh concrete, do not use them if a bond is necessary.

Forms

Forms provide adequate protection against moisture loss if you keep the exposed concrete surfaces wet. Keep wood forms moist by sprinkling, especially during hot, dry weather.

Form removal

You should leave the forms in place for the entire curing period; however, we know that this is not always possible. In any event, you must not strip forms until the concrete has hardened enough to hold its own weight and any other weight that may be placed upon it. The surface must be hard enough to remain undamaged and unmarked when reasonable care is used in stripping the forms. During stripping, make sure there is not any excessive deflection or distortion and no evidence of cracking or other damage to the concrete due to the removal of the forms or the form supports.

Curing period for form removal

You can usually remove haunch boards (side forms on girders and beams) and wall forms after one day. Column forms usually require three days before removing the forms. You can usually remove the forms for soffits on girders and beams after seven days. Floor slab forms (over 20-foot clear span between supports) usually require 10 days before removing the forms.

Inspection and repair

You should inspect the concrete for surface defects after removing the forms. These defects may be rock pockets, inferior quality ridges at form joints, bulges, boltholes and form-stripping damage. Repairs are not always necessary but when they are, you should make them immediately after stripping the forms or within 24 hours.

You can repair defects in various ways. Therefore, let’s look at some common defects you may encounter and ways you can repair them.

Ridges and bulges

To repair ridges and bulges, carefully chip away the defect and then rub with a grinding stone.

Honeycomb

You must chip out defective areas, such as honeycombs. Cut the edges as straight as possible at right angles to the surface or slightly undercut them to provide a key at the edge of the patch. You can fill shallow patches with mortar placed in layers not more than ½-inch-thick. Float, rub or tool the patch to give it a scratch finish to match the surrounding concrete. On formed surfaces, press the form material against the patch while the mortar is still plastic.

Fill large or deep patches with concrete held in place by forms. Reinforce these patches and dowel them to the hardened concrete (fig. 1–67). Patches usually appear darker than the surrounding concrete. Some white cement should be used in the mortar or concrete used for patching if appearance is important. You should make a trial mix to determine the proportion of white and gray cements to use.

Before placing mortar or concrete in the patches, keep the surrounding concrete wet for several hours. Next, brush a grout mixture of cement and water mixed to the consistency of paint into the surfaces to which the new material is to be bonded. Then apply patching material (i.e., mortar or concrete) into the area. Begin curing as soon as possible to avoid early drying. Damp burlap, tarpaulins, and membrane-curing compounds are useful for this purpose.

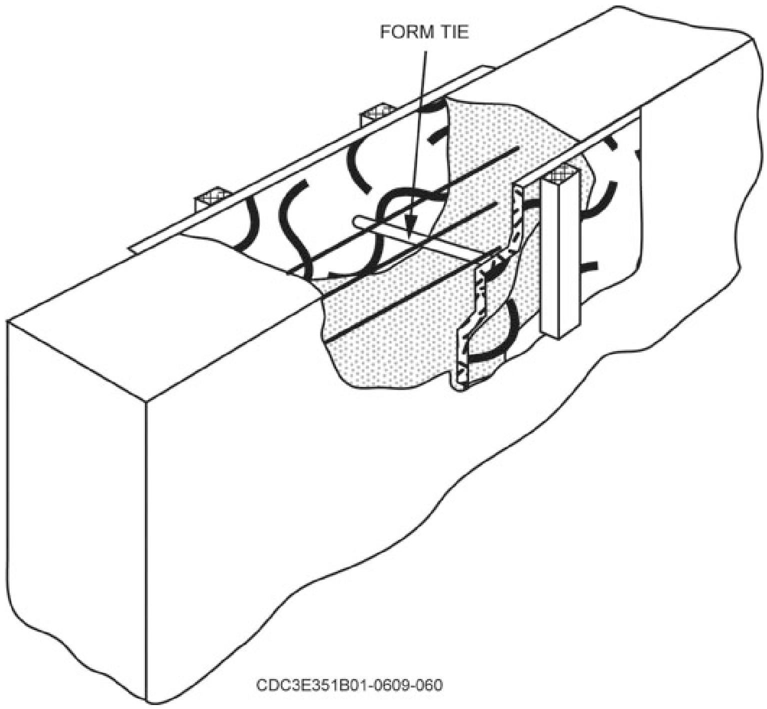


Figure 1–67. Honeycomb repair.

Boltholes

You should fill boltholes with grout carefully packed into place. Mix the grout as dry as possible, with just enough water so it compacts tightly when forced into place. You can fill tie-rod holes extending through the concrete with grout using a pressure gun similar to an automatic grease gun.

Rock pockets

Completely chip out rock pockets to provide sharp edges and form a key (fig. 1–68). The surface of all holes needing repair should be kept moist for several hours before applying the grout. Place the grout in layers not over ¼-inch-thick ensuring they are well compacted. Let the grout set as long as possible before using to reduce the amount of shrinkage and to make a better patch. Scratch each layer to improve the bond with the succeeding layer. Leave the last layer smooth to match the adjacent surface. To make the patch match the surrounding surface, press a piece of material (same as original formwork) against the fresh patch while it is still plastic.

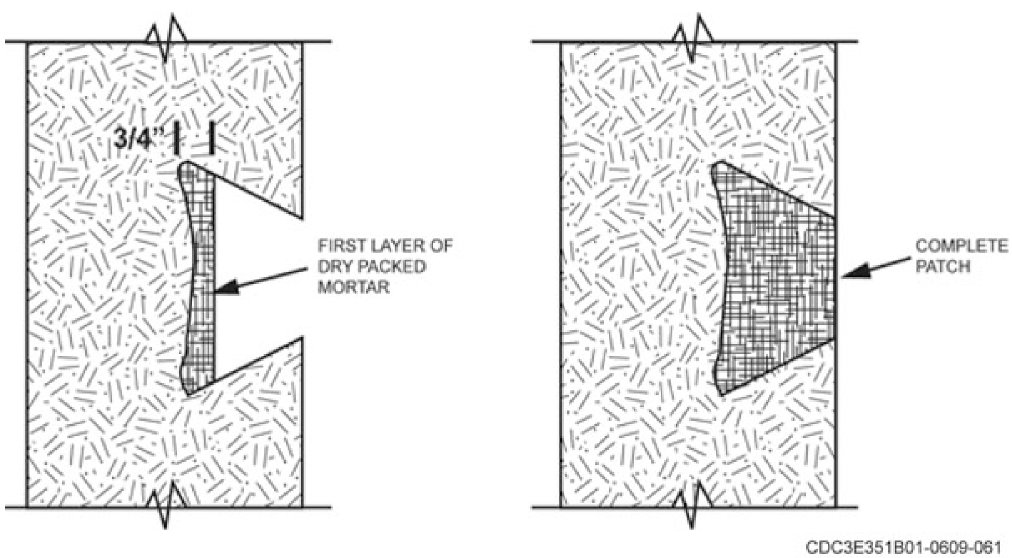


Figure 1–68. Repairing concrete with grout.

View 1 of figure 1–69 shows an incorrectly installed patch. Feathered edges around a patch lack sufficient strength and will eventually break down. View 2 of the figure shows a correctly installed patch. The chipped area should be at least 1-inch deep with the edges slightly excess of 90 degrees (undercut) to the surface. The new concrete should project slightly above the surface of the old concrete. Allow it to stiffen and then trowel and finish it to match the adjoining surfaces.

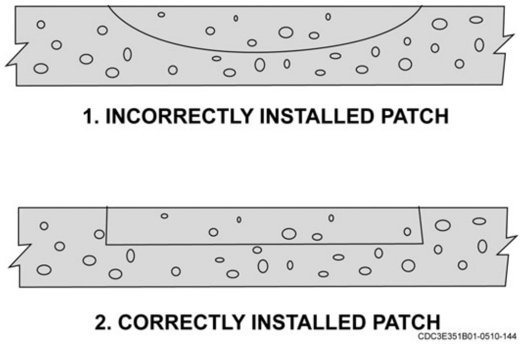


Figure 1–69. Patching concrete.

Surface cracks in existing concrete

You must promptly fill surface cracks that are not structural defects to avoid the water penetration. Thoroughly clean the crack with a high-pressure water jet to remove all foreign matter, moisten the edges of the crack and fill the crack with cement paste or an epoxy-based material. Use a brush if necessary to push the grout into the crack. For wider cracks, use a mortar made of cement, sand and water. After filling the crack, cover with burlap and keep the covering moist for at least three days.

Dusting

Dusting is when hardened concrete surfaces wear away under normal traffic. This results from too much water in the mix, segregation during placement and consolidation, dirty aggregate or adding water to the concrete surface during finishing. Premature or prolonged finishing operations are also a cause. To repair the concrete, you will need to sweep or brush it carefully to remove all loose particles and seal it with a concrete sealer according to the manufacturer's directions. If the dusting is severe, you will need to coat the surface with a commercial surface hardener and then seal it.

Scaling

Scaling is when a thin layer of the concrete surface flakes or peels away leaving the exposed aggregate below (fig. 1–70). Scaling extends down to as deep as ¼ inch. To repair the concrete, you should place a thin concrete overlay over the existing surface. Start by removing all loose or damaged particles. Then install a concrete resurfacing material according to the manufacturer's instructions.

Figure 1–70. Scaling concrete surface.

Repair products

There are numerous types of repair products available. Below are some of the most common that you may encounter.

Fast-fix cement/concrete resurfacer

Use fast-fix cement where you need self-bonding, fast set, chemical resistance, and a non-shrink patch. You can use it for such things as slabs, highways, parking decks, and columns. Most of the fast-fix cements will accept vehicle and/or pedestrian traffic within one hour after placement. Their setting times may range from 5 minutes to 25 minutes, depending on the area, location and application depth.

The method to apply most fast-fix cements the same include:

- Remove all loose or unsuitable concrete and any grease, oil, or dust that could interfere with the bond.
- Most fast-fix cements require that the surface be dampened for better bonding.
- Mix only enough cement to apply within a short time. Firmly place the cement to the manufacturer's recommended depth (usually ½ inch) and trowel the cement in and then work the surface to a final finish.

NOTE: It's critical that you follow the manufacturer's specifications for mixing and placing any fast-fix cement.

Epoxy fillers

Epoxy fillers with cement bonds well to old concrete. There are many epoxy fillers available premixed with other ingredients, such as concrete. We call this type epoxy concrete. You can feather out some epoxy concrete mixes to ⅛-inch-thick depths and still retain good strength without cracking. You can use epoxy concrete to patch small areas or to top and repair other concrete surfaces.

Epoxy fillers provide for shallow, flat applications where rapid, high-strength development permits light foot traffic in 24 hours or less and heavy foot traffic in 72 hours. Epoxy filler advantages include resistance to water and chemicals, high compressive strength, easy to mix and apply. Always follow the manufacturer's specifications for mixing and placing epoxy fillers and cleaning your tools.

Waterproofing

The two popular concrete waterproofing methods are compounds or membranes. We divide waterproofing compounds into two classes; *mixed into the concrete* and *surface washes*. The compounds *mixed into the concrete* are finely ground clay or hydrated lime. We recommend using surface washes over the mixed in compounds. Some surface washes or coatings that give good results are bituminous coatings, emulsified asphalts, mastic cement plaster, metallic powder, and Portland cement paint. Apply surface washes according to the manufacturer's specifications. In backfilling against a waterproofed foundation, be careful not to damage the coating. **NOTE**: All waterproofing compounds deteriorate with time.

Membrane waterproofing is the most effective way to prevent water passage through concrete. With this method, we apply hot asphalt and roofing felt to an outside wall. We normally use it on foundation wall surfaces for basements and other below ground level areas. We usually apply it as soon as the concrete surface is dry enough for it to stick.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

404. Concrete ingredients and mix designs

1. Match the cement types in column B with the descriptions in column A. The items in column B may be used once, more than once or not at all.

Column A	*Column B*
____ (1) Sulfate-resistant cement used where concrete will be subjected to severe sulfate action.	a. Type I.
____ (2) General-purpose cement used for pavements and sidewalks.	b. Type II.
____ (3) Low heat of hydration cement used in very large concrete structures.	c. Type III.
____ (4) High-early strength cement—reaches design strength in 7 days or less.	d. Type IV.
____ (5) Modified cement used to resist moderate sulfate attack.	e. Type V.
____ (6) Cement that reaches it design strength in about 28 days.	

2. What percentage of concrete volume is made up of aggregates?

3. Estimate the approximate amount of cement, sand and course aggregate is needed for one cubic yard of concrete when specifications require a 1:2:4 mix using 2 inch aggregate.

4. What are the procedures for filling a slump cone?

5. How many times is the concrete in a slump cone rodded?

6. Under what condition may you add more water to a concrete mix without making a corresponding adjustment in the cement content?

405. Mixing and placing concrete

1. When hand-mixing concrete, how many times should you turn the mixture over?

2. When machine-mixing concrete, in what sequence are the dry ingredients placed into the skip?

3. What precaution should you take if you must discharge concrete at a height of more than four feet above the placement level?

4. Match the joint in column B with the description in column A. The items in column B may be used once, more than once or not at all.

Column A

____ (1) Allows for differential movement in the vertical plane due to loading conditions or uneven settlement.
____ (2) Make these joints where the concrete placement operations end for the day or where casting one structural element against previously placed concrete.
____ (3) This joint creates a plane of weakness, which forces cracking (if it happens) to occur at this joint.
____ (4) These joints extend completely through the member and have no load transfer devices built into them.
____ (5) Joint runs in both directions at right angles to each other.
____ (6) These joints allow some load transfer from one structural element to another through the use of keys or dowels.

Column B

a. Control joint.
b. Isolation joint.
c. Construction joint.

5. To avoid cracking during settlement, you should allow at least how many hours between placing slabs, beams or girders and the columns and walls they support?

6. How is concrete that is placed when the air temperature is below 40°F classified?

406. Consolidating and finishing concrete

1. What is the purpose of consolidating concrete?

2. What are the procedures used when consolidating concrete in a wall form using an internal vibrator?

3. To avoid the possibility of concrete segregation in wall forms, you should not vibrate concrete that has what slump?

4. What is the first step in finishing concrete?

5. What procedure is used as an alternative to jitterbugging and why?

6. What are the purposes for floating concrete?

7. When should the floating process take place?

8. When should you begin edging concrete?

9. What action can usually close checks that developed before the troweling operation begins?

10. In what direction should concrete be broomed?

407. Curing, inspecting, and repairing concrete

1. How long should concrete be cured when the temperature is at 50°F or above 70°F?

2. What are some concrete curing methods that supply additional moisture?

3. You must *not* strip off the concrete forms until when?

4. If concrete repairs are necessary, when should they be made?

5. How should the defective area be chipped (prepared) when repairing rock pockets?

Answers to Self-Test Questions

401

1. Establishing a baseline.
2. Measure out along the reference line four feet, measure the opposite line three feet, then measure between those two points. If the distance isn't 5 feet, you don't have a 90 degrees corner and you'll have to adjust the angle between the lines accordingly.
3. Minimum of 4 feet; so equipment operators and builders can do their work.
4. (1) b.
   (2) b.
   (3) b.
   (4) a.
   (5) b.
   (6) a.

5. 2 feet.
6. Stiff brooms and compressed air or water.
7. To help keep the subgrade from extracting moisture from the concrete.
8. Burlap, tarpaper, or polyethylene. Overlap the burlap and moisten it, lap the tarpaper at least an inch, and lap the polyethylene at least 12 inches.
9. Moisture could get trapped between the concrete and the barrier, resulting in shifting, cracking or splitting.

402

1. It generally requires less excavation and has greater settling resistance.
2. Pins are wedged in pinholes and secured with end locks.
3. Plywood, ¼- to ⅜-inch-thick.
4. Stakes driven against the sheathing and 1 by 6 tie braces nailed across the top of the form.
5. Lay the form boards to the outside of the building lines with the top of the board flush with the line.
6. 2 feet apart; 4 feet apart.
7. With double wales that run horizontally and are lapped at the corners.
8. With rebar tied into the floor and landing.
9. Bevel the planks for the riser on the bottom edge.
10. No more than a 1:12 slope.
11. Install ½-inch expansion board.
12. Wooden wedges.

403

1. By the adhesion and shrinkage of concrete during hydration.
2. ⅜-inch rebar.
3. Because this will make the rebar lose its temper and tensile strength.
4. Because rust causes poor bonding between the rebar and concrete.
5. 3 inches.
6. Not less than 30 times the bar diameter, or not less than 12 inches.
7. One bolt is required 12 inches from each end and 6 feet on center for one-story homes and 4 feet on center for two story homes.

404

1. (1) e.
   (2) a.
   (3) d.
   (4) c.
   (5) b.
   (6) a.
2. 60 to 80 percent.
3. 6 bags cement, 12 cubic feet of sand and 24 cubic feet of course aggregates.
4. Fill the cone in three layers, each approximately one-third the *volume* of the cone. When placing each scoop in the cone, move the scoop around the edge of the cone as the concrete slides from it, distributing the concrete symmetrically within the cone.
5. Rod each layer 25 times.
6. None.

405

1. As many times as necessary to produce a uniform gray color throughout.
2. Course aggregate first, cement second, and sand third.
3. Use specially designed buckets or chutes to keep the concrete from freefalling.
4. (1) b.
   (2) c.
   (3) a.
   (4) b.
   (5) a.
   (6) c.
5. At least 4 hours; preferably 24 hours.
6. As cold-weather concrete.

406

1. To eliminate rock pockets and air bubbles and bring enough fine material to the surface and against the forms to produce the desired finish.
2. Insert it at approximately 18-inch intervals into air-entrained concrete for 5 to 10 seconds and into nonair-entrained concrete for 10 to 15 seconds.
3. 5 inches or more.
4. Screeding—the *striking off* process that moves excess concrete to bring the surface to its proper elevation.
5. Rollerbugging—it does not disturb the aggregate below the surface, making the slab stronger and allowing it to resist weathering, spalling and dusting better than tamped slabs.
6. (1) Embeds aggregate particles just beneath the surface.
   (2) Removes slight imperfections (high and low spots).
   (3) Compacts the concrete at the surface in preparation for other finishing operations.
7. Immediately after screeding or tamping while the concrete is still plastic and workable.
8. As the sheen of water begins to leave the surface.
9. Pounding the concrete with a hand float.
10. At right angles to the traffic.

407

1. Five days; three days.
2. Sprinkling and wet covers.
3. Until the concrete has hardened enough to hold its own weight and any other weight that may be placed upon it.
4. Immediately after stripping the forms, within 24 hours.
5. The chipped area should be at least 1-inch deep with the edges slightly excess of 90 degrees (undercut) to the surface.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) What is the *first* step you should do in locating corner stakes for a building?
   a. Establish a baseline.
   b. Layout the rear corner.
   c. Determine the soil composition.
   d. Plumb and level the batterboards.

2. (401) Once the building corners are square, which step is taken next when you are preparing a site for concrete?
   a. Plumb the corners only.
   b. Erect the batterboards only.
   c. Plumb the corners and place the building lines.
   d. Erect the batterboards and place the building lines.

3. (401) You *must* install bracing on batterboards if the soil is
   a. loose only.
   b. hard only.
   c. loose or the stakes are higher than three feet.
   d. hard or the stakes are higher than three feet.

4. (401) How do you hold the building lines securely in place in batterboard construction?
   a. Fasten the line to a plumb bob.
   b. Tie the line around a duplex nail.
   c. Make a saw kerf in the inside edge of each ledger board.
   d. Make a saw kerf in the outside edge of each ledger board.

5. (401) When excavating around the outside wall planes, how much working space should you allow for form construction?
   a. 1 foot.
   b. 2 feet.
   c. 3 feet.
   d. 4 feet.

6. (402) When grade stakes are used between wooden footing forms, which action *must* you take before the concrete sets?
   a. Drive the stakes one inch below the concrete surface.
   b. Remove the stakes and fill the holes with concrete.
   c. Do not use grade stakes with these forms.
   d. Remove the stakes only.

7. (402) How do you form any square or rectangular dimensioned slab using metal forms?
   a. By ordering the correct dimensions.
   b. By cutting the form to size with a hacksaw.
   c. By letting one form end extend past each corner.
   d. They are only used for slabs sized in 10-foot increments.

8. (402) When constructing a footing for a bearing wall, the sides are held in place with the correct distance maintained between them through the use of
   a. stakes and rebar.
   b. rebar only.
   c. stakes and spreaders.
   d. spreaders only.

9. (402) When using 1-inch lumber for slab forms, at what approximate distance should you drive stakes along the board?
   a. 2 feet.
   b. 4 feet.
   c. 6 feet.
   d. 8 feet.

10. (402) When using 2-inch lumber for slab forms, at what approximate distance should you drive stakes along the board?
    a. 2 feet.
    b. 4 feet.
    c. 6 feet.
    d. 8 feet.

11. (402) How do you reinforce studs that extend *over* four or five feet when constructing wall forms?
    a. Run double wales vertically.
    b. Run double wales horizontally.
    c. Do not use studs over 4 feet long.
    d. Secure with a single strand of tie wire.

12. (402) When constructing a new ramp, you *must* ensure the ramp's width is *not*
    a. less than 36 inches.
    b. less than 48 inches.
    c. more than 36 inches.
    d. more than 48 inches.

13. (403) When reinforcing steel specifications require a No. 5 rebar, what is the actual need?
    a. ¼ inch.
    b. ⅜ inch.
    c. ½ inch.
    d. ⅝ inch.

14. (403) When splicing welded wire fabric, a normal splice is made by lapping
    a. one full square plus one inch.
    b. one full square plus two inches.
    c. two full square plus one inch.
    d. two full squares plus two inches.

15. (403) When constructing footings and other structural members that are against the ground, how much space should you allow between the steel and ground?
    a. 1 inch.
    b. 2 inches.
    c. 3 inches.
    d. 4 inches.

16. (403) When reinforcing beams, footings, walls and floors, what should be the *minimum* clearance distance between parallel bars?
    a. 1 inch or 1⅓ times the largest aggregate particle in the concrete.
    b. 1⅓ times the largest aggregate particle in the concrete only.
    c. 2 inches or 2½ times the largest aggregate particle in the concrete.
    d. 2½ times the largest aggregate particle in the concrete only.

17. (403) How do you keep concrete from entering the sleeve when using a pipe sleeve anchor bolt?
    a. Pack it with a rag or newspaper.
    b. Use a sleeve ¼ inch larger than the bolt.
    c. Keep the sleeve ½ inch above the concrete surface.
    d. Use concrete with aggregate larger than the sleeve opening.

18. (404) When constructing pavements, sidewalks and reinforced concrete buildings, which type of concrete should you use when it *must* reach its design strength in about 28 days?
    a. Type I.
    b. Type II.
    c. Type III.
    d. Type IV.

19. (404) When constructing large structures where moderate heat of hydration is needed, which type of cement should you use when it *must* reach its design strength in about 45 days?
    a. Type I.
    b. Type II.
    c. Type III.
    d. Type IV.

20. (404) Which type of cement should you use when the concrete *must* reach its design strength in seven days or less?
    a. Type I.
    b. Type II.
    c. Type III.
    d. Type IV.

21. (404) Estimate the amount of sand needed to mix one cubic yard of concrete when specifications call for a 1:2:4 mix using 2-inch course aggregates.
    a. 6 cubic feet.
    b. 7 cubic feet.
    c. 12 cubic feet.
    d. 14 cubic feet.

22. (404) Estimate the amount of course aggregate needed to mix one cubic yard of concrete when specifications call for a 1:2:4 mix using 2-inch course aggregates.
    a. 12 cubic feet.
    b. 14 cubic feet.
    c. 18 cubic feet.
    d. 24 cubic feet.

23. (404) When performing a slump test, how should you fill the cone?
    a. In one layer, the entire cone volume.
    b. In two equal layers, each ½ the cone volume.
    c. In three equal layers, each ⅓ the cone volume.
    d. In four equal layers, each ¼ the cone volume.

24. (405) When hand-mixing concrete, which of the following procedures is correct?
    a. Mix the sand and cement together first, then add the coarse material.
    b. Mix the sand and course material together first, then add the cement.
    c. Mix half the water with the sand and cement, then add the course material.
    d. Mix half the water with the sand and course material, then add the cement.

25. (405) Identify the *correct* sequence for loading the skip of a concrete mixer.
    a. The cement first, the sand second, and the coarse aggregate third.
    b. The coarse aggregate first, the cement second, and the sand third.
    c. The sand first, the cement second, and the coarse aggregate third.
    d. The coarse aggregate first, the sand second, and the cement third.

26. (405) Which of the following *concrete joints* should you use to separate adjacent structural members to allow differential movement in the vertical plane?
    a. Control.
    b. Isolation.
    c. Doweled.
    d. Construction.

27. (405) Which of the following *concrete joints* should you cut into a concrete slab to create a plane of weakness, which forces cracking at the joint?
    a. Keyed.
    b. Control.
    c. Isolation.
    d. Construction.

28. (406) When pouring concrete in layers, how far should you insert an internal vibrator into the previous layer and why?
    a. Several inches; to ensure a good bond.
    b. Several inches; to help place the concrete.
    c. No more than one inch; to assure a good bond.
    d. No more than one inch; to help place the concrete.

29. (406) You can tell the concrete has been vibrated long enough with an internal vibrator when a
    a. thin sand line appears on the form’s edge.
    b. thin mortar line appears on the form’s edge.
    c. ½-inch layer of water forms on the surface.
    d. ¾-inch layer of water forms on the surface.

30. (406) Which of the following actions is used to the strike off the excess concrete to bring the surface to its proper elevation?
    a. Edging.
    b. Jointing.
    c. Floating.
    d. Screeding.

31. (406) You should begin the edging operation
    a. after the first troweling.
    b. just before floating the concrete.
    c. immediately after screeding the concrete.
    d. as the sheen of water begins to leave the surface.

32. (406) Which action can you take to close hairline cracks (i.e., checks) that developed due to a concentration of water and extremely fine aggregates at the surface?
    a. Apply a thin layer of dry cement to the cracks.
    b. Broom the concrete in the direction of the cracks.
    c. Pound the concrete with a hand float before troweling.
    d. Follow the first regular troweling with a second troweling.

33. (407) When the temperature is at or above 50°F, you should cure concrete for at least how many days?
    a. 1.
    b. 3.
    c. 5.
    d. 7.

34. (407) When the temperature is at or above 70°F, you should cure concrete for at least how many days?
    a. 1.
    b. 3.
    c. 5.
    d. 7.

35. (407) When using waterproof paper to cure horizontal concrete surfaces, you should lap the adjacent sheets at least how many inches?
    a. 1.
    b. 6.
    c. 12.
    d. 24.

36. (407) When using epoxy cement to repair concrete, what is the *minimum* thickness you can apply and still retain good strength without cracking?
    a. ⅛ inch.
    b. ½ inch.
    c. ¾ inch.
    d. ⅞ inch.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Masonry Construction

AS A STRUCTURAL JOURNEYMAN, you will be involved with various types of masonry projects. As we enter a time when our forces deploy forward to austere environments, you may be faced with the challenge of repairing existing masonry structures or building new ones. The more familiar you are with the procedures used, the sooner the buildings can be used to accomplish the mission. This unit will provide you with the knowledge needed to be able to tackle those projects successfully.

2–1. Mortar Mixing

Before you can successfully complete any masonry project, you must first learn how to determine what type of mortar mix is required and know how to mix the mortar. Mortar is the common ingredient used for concrete blocks (i.e., concrete masonry units), brick (i.e., clay masonry units), and structural tile construction. In this section, we will focus on the mortar itself.

408. Determining mortar mix and mixing procedures

In this lesson, we will discuss the types of mortar used and how to properly mix mortar. As with cement, there are different types of mortar. The type you choose will depend on different variables.

Masonry mortar

Properly mixed and applied mortar is necessary for good workmanship and good masonry service because it must bond the masonry units into a strong, cohesive structure. The mortar that bonds concrete block, brick, or structural tile will be the weakest part of the masonry unless you mix and apply it properly. When masonry leaks, it is usually through the joints. Both the strength of masonry and its resistance to rain penetration depend largely on the bond strength between the masonry unit and the mortar.

Workability of mortar

Mortar must be plastic enough to work with a trowel. You obtain good plasticity and workability by using mortar having good water retentivity, using the proper grade of sand, and thorough mixing. You do not obtain good plasticity by using a lot of cementitious materials. Mortar properties depend largely upon the type of sand it contains. Clean, sharp sand produces excellent mortar, but too much sand causes mortar to segregate, drop off the trowel, and weather poorly.

Water retentivity

Water retentivity is the mortar property that resists rapid loss of water to highly absorbent masonry units. Mortar must have water to develop the bond. If it does not contain enough water, the mortar will have poor plasticity and workability, and the bond will be weak and spotty. Sometimes you must wet brick to control water absorption before applying mortar but never wet concrete masonry units.

Types of mortar

The table below lists the five types of mortar recommended for various masonry applications.

Mortar Type	Uses
Type M	Suitable for general use, but is recommended specifically for below-grade masonry that contacts the earth, such as foundations, retaining walls, and walks.
Type S	Also suitable for general use, but is recommended where high resistance to lateral forces is required.
Type N	Suitable for general use in above-grade exposed masonry where high compressive or lateral strength is not required.
Type O	Recommended for nonloadbearing, solid-unit walls when the compressive stresses do not exceed 100 pounds per square inch (psi) and the masonry is not subject to freezing and thawing in the presence of a lot of moisture.
Type K	Used for non-loadbearing partitions where building codes allow low compressive and bond strengths.

Mix ratio

Type N mortar is the most appropriate type for residential work. The typical mix ratio using Portland cement, hydrated lime and sand is 1:1:6 (one part Portland cement, one part hydrated lime, and six parts sand [masonry]). If you are using masonry cement mortar, a typical mix proportion is 1:3 (one part masonry cement and three parts sand). You will need to refer to the manufacturer and project specifications for the specific mix ratios.

Mixing mortar

The manner in which mortar is mixed has a lot to do with the quality of the final product. In addition to machine and hand mixing, you need to know the requirements for introducing various additives including water to the mix in order to achieve optimum results.

Machine mixing

Machine mixing refers to mixing large quantities of mortar in a drum-type mixer. Different styles of mixers (fig. 2–1) may require different techniques for mixing based on the material being mixed. Always follow the instructions for the machines and materials that you are using. The following is one suggested way to mix mortar with some machines:

1. Load ¾ amount of water.
2. Load ½ of the sand.
3. Add all masonry cement or Portland cement and lime.
4. Add the balance of sand and water.
5. Mix three (minimum) to five (maximum) minutes. The mortar should be mixed completely until a uniform mixture is obtained.

NOTE: When adding water, you should always add it slowly.

Hand Mixing

Hand mixing involves mixing small amounts of mortar by hand in a mortar box or wheelbarrow. Take care to mix all ingredients thoroughly to obtain a uniform mixture. Mix all dry materials together first before adding water. Keep a steel drum of water close at hand to use as the water supply. You should also keep all your masonry tools free of hardened mortar mix and dirt by immersing them in water when not in use.

To hand mix mortar, we recommend that you follow the four steps below:

1. Add half the sand, followed by all of the cement and lime (if used), and then the remaining amount of sand. This method allows the blending process to take place easier and quicker.
2. Alternately push and pull the materials back and forth until there is an even color.

3. Once the materials are blended, you can either push all the materials to one end of the container or make a hole in the middle (push to both ends).
4. Add one to two gallons of water and mix the dry ingredients into the water using a chopping motion. Then alternately push and pull the mix adding water as needed.

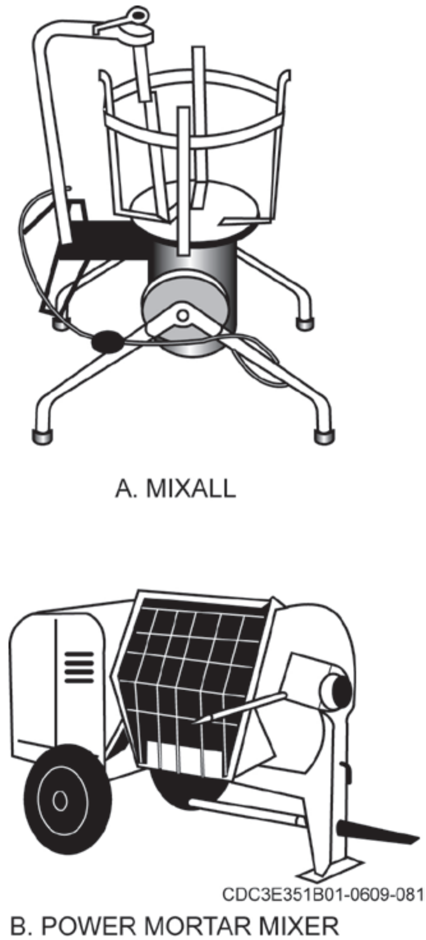


Figure 2–1. Machine mixers.

Requirements

You occasionally need to mix lime putty with mortar. Use a pail to measure the lime putty when machine mixing. Place the putty on top of the sand. When hand mixing, add the sand to the lime putty. Wet pails before filling them with mortar and clean them immediately after emptying.

Mixing water for mortar must meet the same quality requirements as mixing water for concrete. Do not use water containing large amounts of dissolved salts. Salts weaken the mortars.

You can restore the workability of any mortar that stiffens on the mortarboard due to evaporation by remixing it thoroughly (i.e., retempering). Add water as necessary but discard any mortar stiffened by initial setting. Because it is difficult to determine the cause of stiffening, a practical guide is to use mortar within 2½ hours after the original mixing. Discard any mortar you do not use within this time.

Cold weather

Just as concrete requires special precautions during winter so does mortar. Cement hydration stops when temperatures reach 40°F or below. Do not use an antifreeze admixture to lower the freezing point of mortars during winter construction. The quantity necessary to lower the freezing point to any appreciable degree is so large it will seriously impair the strength and other desirable properties of the mortar.

Do not add more than 2-percent calcium chloride (an accelerator) by weight of Portland cement to accelerate mortar's hardening rate and increase its early strength. Do not add more than 1-percent calcium chloride to masonry cements. Calcium chloride should not be used for steel-reinforced masonry. You can also obtain high early strength in mortars with high-early-strength Portland cement.

Another alternative is to heat the materials used in the mix. Water should be heated to produce mortar with a temperature range between 40° and 70°F. **NOTE:** You need to be careful when heating water. Water temperatures above 180°F may cause the cement to flash set.

Estimating mortar

You can use "rule 38" for calculating the raw material needed to mix one cubic yard of mortar; however, this rule does not accurately calculate the materials for large masonry projects. For larger jobs, use the absolute volume or weight formula. In most cases, though, you can use rule 38 to quickly estimate the quantities of the required raw materials.

Rule 38 is based on the fact that it takes about 38 cubic feet of raw materials to make one cubic yard of mortar. In using rule 38 for calculating mortar, take the rule number and divide it by the sum of the numbers specified in the mix. For example, let's assume that the building specifications call for a 1:3 mix for mortar.

$$1 + 3 = 4$$

$$38 \div 4 = 9\tfrac{1}{2}$$

9½ is the prime factor

Multiply the prime factor (in this case 9½) by each number in the mix ratio.

1 × 9½ = 9½ sacks, or 9½ cubic feet, of cement

3 × 9½ = 28½ cubic feet of fine aggregate (sand)

The sum of the two required quantities should always equal 38. This is how you can check whether you are using the correct amounts. In the above example, 9½ sacks of cement plus 28½ cubic feet of sand equal 38. **NOTE:** If using lime, include it when computing the prime factor (1:1:3 = 5 as the prime factor).

Safe handling of material

Wear goggles and snug-fitting neckbands and wristbands when you handle cement or lime bags. Always practice good personal cleanliness and never wear clothing that has become stiff with cement. Cement-impregnated clothing irritates the skin and may cause serious infection. You should report any skin burns caused from cement or lime.

Bags of cement or lime should not be piled more than 10 bags high on a pallet. The only exception is when storage is in bins or enclosures built for such storage. The bags around the outside of the pallet should be placed with the mouths of the bags facing the center. The first five tiers of bags each way from any corner must be cross piled. A setback starting with the sixth tier should be made to prevent piled bags from falling outward. If you have to pile bags above 10 tiers, another setback must be made. The back tier, when not resting against an interior wall of sufficient strength to withstand the pressure, should be set back one bag every five tiers; the same as the end tiers. During unpiling the entire top of the pile should be kept level and the necessary setbacks maintained.

Lime and cement must be stored in a dry place. This helps prevent lime from crumbling and the cement from hydrating before it is used.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Determining mortar mix and mixing procedures

1. Which type of mortar is the most appropriate for residential work?

2. What does a mix ratio of 1:1:6 indicate?

3. What is the suggested way to mix mortar in some machines?

4. When hand-mixing mortar, in what sequence should the dry materials be added together?

5. Within what timeframe should you use or discard mortar after the original mixing?

6. Estimate how much Portland cement, hydrated lime and sand are needed for one cubic yard of mortar when using a 1:1.25:5 mix ratio.

2–2. Masonry Construction and Repair

Now that you know how to calculate and mix mortar, it's time to get into the construction techniques. The three main types of masonry materials are concrete block (i.e., concrete masonry unit), brick (i.e., clay masonry unit), and structural tile, also a clay masonry unit. The procedures used for structural tile are also the procedures used for concrete blocks; thus, this section will only discuss the procedures for concrete blocks and bricks and their maintenance techniques. Let's begin with concrete blocks.

409. Concrete masonry unit construction

Concrete masonry unit (CMU) is a commonly used term for concrete block. In this lesson, we will discuss common construction methods for CMU. With a little practice and a good understanding of the methods used, you'll be able to lay CMUs for simple construction projects. **NOTE:** The terms concrete masonry units and concrete blocks are used interchangeably throughout this lesson.

Concrete masonry unit

Concrete block may be completely solid or contain single or multiple hollows. It is made from conventional cement mixes and various types of aggregate. The aggregate types include sand, gravel, crushed stone, air-cooled slag, coal cinders, expanded shale or clay, expanded slag, volcanic cinders, pumice, and "scotia" (refuse obtained from metal ore reduction and smelting). The term "concrete block" was formerly limited to only hollow masonry units made with such aggregates as sand, gravel, and crushed stone. Today the term covers all types of concrete block—both hollow and solid—made with any kind of aggregate. Concrete blocks are also available with applied glazed surfaces, various pierced designs, and a wide variety of surface textures, as shown in figures 2–2 and 2–3.

Although concrete block is made in many sizes and shapes, the most common size is 7 ⅝ by 7 ⅝ by 15 ⅝ inches. We call this by its nominal size—8 × 8 × 16-inch block. When laid with ⅜-inch mortar joints, the unit should occupy a space exactly 8 × 8 × 16 inches.

All concrete block must meet certain specifications covering size, type, weight, moisture content, compressive strength, and other characteristics. Concrete masonry units are usually manufactured in four loadbearing classes:

1. Hollow loadbearing.
2. Solid loadbearing.
3. Hollow nonloadbearing.
4. Solid nonloadbearing.

Concrete blocks were previously classified into two grades: N and S. The lower grade has been discontinued and there is now only one type, and it is no longer given a grade classification; however, there are two types available—Type I and Type II. Type I consists of moisture-controlled units for use in arid climates. Type II consists of non-moisture controlled units.

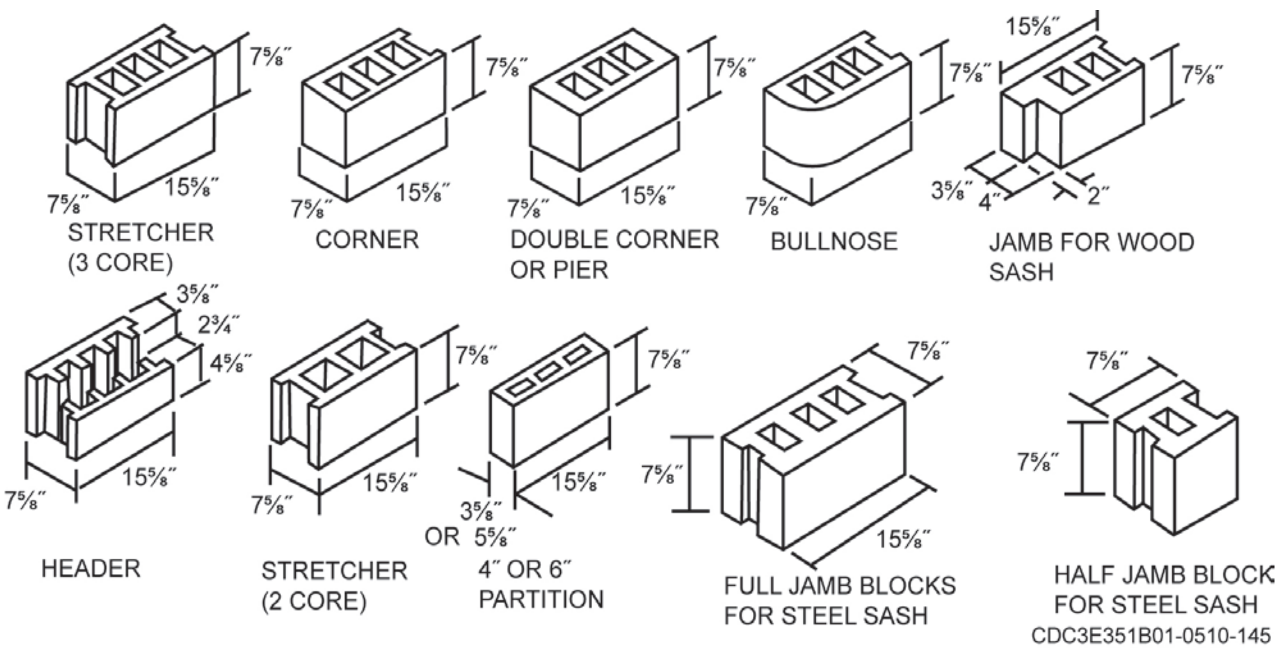


Figure 2–2. Typical concrete blocks.

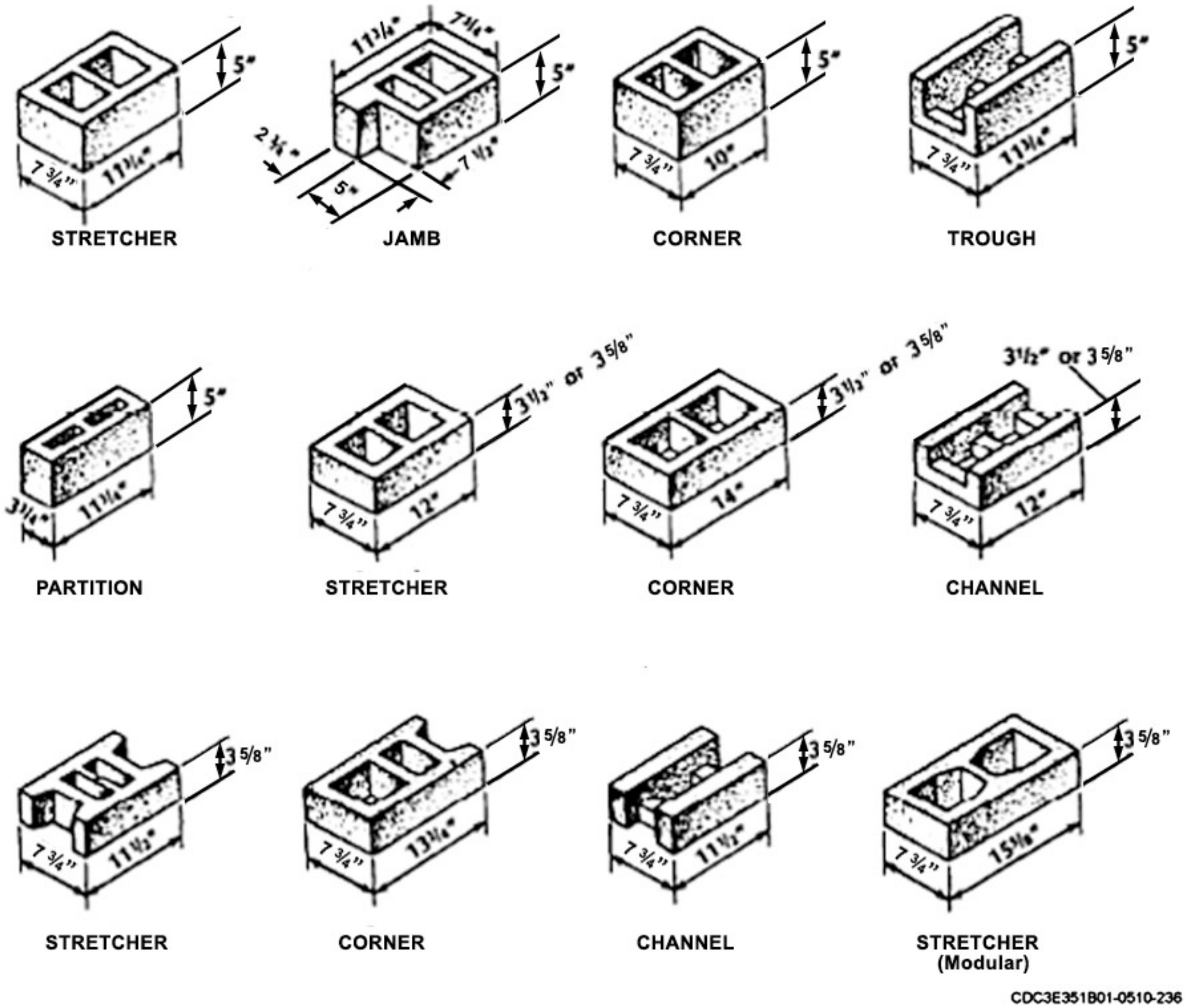


Figure 2–3. Special size concrete blocks.

Block mortar joints

The sides and the recessed ends of a concrete block are called the shell. The material that forms the partitions between the cores is called the web. The long sides of a block are called the face shell. The recessed ends are called the end shell. The vertical ends of the face shells, on either side of the end shells, are called the edges. Figure 2–4 shows some of the block parts, as well as how the mortar is applied to tie (bond) the block courses together.

Bed joints on first courses and bed joints in column construction are mortared by spreading a 1-inch layer of mortar. This procedure is referred to as “full mortar bedding.” For most other bed joints, only the upper edges of the face shells need to be mortared. This is referred to as “face shell mortar bedding.”

Head joints may be mortared by buttering both edges of the block being laid or by buttering one edge on the block being laid and the opposite edge on the block already in place.

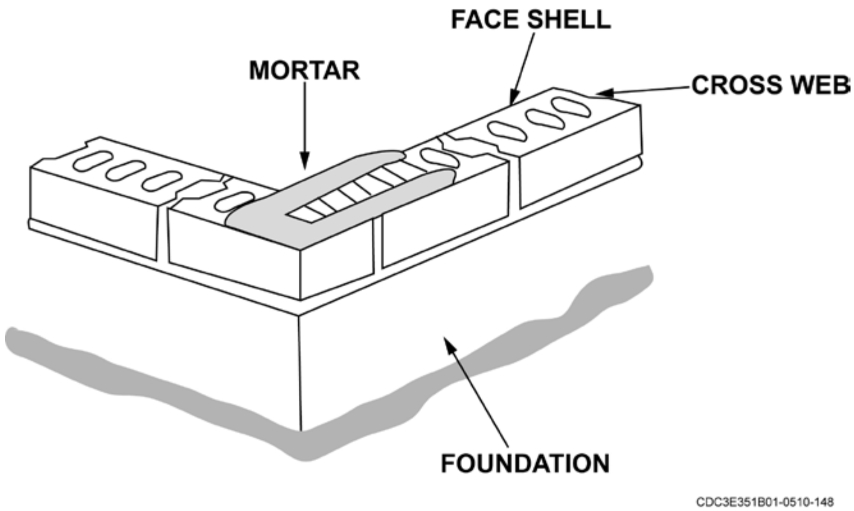


Figure 2–4. Mortar joints.

Modular planning

You should layout concrete masonry walls to make maximum use of full- and half-length units. This will minimize cutting and fitting. This refers to length and height of walls, width and height of openings, and wall areas between doors, windows, and corners. Thus, window and doorframes ordered should be modular dimensions to fit.

There are tables available that list the nominal length of concrete masonry walls by stretchers and the nominal height of concrete masonry walls by courses. If the thickness of the wall is greater or less than the length of a half unit, a special-length unit is required at each corner in each course. The table below lists the average number of concrete masonry units by size and approximate number of cubic feet of mortar required for every 100 square feet of concrete masonry wall.

Average CMU's and Mortar per 100 Square Feet of Wall			
Size of Block (inches)	Thickness Wall (inches)	Number of Units per 100 ft^2 of Wall Area	Mortar (ft^3)
8 x 8 x 16	8	110	3.25
8 x 8 x 12	8	146	3.5
8 x 3 x 12	3	146	3.5
8 x 4 x 16	4	110	3.25
8 x 4 x 12	4	146	4
8 x 6 x 16	6	110	3.25

When using tables, you should always use outside measurements when calculating the number of blocks required per course—remember to take deductions for windows and doors.

You might find yourself in the field without tables to use. If that's the case, you should have learned how to calculate the number of block needed for a project when you completed 3E351D, Volume 3, *Project Planning, Tools and Equipment*. Use 3/4 times the length and 3/2 times the height for figuring how many 8 × 8 × 16-inch blocks you need for a wall.

Construction sequence

There are various ways to begin your construction project. The steps below are one suggested construction method.

Locate corners

When constructing a concrete masonry wall, your first step is to locate the corners. After you have located the corners, you should check if the footing or slab is level. If it is not level, you may have to build up the bed joints on the low sides to get the first course level. Thus, instead of having the height at 8 inches, you may need to lay one corner at 8¼ inches if the slab is ¼ inch low. **NOTE:** If the slab is badly out of level, you should complete the entire first course before you begin working on other courses.

Chase the bond

Once the corners are located, you should "chase the bond," or lay out the blocks. You do this by placing the first course of blocks without mortar (fig. 2–5, view 1). Snap a chalk line to mark the outside walls of the building to align the blocks accurately. Then use a piece of material ⅜-inch-thick to properly space the blocks. This helps you get an accurate measurement and to plan for any cuts.

Spread mortar bed

After you chase the bond, you're ready to begin laying the blocks. Take a look at the next set of steps to properly lay the blocks.

1. Remove all the loose blocks and spread a full mortar bed to begin laying the first course. Spread and furrow the mortar bed with a trowel to ensure plenty of mortar under the bottom edges of the first course (fig. 2–5, view 2).
2. Lay the corner block first. Make sure that it is carefully positioned and aligned (fig. 2–5, view 3).
3. Lay the remaining blocks in the first course with the thicker side (web) up to provide a larger mortar-bedding area. For the vertical joints, apply mortar only to the block end. To speed up the operation, place several blocks on end and butter them all in one operation (fig. 2–5, view 4). Make the joints ⅜-inch-thick. Then place each block in its final position, and push the block down vertically into the mortar bed and against the previously laid block. This ensures a well-filled vertical mortar joint (fig. 2–5, view 5).
4. After laying three or four blocks, use a mason's level as a straightedge to check correct block alignment (fig. 2–6, view 1) and for level and/or plumb. Tap the blocks with the trowel handle as shown in view 2 to make any adjustments.

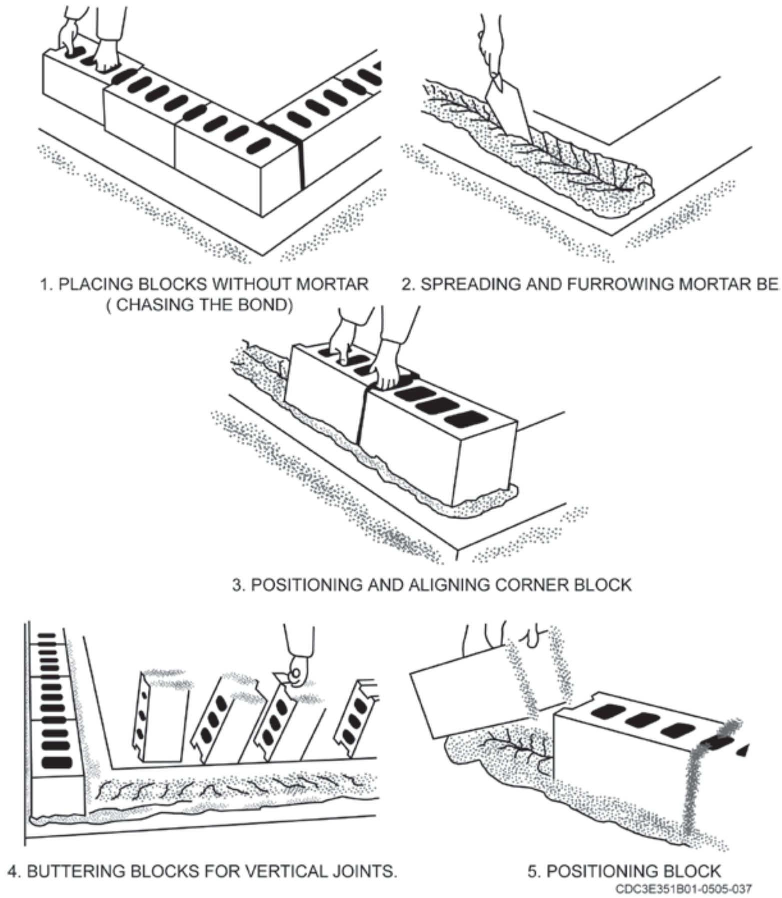


Figure 2–5. Laying block.

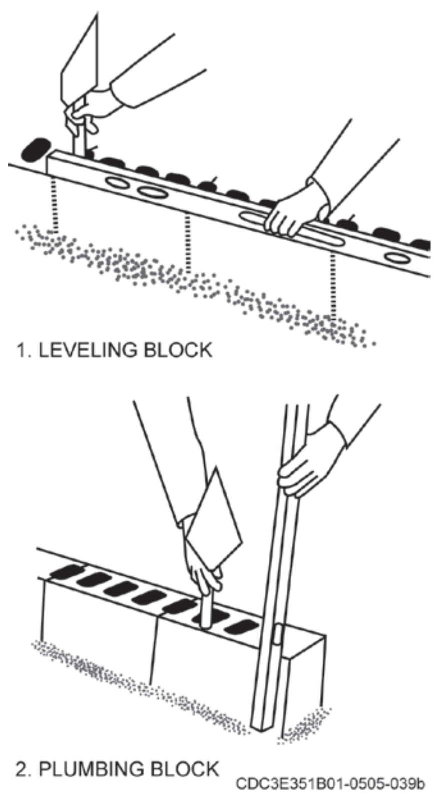


Figure 2–6. Block aligning.

Build corner leads

Build up the corners (corner lead) of the wall once the first course is laid, usually five or six courses high (fig. 2–7). To lay the corner lead follow the five steps below:

1. Step back each course one-half block. For the horizontal (bed) joints, apply mortar only to the tops of the blocks already laid. For the vertical (head) joints, you can apply mortar either to the ends of the new block or the end of the block previously laid, or both (fig. 2–8).
2. As you lay each course at the corner, check the course with a level for alignment (fig. 2–9, view 1), for level (view 2), and for plumb (view 3).
3. Carefully check each block with a level or straightedge to make sure that all the block faces are in the same plane.
4. Use a story pole, a board with markings eight inches apart, to accurately place each course. **NOTE:** Check the vertical height at the outside corner locations only.
5. Check the horizontal block spacing by placing a level diagonally across the corners of the blocks (fig. 2–10).

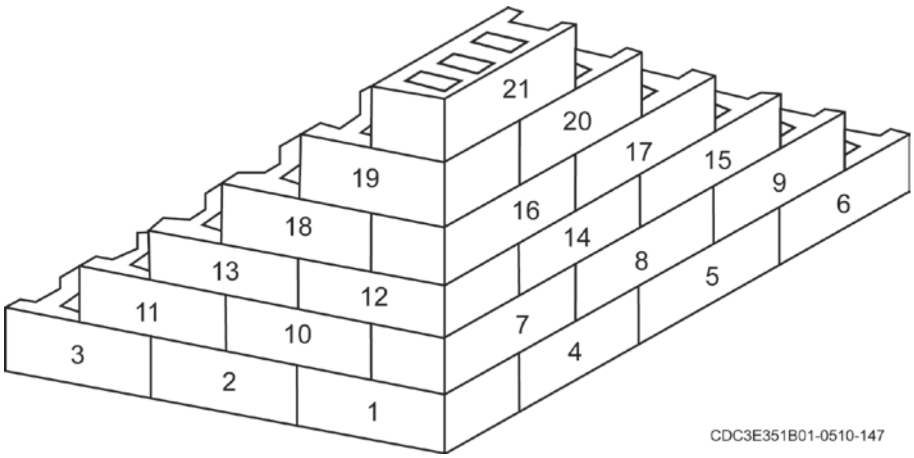


Figure 2–7. Corner lead.

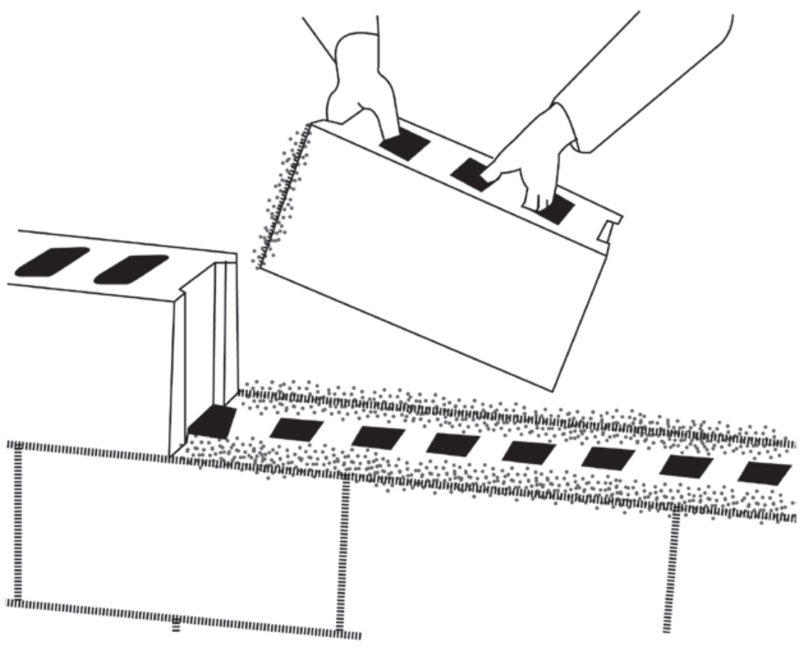


Figure 2–8. Setting block with buttered end.

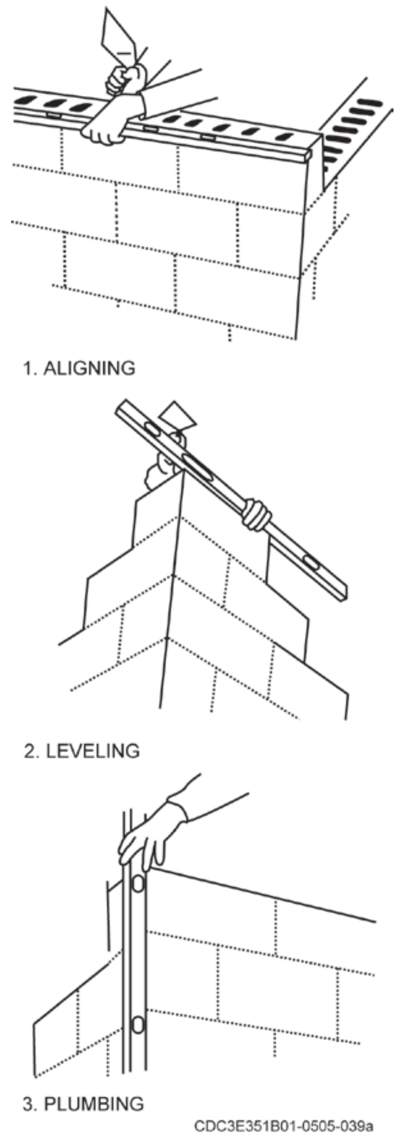


Figure 2–9. Checking block with level.

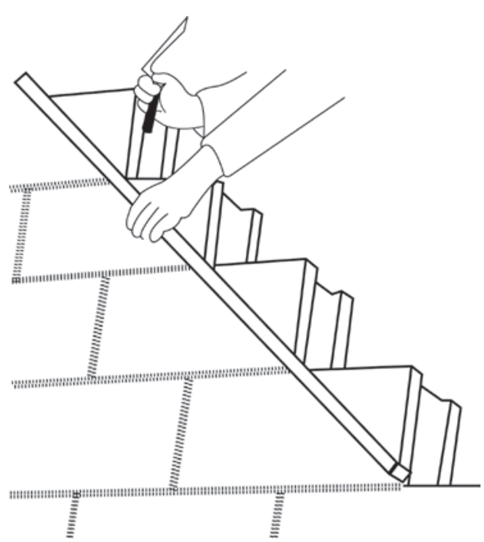


Figure 2–10. Checking block diagonally with level.

Laying stretcher blocks

After the corner leads are laid, you begin filling in the wall between the corners. To do this, we suggest that you complete the following three steps:

1. Stretch a mason’s line along the outer block edges from corner to corner (one course at a time).
2. Lay the top outside edge of each new block to this line (fig. 2–11). To grip the block, tip it slightly toward you so that you can see the edge of the course below. Then place the lower edge of the new block directly on the edges of the block below.
3. Make all position adjustments while the mortar is soft and plastic. Any adjustments you make after the mortar stiffens will break the mortar bond and allow water to penetrate. Level each block and align it to the mason’s line by tapping it lightly with a trowel handle.

Closure block

Before installing the closure block, butter both edges of the opening and all four vertical edges of the closure block with mortar. Then lower the closure block carefully into place (fig. 2–12). If any mortar falls out leaving an open joint, remove the block and repeat the procedure.

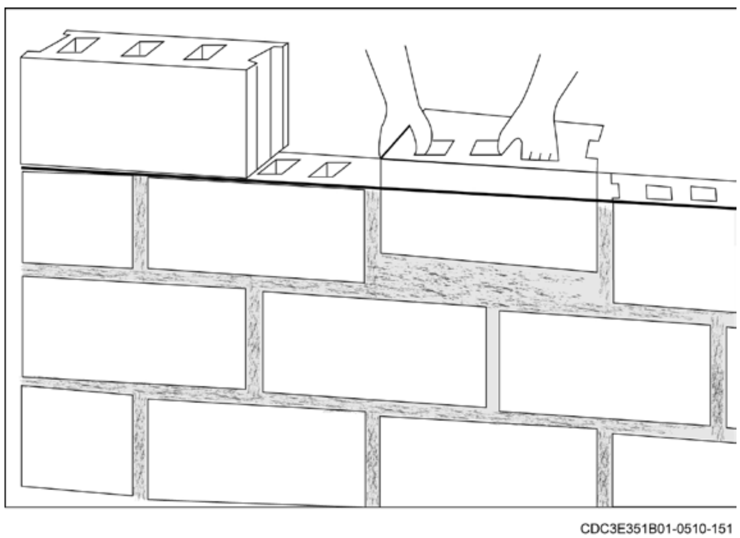


Figure 2–11. Laying block to the line.

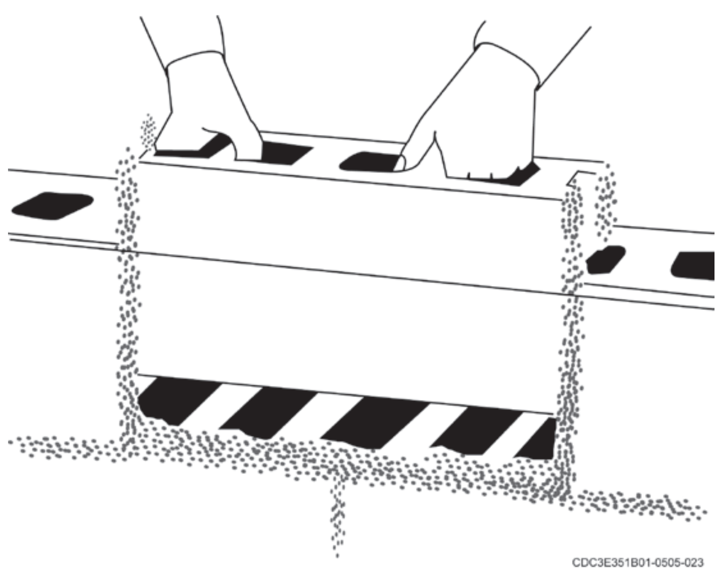


Figure 2–12. Setting closure block.

General construction notes

To ensure a good bond, do not spread mortar too far ahead when laying the blocks; the mortar will stiffen and lose its plasticity. Joints should be ⅜ inch unless specifications call for something different. When properly made, these joints produce a weathertight, neat, and durable wall. As you lay each block, use the trowel to cut off excess mortar from the joints (fig. 2–13) and throw it back on the mortarboard to rework into the fresh mortar. **NOTE:** It's not recommended to rework any mortar that was dropped on the scaffold or floor.

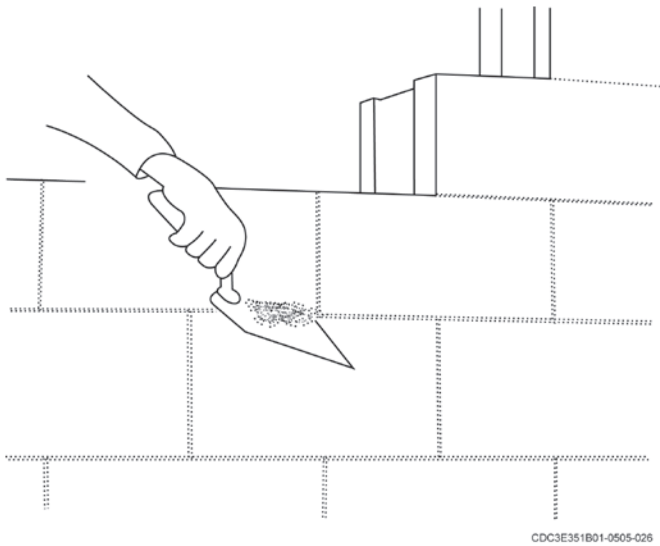


Figure 2–13. Cutting off excess mortar.

Tooling the joints

Weathertight joints and the neat appearance of concrete masonry walls depend on proper striking (tooling). After laying a wall section, start tooling the joint when the mortar becomes "thumb print" hard. Tooling compacts the mortar and forces it tightly against the masonry on each side of the joint. Use either concave or V-shaped jointer on all joints (fig. 2–14). Tool horizontal joints (fig. 2–15, view 1) with a long jointer first, followed by tooling the vertical joints (view 2) with an S-shaped jointer. Use a trowel to trim off mortar burrs, created from the tooling.

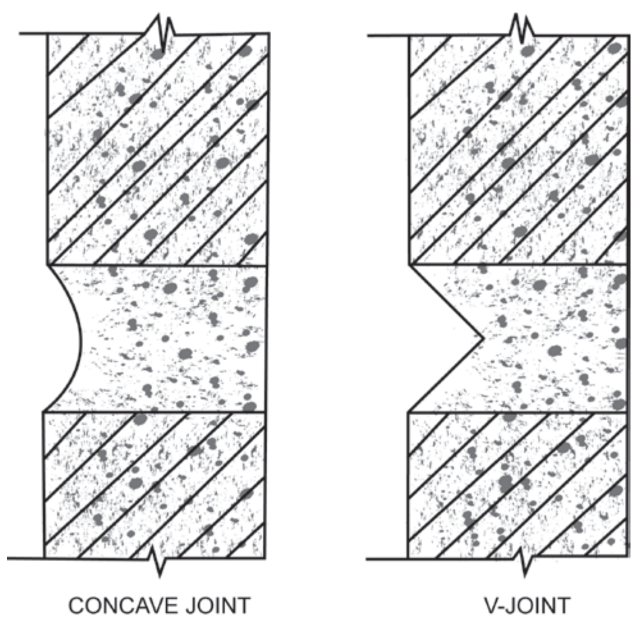


Figure 2–14. Tooled joints.

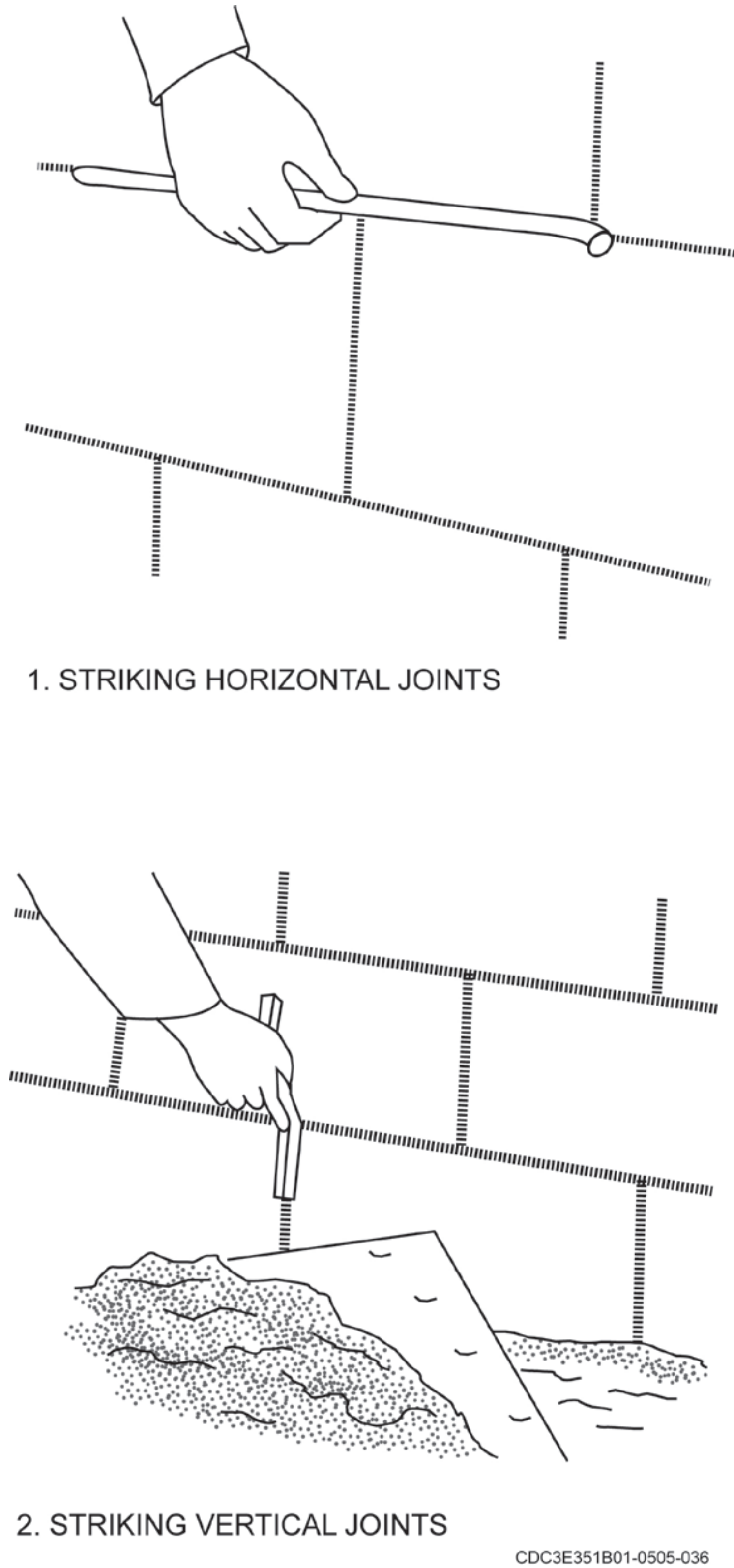


Figure 2–15. Striking (tooling) the joints.

Anchor bolts

You must prepare in advance for installing wood plates (sills) with anchor bolts on top of hollow concrete masonry walls. To do this, place pieces of metal lath in the second horizontal mortar joint from the top of the wall under the cores that will contain the bolts (fig. 2–16, view 1). Use anchor bolts ½ inch in diameter and 18 inches long. Space them not more than four feet apart. Then when you complete the top course, insert the bolts into the cores of the top two courses and fill the cores with concrete or mortar. The metal lath underneath holds the concrete or mortar filling in place. The threaded end of the bolt should extend above the top of the wall (view 2).

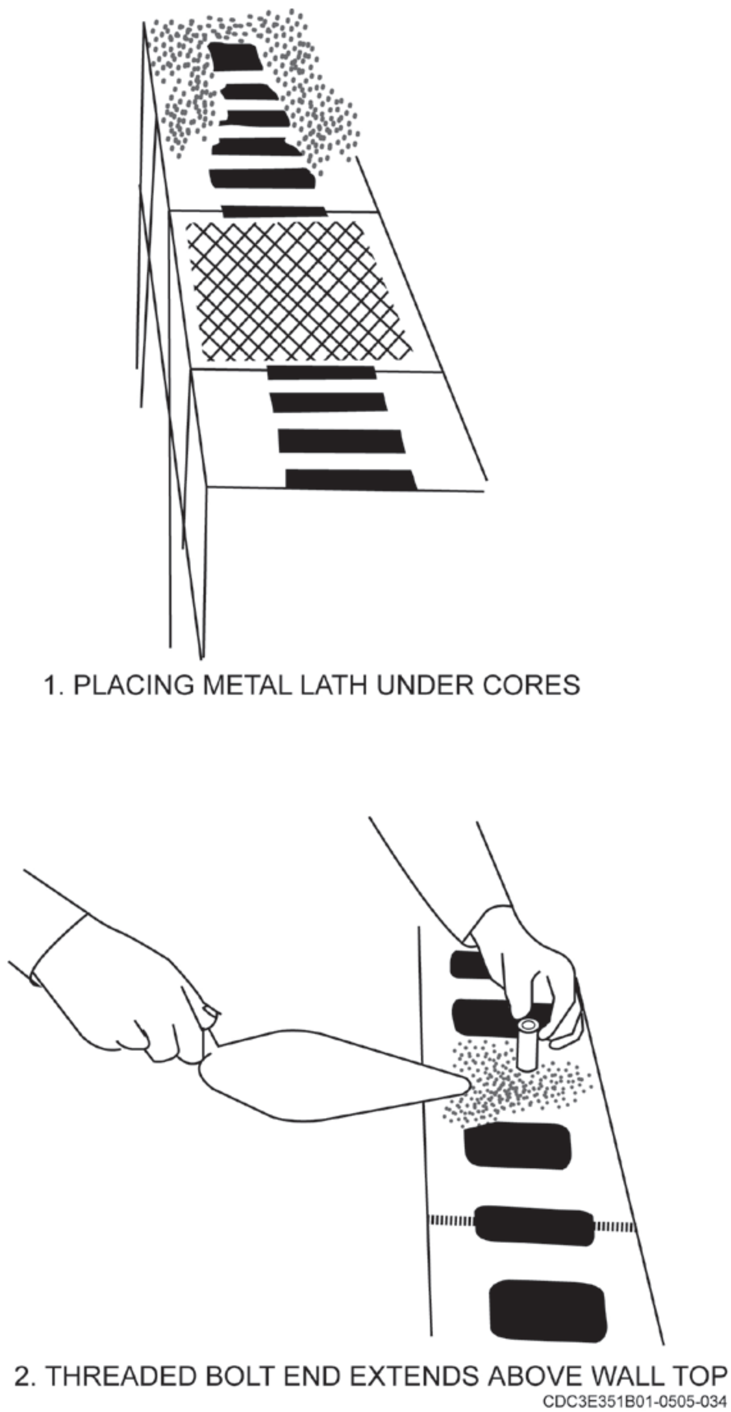


Figure 2–16. Installing anchor bolts.

Control joints

Control joints (fig. 2–17) are continuous, weakened vertical joints that permit a masonry wall to move slightly to accommodate concrete's natural shrinkage. This allows any cracking to take place at these joint instead of random locations throughout the wall. There are a number of types of control joints that can be built into a concrete masonry wall. The three types discussed here are the Michigan, tongue and groove, and the Z-bar.

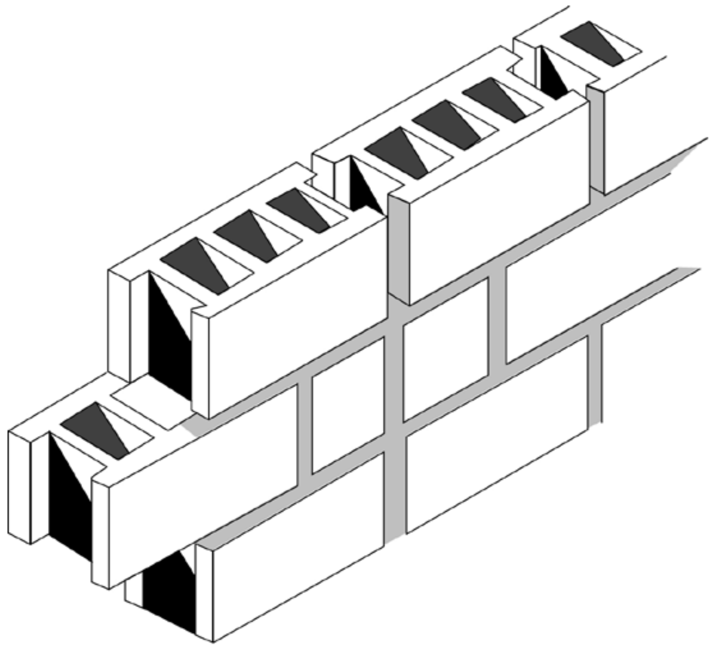


Figure 2–17. Control joint made using half- and full-length block.

Michigan control joint

A common method is known as the *Michigan control joint* made with roofing felt. A strip of felt is curled into the end core, covering the end of the block on one side of the joint (fig. 2–18, view 1). As the other side of the joint is laid, the core is filled with mortar. The filling bonds to one block, but the paper prevents bond to the block on the other side of the control joint.

Tongue and groove control joint

View 2 of figure 2–18 shows the tongue-and groove control joint. These units are manufactured in sets consisting of full and half blocks. The tongue of one unit fits into the groove of another unit. The units are laid in mortar exactly the same as any other masonry unit, including mortar in the head joint. The head joint is then raked ½- to ¾-inch and later filled with caulk.

Control joint using Z-bar

This method (fig 2–18, view 3) makes use of full- and half-length stretcher blocks with a Z-shaped bar placed across the joint. These bars should be placed every other course. Lay up control joints in mortar just as any other joint. After the mortar is stiff, rake it out to a depth of ½- to ¾-inch to make a recess for the caulking compound. Use a thin, flat caulking trowel to force the compound into the joint.

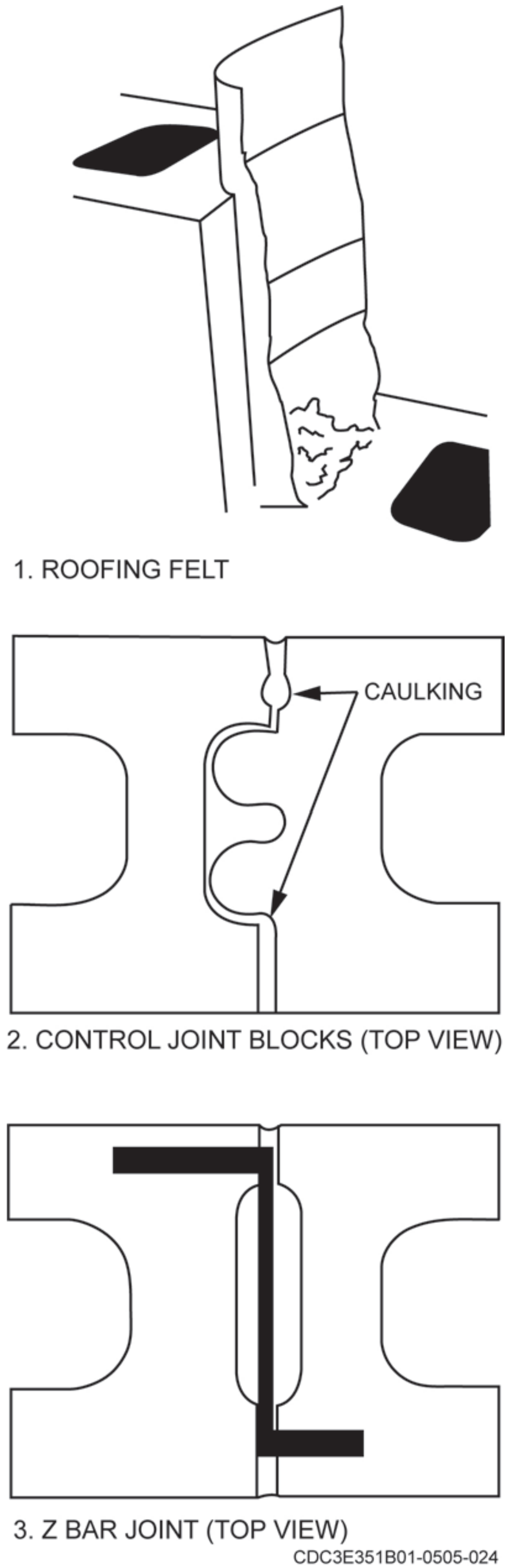


Figure 2–18. Types of control joints.

The location of control joints should be noted in the plans and specifications; however, they are typically spaced so as to divide the wall into sections that are no more than 20 feet long.

Walls

There are two types of walls—loadbearing and nonloadbearing. Loadbearing walls provide structural support for whatever is above them. Nonloadbearing walls function solely as partitions between spaces.

Loadbearing walls

Do not join intersecting concrete block loadbearing walls with a masonry bond, except at the corners. Use a control joint to tie one wall at the face of the second wall. Use Z-shaped metal tie bars ¼-inch-thick by 1¼-inch wide by 28 inches in size to tie the intersecting walls together. The tie bars should have 2-inch right-angled bends on each end (fig. 2–19, view 1). Space the tie bars no more than four feet apart vertically and place pieces of metal lath under the block cores that will contain the tie bars ends (fig. 2–20). Embed the right-angle bends in the cores by filling them with mortar or concrete (fig. 2–19, view 2).

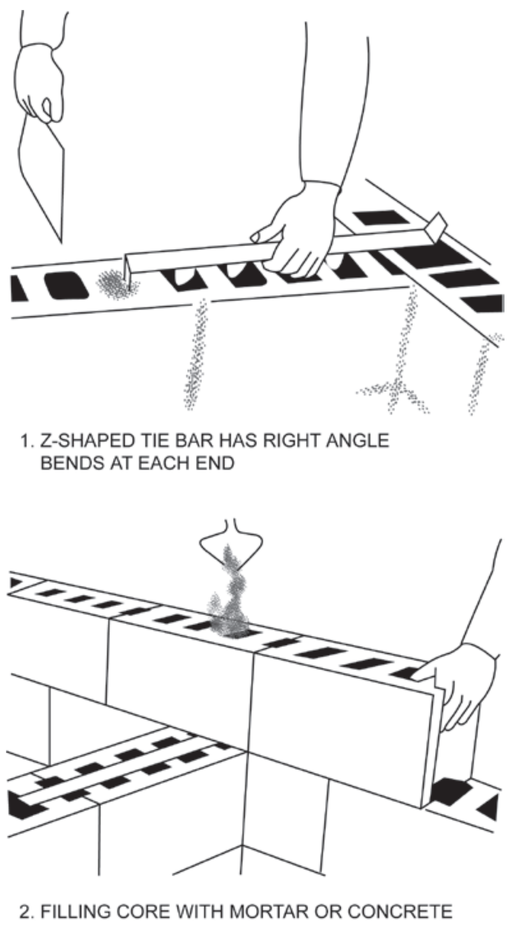


Figure 2–19. Tying intersecting loadbearing walls.

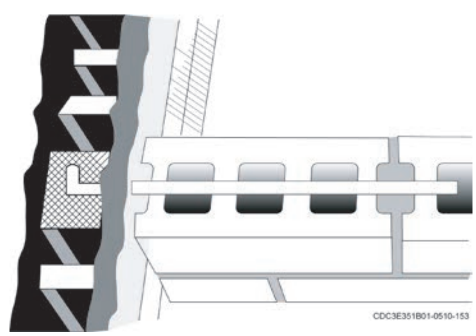
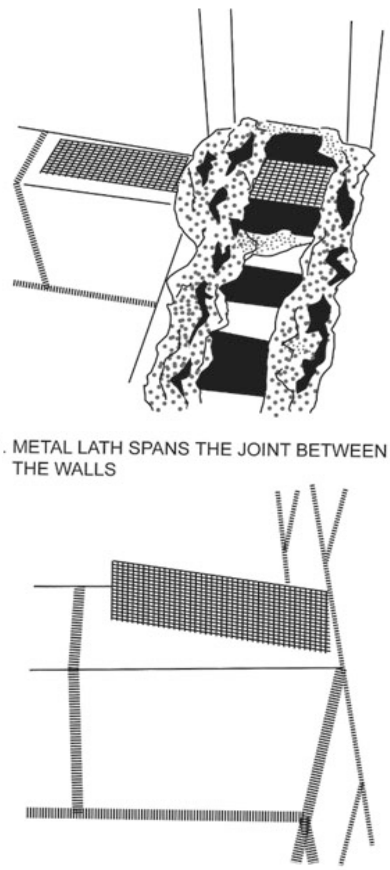


Figure 2–20. Metal lath under the tie bar end.

Nonloadbearing walls

To join intersecting nonloadbearing block walls, terminate one wall at the face of the second with a control joint. Place strips of metal lath (¼-inch galvanized mesh) across the joint between the two walls (fig. 2–21, view 1) every alternate course. Insert one-half of the metal lath into one wall as you build it, and then tie the other halves into the mortar joints as you lay the second wall (view 2).



1. METAL LATH SPANS THE JOINT BETWEEN THE WALLS

2. SET LATH IN THE MORTAR JOINT AS YOU CONSTRUCT THE SECOND WALL

Figure 2–21. Tying intersecting nonloadbearing walls.

Bond beams, lintels, and sills

Bond beams are reinforced courses of block that bond and integrate a concrete masonry wall into a stronger unit. They increase the bending strength of the wall and are particularly needed to resist the high winds of hurricanes and earthquake forces. In addition, they exert restraint against wall movement reducing the formation of cracks.

Bond beams

Bond beams are constructed with special-shape masonry units (beam and lintel block) filled with concrete or grout and reinforced with embedded steel bars. These beams are usually located at the top of walls to stiffen them. In some areas, bond beams are required every sixth course. To install a bond beam on the top of the wall refer to the next three steps.

1. Lay the U-shaped block (bond beam block) as you would regular block.
2. Install the required size rebar inside the block to tie together the entire top of the wall. Lap all splices at least 40 times the bar diameter. **NOTE:** Make sure the rebar is at least ⅝ inch away from the exterior face of the joint.
3. Fill the block core with concrete.

Lintels and sills

Figure 2–22 shows the use of lintel blocks to place a lintel over a metal door, using the door case for support. As a rule of thumb, provide one inch of bearing at each end for every foot of clear space (minimum bearing of six inches) when installing lintels.

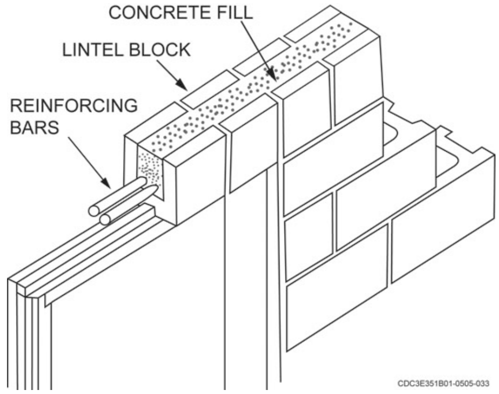


Figure 2–22. Lintel made using lintel blocks.

Modular door and window openings usually require lintels to support the blocks over the openings. You can use precast concrete lintels (fig. 2–23) that contain an offset on the underside to fit the openings. You can also use steel lintel angles that you install with an offset on the underside (fig. 2–24) to fit the openings. In either case, place a noncorroding metal plate under the lintel ends at the control joints to allow the lintel to slip and the control joints to function properly. Apply a full bed of mortar over the metal plate to uniformly distribute the lintel load.

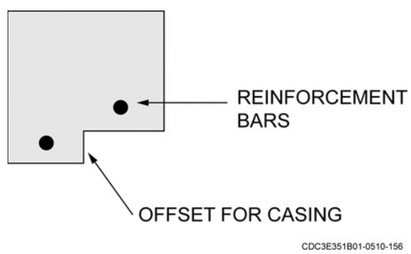


Figure 2–23. Precast concrete offset on lintel underside.

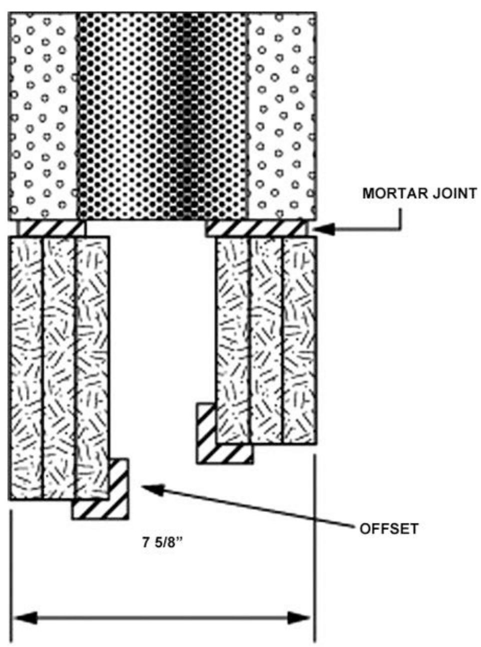


Figure 2–24. Steel angles offset on lintel underside.

You usually install precast concrete sills (fig. 2–25) following wall construction. Fill the joints tightly at the ends of the sills with mortar or a caulking compound.

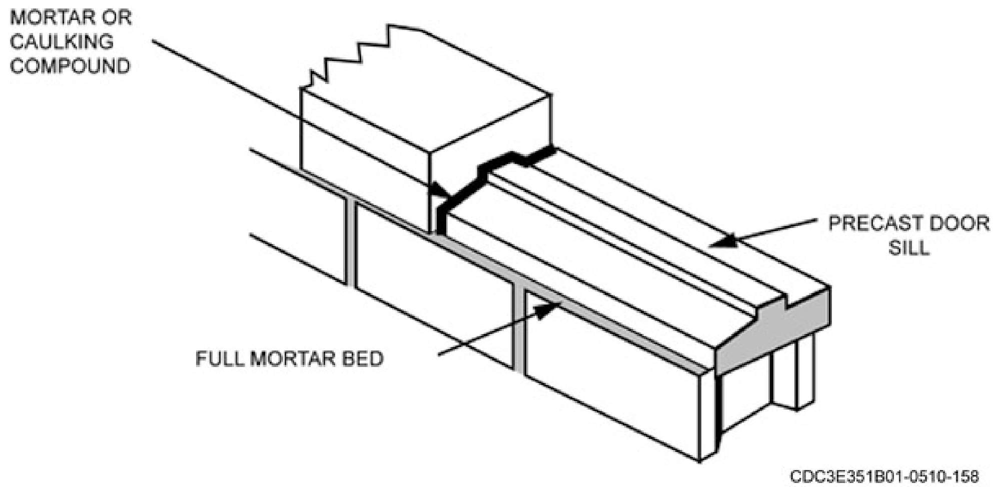


Figure 2–25. Precast concrete door sill.

Reinforced block walls

You may reinforce block walls vertically or horizontally. To reinforce vertically, place reinforcing rods (rebar) into the cores at the specified spacing and fill the cores with a relatively high-slump concrete. Rebar should be placed at each corner and at both sides of each opening. Vertical rebar should be spaced a maximum of 32 inches on center in walls. Where splices are required, the bars should be lapped 40 times the bar diameter. The concrete should be placed in one continuous pour from foundation to plate line.

Horizontal joint reinforcement controls cracking and aids wall flexibility. The amount of joint reinforcement depends largely upon the type of construction. Horizontal joint reinforcement, where required, should consist of not less than two deformed longitudinal No. 9 or heavier cold-drawn steel wires. Truss-type cross wires should be ⅛-inch diameter or heavier of the same quality. Figure 2–26 shows joint reinforcement on 16-inch vertical spacing.

NOTE: Your plans and specifications should show the location and details of bond beams, control joints and joint reinforcing.

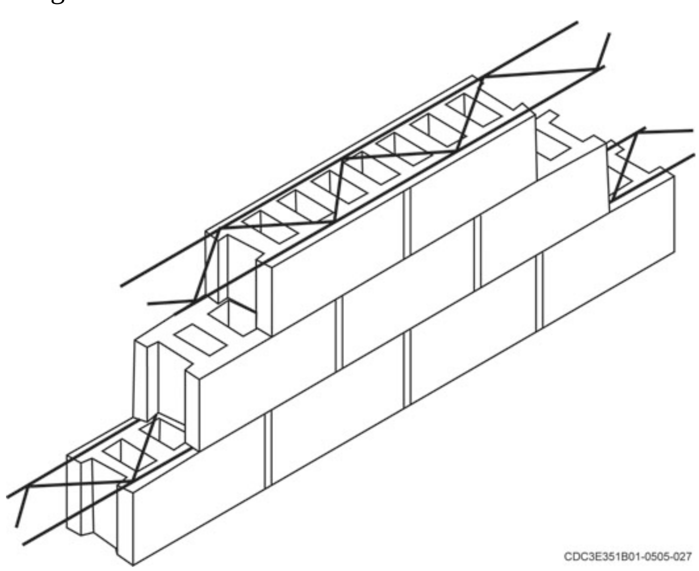


Figure 2–26. Horizontal joint reinforcement.

410. Clay masonry construction

The two types of clay masonry discussed in this lesson are brick and structural tiles. It's important for you to be able to distinguish the different characteristics of each and to know how to use them for various construction projects. We'll begin the lesson with brick and finish our discussion with structural tiles.

Brick masonry

Brick masonry is masonry construction in which units of baked clay or shale of uniform size, small enough to be placed with one hand, are laid in courses with mortar joints to form walls. Bricks are kiln-baked from various clay and shale mixtures.

Terms

To lay brick efficiently and effectively, you must be familiar with the terms that identify the position of masonry units in a wall. The following list provides some of the basic terms you will encounter:

- Course—One of several continuous, horizontal layers (or rows) of masonry units bonded together.
- Wythe—The Wythe is a continuous vertical section of a wall, one masonry unit thick. This is sometimes called a tier.
- Stretcher—A masonry unit laid flat on its bed along the length of a wall with its face parallel to the face of the wall.
- Header—A masonry unit laid flat on its bed across the width of a wall with its face perpendicular to the face of the wall. It is generally used to bond two Wythes.
- Rowlock—A header laid on its face or edge across the width of a wall.
- Bull header—A rowlock brick laid with its bed perpendicular to the face of the wall.
- Bull stretcher—A rowlock brick laid with its bed parallel to the face of the wall.
- Soldier—A brick laid on its end with its face perpendicular to the face of the wall.

Brick classification

A finished brick structure contains *face* brick (brick placed on the exposed face of the structure) and *backup* brick (brick placed behind the face brick). The face brick is often of higher quality than the backup brick; however, the entire wall may be built of *common* brick. Common brick is made from pit-run clay with no attempt at color control and no special surface treatment, like glazing or enameling. The most common brick is red.

Face brick

Although any surface brick is a face brick as distinguished from a backup brick, the term "*face brick*" is also used to distinguish high-quality brick from brick that is of common-brick quality or less. Face brick is more uniform in color, has a better surface appearance and may also be more durable than common brick.

Backup brick

Backup brick may consist of brick that is inferior in quality to common brick. Brick that has been underburned or overburned, or brick made with inferior clay or by inferior methods, is often used for backup brick.

Brick grades

Still another type of classification divides brick into grades according to the probable climatic conditions to which they are to be exposed. These grades of brick are as follows:

- Grade SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.

- Grade MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that of the northern regions of the United States.
- Grade NW is brick primarily intended for interior or backup brick. It may be exposed; however, it should only be used in regions where no frost action occurs.

Types of bricks

Brick masonry units may be solid, hollow, or architectural terra cotta. All types can serve a structural function, a decorative function, or a combination of both. The various types differ in their formation and composition. Here are some of the types of bricks used most often:

Common

Building brick, also called common, is made from ordinary clay or shale and is fired in kilns. These bricks have no special shoring, markings, surface texture, or color. Because building bricks are generally used as the backing courses in either solid or cavity brick walls, the harder and more durable types are preferred.

Face

Face brick is better quality and has better durability and appearance than building brick. Because of this, face bricks are used in exposed wall faces.

Clinker

Clinker brick is overburned in the kiln. Clinker bricks are usually rough, hard, durable, and sometimes irregular in shape.

Pressed

Pressed brick is made by a dry-press process, rather than by kiln firing. Pressed bricks have regular, smooth faces, sharp edges, and perfectly square corners. Ordinarily they are used like face brick.

Glazed

Glazed brick has one surface coated with a white or colored ceramic glazing. Glazed bricks are particularly suited to walls or partitions in hospitals, dairies, laboratories, and other structures requiring sanitary conditions and ease of cleaning.

Fire

Firebrick is made from a special type of clay. This clay is very pure and uniform and is able to withstand the high temperatures of fireplaces, boilers, and similar constructions. Firebricks are generally larger than other structural bricks and are often hand-molded.

Brick characteristics

Bricks vary in size, color, weight, and even strength because there are variations in the baking process. It’s important to know the brick’s physical characteristics as well as its use.

Size

There are two standard brick sizes. Common bricks and rough-faced bricks are 2¼ inches high (deep), 3¾ inches wide, and 8 inches long. Smooth-faced bricks or pressed bricks are 2¼ × 3 × 8 inches. Bricks vary slightly from these sizes because of shrinkage during burning. Special bricks are also made in other sizes. Firebricks, for instance, are usually 2¼ × 4½ × 9 inches.

Shape

The standard brick is rectangular; however, figure 2–27 shows a few variations. When ¼ of a brick is cut off, we call the remaining part a three-quarter bat or closure. When a brick is cut across the 3¾-inch (or 3-inch) face, we call the parts quarter bats, half bats, three-quarter bats or closures.

Weight

A brick's weight varies with its size, material, time burned, and processing method, but generally a common brick weighs about 4½ pounds.

Quality

Good-quality bricks must be uniform in size and shape. Their edges should be straight, square, and well defined. The bonding surfaces are slightly rough to get a good bond. A good brick won't absorb more than 10 to 15 percent of its dry weight if you leave it in water for 24 hours. You should hear a metallic ring when you strike two good bricks together.

Color

Most bricks are various shades of red or yellow. Differences in the clay and the manufacturing process accounts for the different shades. The burn time also causes slight color differences, so try to avoid these color differences by getting all the bricks you need for a job at one time.

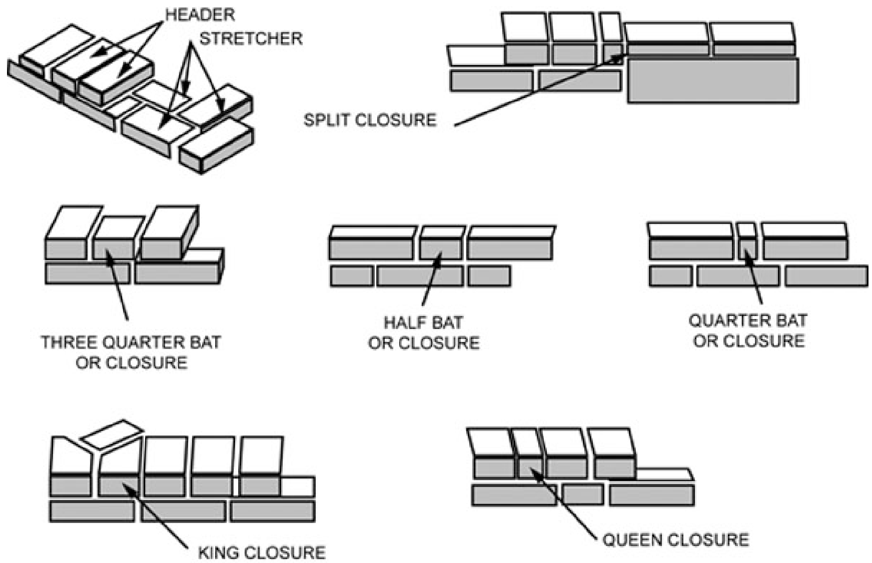


Figure 2–27. Various brick shapes.

Strength

Bricks' compressive and tensile strengths vary with the burn time (baking) and the material in them. Bricks are classified as vitrified, hard, medium, and soft, with vitrified brick being the strongest and the others are in descending strength order. Although bricks add strength to a wall, it is quality mortar joints that hold the wall together and give it strength throughout the entire wall. Your skill as a craftsman is what it takes to build a strong brick wall.

Receiving and handling bricks

You must receive and handle bricks carefully. There's only so much you can do about variations in color and size, but there are several techniques that you can use to obtain professional results.

Sampling

Keep a sample from the first face brick load that you receive at the job site. Inspect all later loads and compare them with the sample as they're being unloaded. This assures you that the bricks are uniform in quality, size, and color.

Stacking

Stack face bricks in neat piles on the job site. Also, place straw layers between the courses to protect the faces of the bricks. Face bricks carried to the mason should be stockpiled face up on the scaffold for convenience in handling.

Wetting

Normally bricks are stacked where they can be easily wetted down before they're used. In hot, dry weather, bricks can absorb a lot of water. Use a hose or sprinkler to wet the bricks but don't saturate them. The following list provides you the reasons for wetting:

- Damp bricks spread the mortar more evenly and they stick to the mortar better.
- Dry bricks absorb moisture from the mortar and make the mortar set too fast.
- Wetting washes the kiln dust from the bricks.
- Results in better mortar joints.

Avoid laying bricks in cold weather. If you must lay them in cold weather, don't allow them to get wet. Warm them up before you use them. Other requirements include using warm water and warm sand for the mortar mix.

Cutting brick

There are several methods you can use to cut or split brick into various shapes. You can use a brick hammer to split a brick (fig. 2–28, view A), then use the chisel-like end to smooth the surface by chipping (fig. 2–28, view B).

You can use a brick set (fig. 2–29) to make more accurate cuts. To use the brick set do the following:

- Turn the straight side of the cutting edge so it faces the brick part to be saved. Score the brick on all four sides.
- After you score the brick, hit the brick set with one sharp blow with the hammer to break the brick in the right location.

Some craftsmen use the heavy back edge of a trowel to chip brick to fit if the rough edges won't show. Just be careful to not cut your fingers or dent the trowel blade. However, you should use a masonry saw if one is available especially if the job requires cutting several bricks. The masonry saw leaves a smooth, even surface. Always wear a face shield or goggles when you cut bricks and follow the manufacturer's instructions for safety.

Bonding brick

Bonding the bricks makes brickwork strong, solid and durable. Mortar joints tie all bricks together. If you don't place the bricks to form a strong bond, the structure won't have the strength to support heavy loads. The term *bond*, as used in masonry, has one of three different meanings—structural bond, mortar bond, or pattern bond.

Structural bond

Structural bond refers to how the individual masonry units interlock or tie together into a single structural unit. You can achieve structural bonding of brick in one of the following three ways:

1. Overlapping (interlocking) the masonry units.
2. Embedding metal ties in connecting joints.
3. Using grout to adhere adjacent Wythes of masonry.

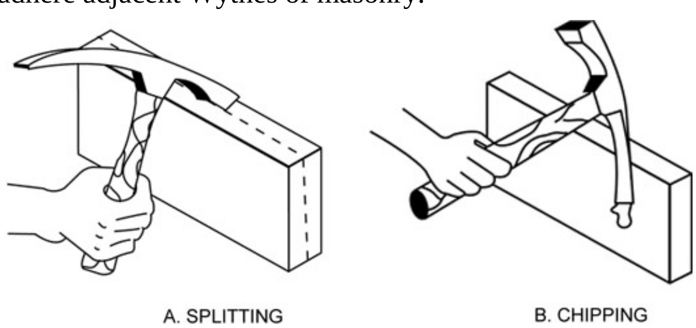


Figure 2–28. Splitting a brick with a brick hammer.

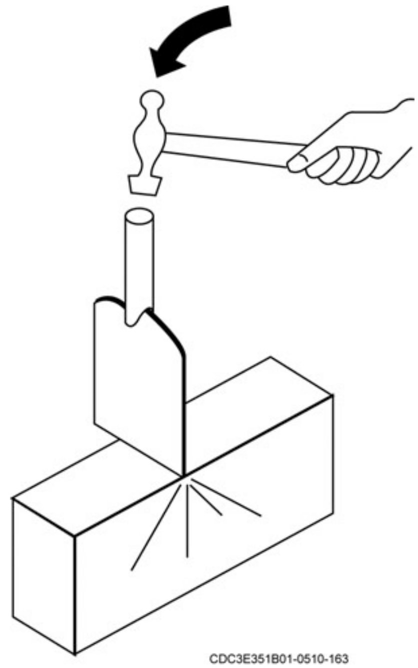


Figure 2–29. Brick set.

Mortar bond

Mortar bond refers to the adhesion of the joint mortar to the masonry units or to the reinforcing steel.

Pattern bond

Pattern bond refers to the pattern formed by the masonry units and mortar joints on the face of a wall. The pattern may result from the structural bond or it may be purely decorative and unrelated to the structural bond. There are six basic pattern bonds in common use today. They are running, common or American, Flemish, English, stack, and English cross or Dutch bond. Figure 2–30 shows three of them.

Running

The running bond is the simplest of the six patterns, it consists of all stretchers. Because the bond has no headers, metal ties usually form the structural bond. The running bond is used largely in cavity wall construction and brick veneer walls.

Common

The common, or American, bond is a variation of the running bond. It has a course of full-length headers at regular intervals that provide the structural bond as well as the pattern. Header courses usually appear at every fifth, sixth, or seventh course depending on the structural bonding requirements. In laying out any bond pattern, be sure to start the corners correctly. In a common bond, use a three-quarter closure at the corner of each header course.

Flemish

The Flemish bond consists of alternating header and stretcher courses. The headers in every other course are centered over and under the stretchers in the courses in between. The joints between stretchers in all stretcher courses align vertically.

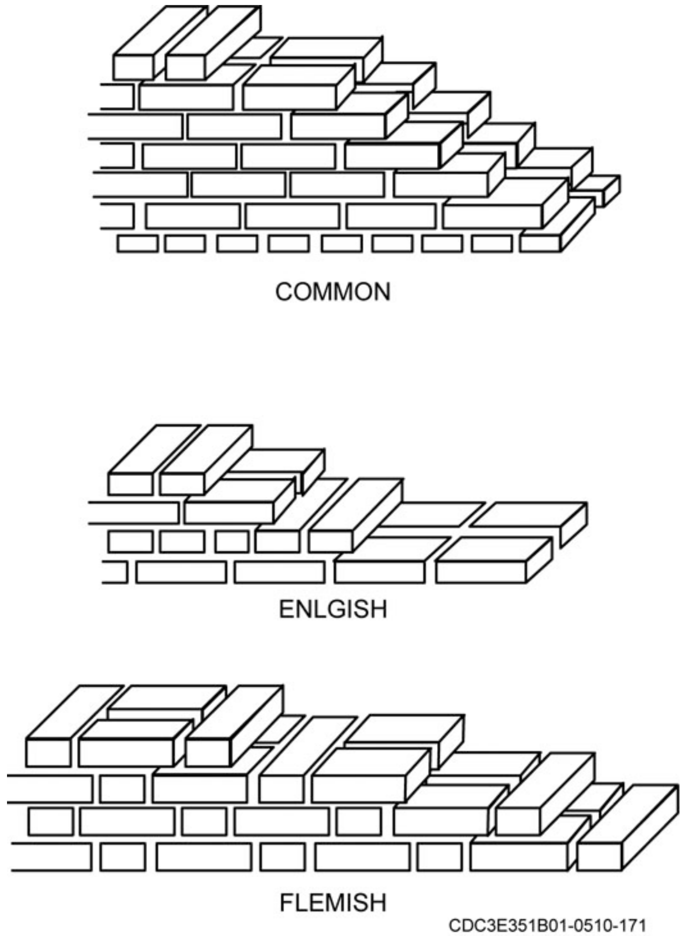


Figure 2–30. Brick bonds.

English

The English bond consists of alternating courses of headers and stretchers. The headers are centered over and under the stretchers. However, the joints between stretchers in all stretcher courses do not align vertically.

Stack

The stack bond is purely a pattern bond without overlapping units. All vertical joints are aligned. This pattern usually bonds to the backing with rigid steel ties or 8-inch-thick stretcher units when available. In large walled areas or load-bearing construction, insert steel pencil rods into the horizontal mortar joints as reinforcement.

English cross (Dutch)

The English cross, or Dutch, bond is a variation of the English bond. It differs only in that the joints between the stretchers in the stretcher courses align vertically. These joints center on the headers in the courses above and below.

Bonding joints

You make bonding joints by lapping one brick over two bricks in the course just below it (fig. 2–31). Obviously the natural consideration is how much they should lap. It’s standard practice to make a brick lap over bricks ¼, ⅓, ½, or ¾ of its length. A brick shouldn’t overlap (bond) another brick that’s less than ¼ of its length.

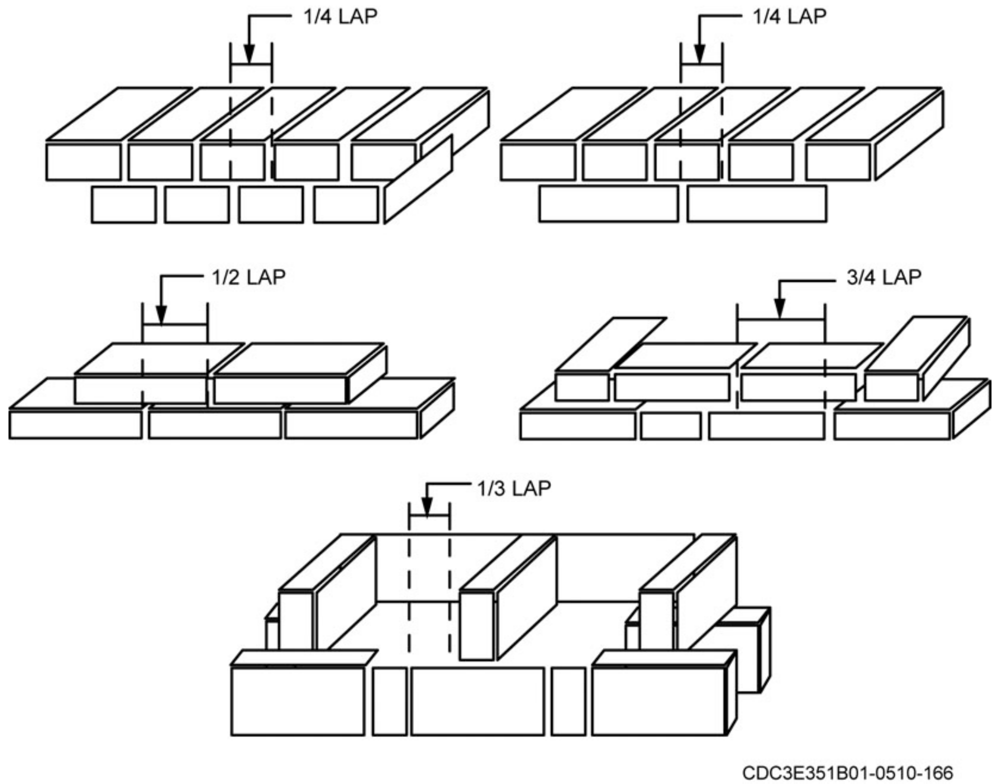


Figure 2–31. Lapping bricks.

Keep each vertical joint perpendicular—directly over the vertical joint two or more courses below. In adjacent courses, lap vertical joints between bricks at relatively different positions. You may have to use one or more special-sized brickbats as spacers, or fillers, to make the course end properly at the ends or corners. Place these brickbats one or more bricks from the end, rather than at the end especially if you're using small bats. **NOTE:** A small bat at the corner weakens the bond.

We sometimes use metal ties (fig. 2–32) to help bond solid and hollow walls. There are many different types of ties, just be sure to use the size recommended for the thickness joint you are laying.

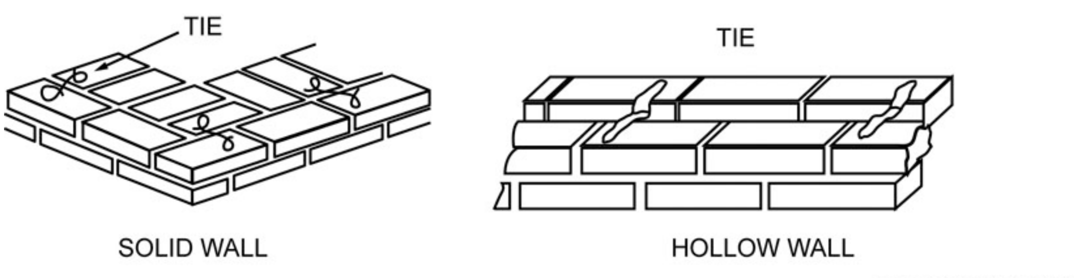


Figure 2–32. Bonding with metal ties.

Brick wall construction

For ease in explanation, the discussion on brick wall construction will focus on standard-sized bricks. By placing standard bricks in various positions, you can build walls in any thickness relative to the brick's width and length. Standard bricks are 4 × 8 inches after they're laid, so we can build walls to any brick width multiple (4, 8, 12, 16 inches, etc.).

Four-inch brick walls

We use 4-inch walls for nonloadbearing walls and partitions. We call a wood or steel frame covered with a 4-inch brick facing a *brick veneer* wall (fig. 2–33). For new buildings, we make the foundation wide enough to accommodate a brick face; in old buildings, we may have to pour a 5- to 6-inch-thick foundation below the ground, against the old foundation, to support the bricks. Cover a frame building with waterproof building paper before you face it. The brick's arrangement is the same in a 4-inch partition or a veneer surface, but it's a good idea to make the partition with bricks that are faced on both sides. You may have to cut the brick around openings in an old building because whoever did the original layout probably didn't consider that someone might later want to add brick veneer.

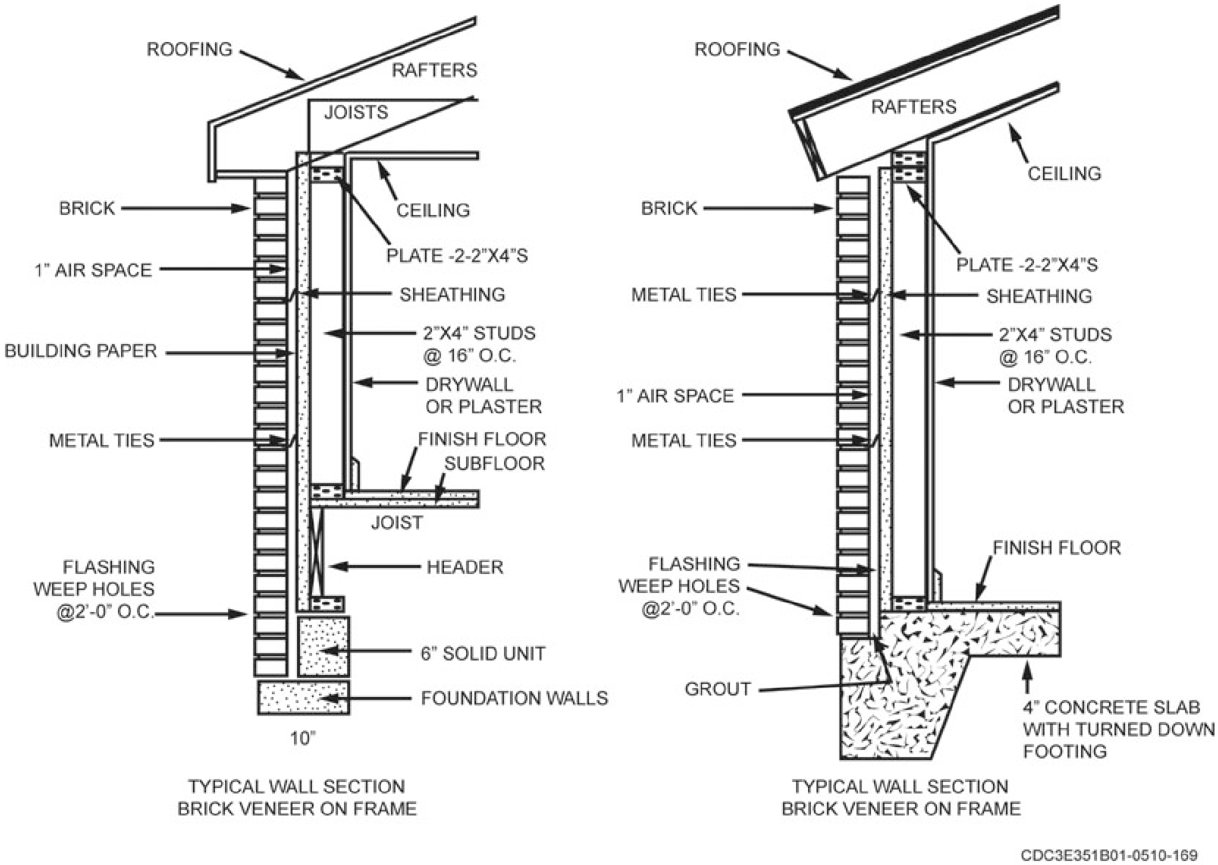


Figure 2–33. Brick veneer.

Four-inch partition walls are laid without ties or bonding. They are held in place with mortar and course laps. Metal strips or wire ties fastened to the framework and embedded in the mortar between brick courses strengthen veneer walls (fig. 2–34).

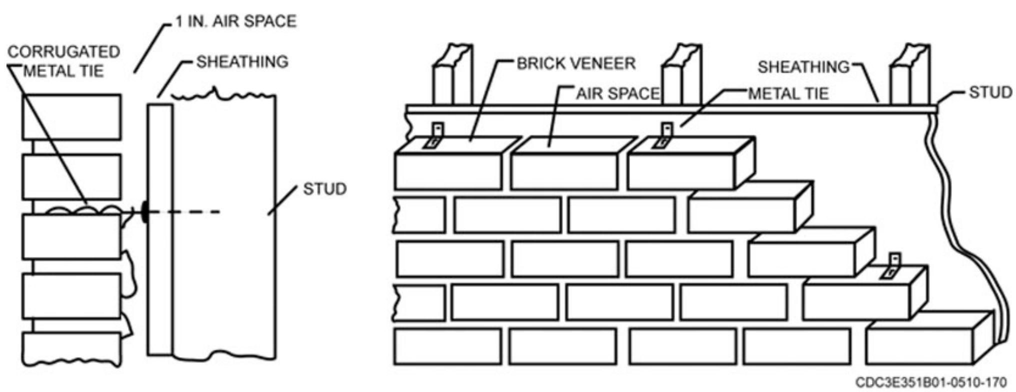


Figure 2–34. Brick secured with metal ties.

Eight-inch brick walls

You may have to build small structures with 8-inch walls. Under normal load conditions, 8-inch walls are thick enough to support the load placed on them. Larger buildings may need thicker bricks, concrete block or clay tile backup units. The three most common bond patterns for 8-inch walls are American (or common), English, and Flemish bond. In essence, two 4-inch walls are tied together to add strength to the wall and to make the wall eight inches thick. Figure 2–35 shows an 8-inch corner built with using the common bond pattern.

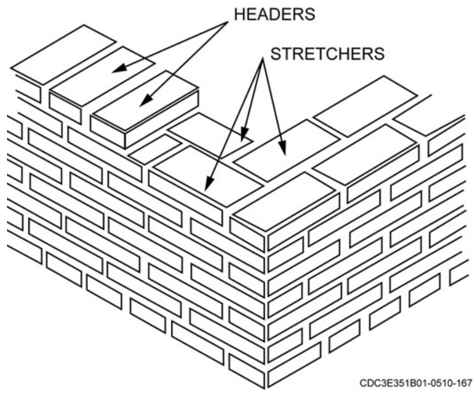


Figure 2–35. An 8-inch corner.

Corners and intersections

A corner is formed where two wall ends meet; it is here that the bond starts. We can classify corners as being square, acute, or obtuse or as being outside or inside corners. A square corner is a 90 degrees corner, an acute corner is less than 90 degrees, and an obtuse corner is between 90 degrees and 180 degrees (fig. 2–36).

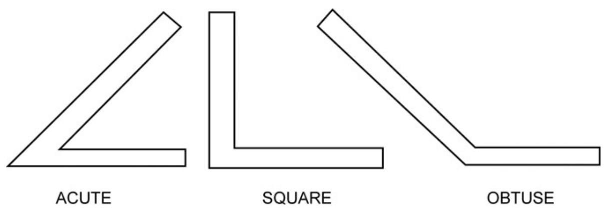


Figure 2–36. Corner types.

You need special arrangements for standard and special brick shapes to get the proper lap when you start a course at a corner or intersection. In figure 2–37, views A and B show a 4-inch wall that starts with the stretcher bond having a half lap and three-quarter lap. The end brick should always be a whole brick or a three-quarter quoin (fig. 2–37, view C). When you arrange bricks in a corner, you must consider both walls. In some cases, a wide wall end may meet a narrower end wall to form a corner. Figure 2–37, view C shows how to arrange standard and special bricks when an 8- and a 12-inch American-bond wall meet at a corner.

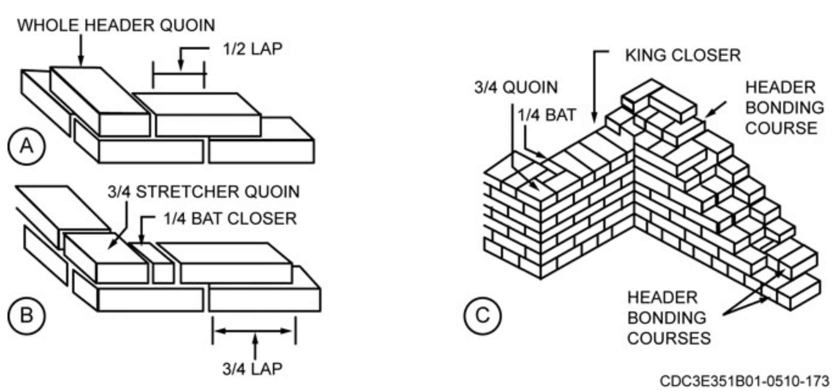


Figure 2–37. Corner arrangements.

Sills, lintels, flashings, copings, and weep holes

The architect or structural engineer works out the bond design for the structure; that includes calculating the size and placement of door and window openings to avoid any irregularities in lapping the bricks and to reduce cutting bricks to a minimum. Still make a dry run course (chase the bond) to the bond type specified to see how the openings work out.

Sills

Bricks in sills are usually laid on edge at a slope (incline) of ¼ inch per six inches of run to shed water. Figure 2–38 shows how you start a window opening and how you position the bricks in the sill mortar bed. A brick rowlock course (fig. 2–39) is bricks placed on edge with their ends visible and is used directly under window openings. For doorsills, you can lay the bricks flat as a header course or on edge as a rowlock course.

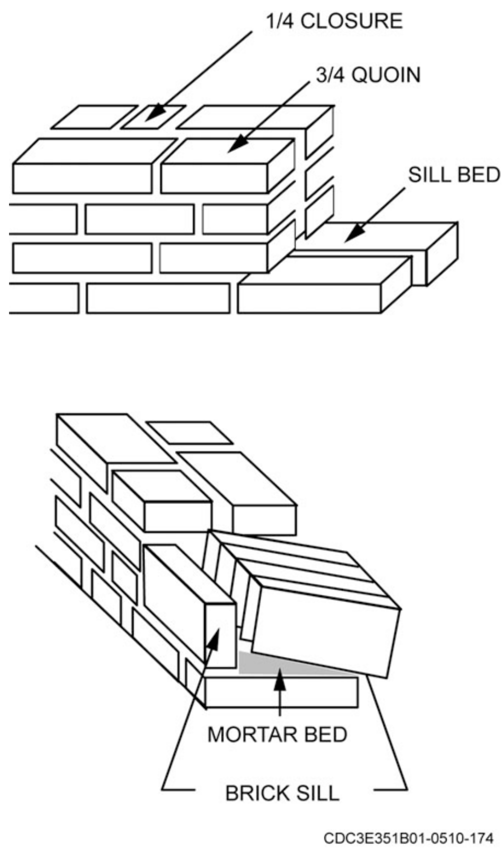


Figure 2–38. Constructing a brick windowsill.

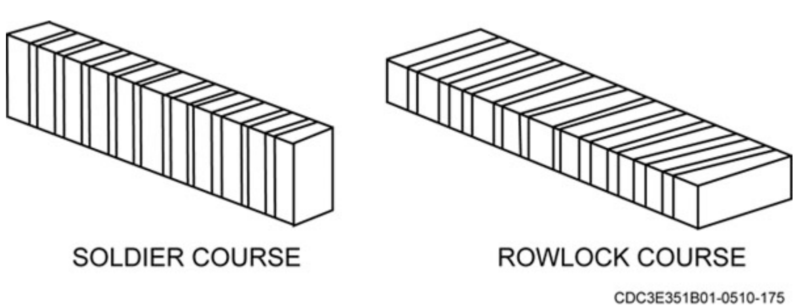


Figure 2–39. Soldier and rowlock courses.

Lintels

A steel lintel (lintel bar) supports brickwork above window and door openings. Usually an angle iron lintel is installed above the opening with each end resting on at least one-half a brick. We then use a brick soldier course over the window opening. Figure 2–40 shows how we place bricks on the lintel. You may use a soldier course over door openings or you may continue the brick pattern used in the wall construction.

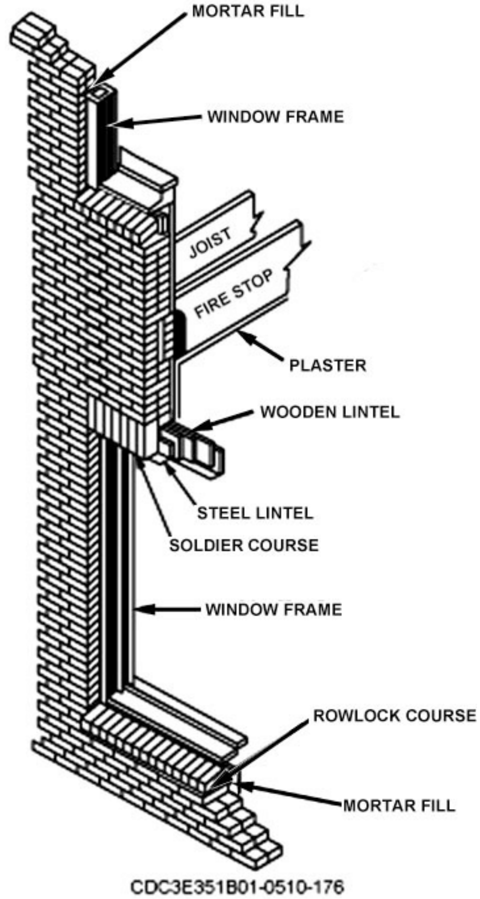


Figure 2–40. Soldier course and rowlock course used in a window opening.

Flashing

Install flashing at any spot where moisture is likely to enter a brick masonry structure (fig. 2–41). Flashing diverts the moisture back outside. Always install flashing under horizontal masonry surfaces, such as sills and copings; at intersections between masonry walls and horizontal surfaces, such as a roof and parapet or a roof and chimney; above openings (e.g. doors and windows); and frequently at floor lines depending on the type of construction. The flashing should extend through the exterior wall face and then turn downward against the wall face to form a drop.

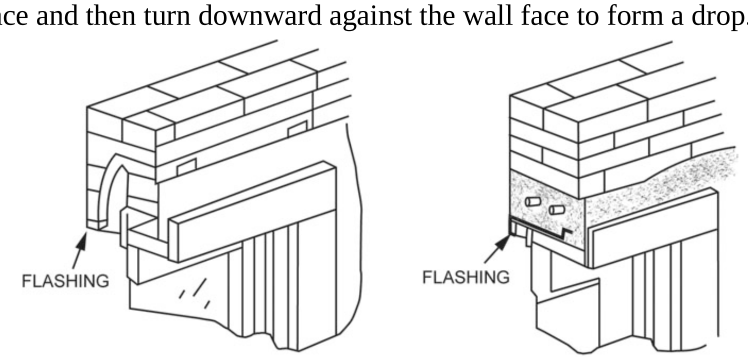


Figure 2–41. Head flashing.

Copings

Copings protect the tops of walls and other brickwork exposed to the weather. Figure 2–42 shows a concrete coping on top of a brick wall. The coping bond, the brick's top course, and tends to divert water and keep it from seeping into the mortar joints. Mortar joints saturated with water can freeze and loosen the brick. The drip is a groove, or slot, extended all the way around the coping bottom so that the water passing from the top will drip to the ground without contacting the wall.

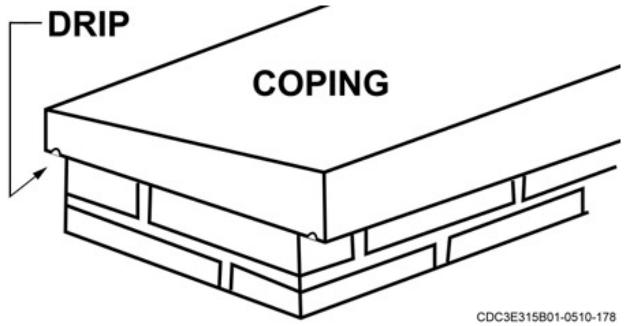


Figure 2–42. Coping cap.

Weep holes

Install *weep holes* at 18- to 24-inch intervals to drain water to the outside that might accumulate on the flashing. Weep holes are even more important when appearance requires the flashing to stop behind the wall face instead of extending through the wall.

Brickwork joints

As a bricklayer, unless you make your joints properly, your brickwork fails. Good bricks and good mortar alone won't make a good wall. You must use quality craftsmanship in your mortar joints to make a strong and attractive wall. The common joints we use for most brickwork are bed joints, head joints, closure joints, and cross-joints.

Bed joints

Bed joints are the horizontal mortar joints between brick courses. Another definition is a mortar bed on which bricks rest. You must make the bed joints right because they bond the bricks together, distribute pressures uniformly throughout the wall, and make the wall moisture and air resistant. Spread the mortar about one inch thick and uniformly over the top of the foundation or lower brick course. After you spread the mortar over four or five bricks at one time, make several shallow channels (riffles or furrows) down the bed center, as shown in figure 2–43. Mortar won't stay plastic very long during hot weather, so spread mortar on only a few bricks at a time and then lay the bricks.

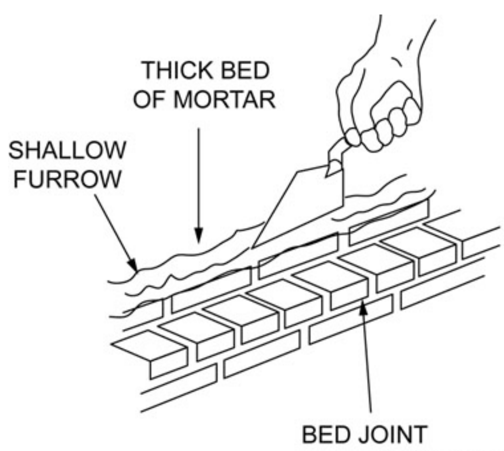


Figure 2–43. Making a bed joint.

Head joints

Head joints are the vertical mortar joints that bond bricks together at their ends. Butter a thick mortar layer on one end of the brick to be laid. Place the buttered brick on the mortar bed and press and shove until you get the right bed and head joint thickness. This assures a good bond between the bricks. Use your trowel to cut off the mortar that's squeezed from the head and bed joints (fig. 2–44).

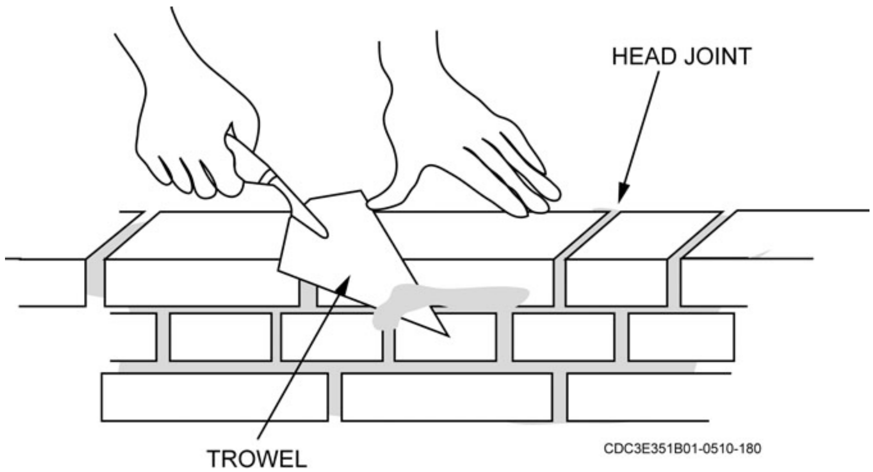


Figure 2–44. Cutting off excess mortar.

Closure joints

We call the last two head joints in a course *closure joints*. To make a closure joint in a stretcher course, you first butter the clean ends of both bricks that you already laid in the course and then butter both ends of the closure brick and lay it in place (fig. 2–45). Make sure the closure joint is completely filled, squeeze the excess mortar from between the bricks and cut it off. Obviously the process is the same for a closure joint in a header course except that you're buttering the bricks' sides instead of their ends.

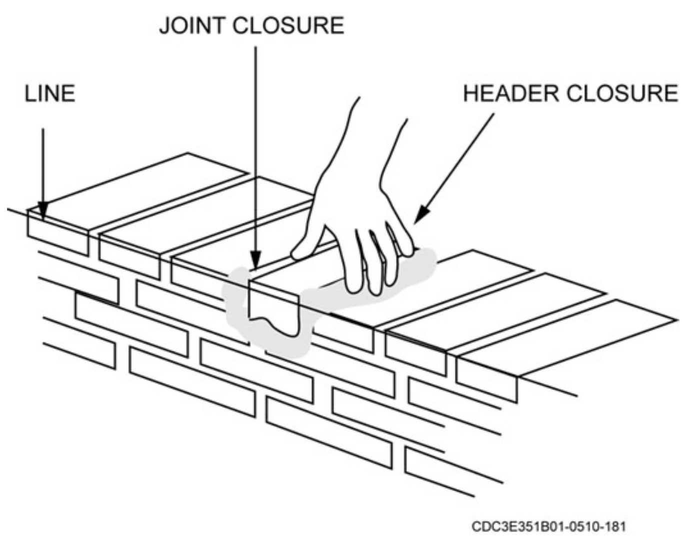


Figure 2–45. Filling a closure joint in a stretcher course.

Cross joints

Although header bricks are laid to form the horizontal bed joint, we often call the vertical joints they form *cross-joints* instead of *head joints* because you butter the brick edges rather than the brick ends.

Job layout

Bricklaying consists of laying out the job, laying the brick and finishing the joints. Before you lay bricks, you must establish the building corners, mark the head joints and establish the leads. The first step is to lay out the corners. You can use the batter boards as shown in figure 2–46, marking the corner points on the foundation or slab with a chisel or chalk mark, and then striking a chalkline from corner to corner to establish the first course's outer edge. This step also identifies the brick's course length. The steps we use to lay out brick are similar to the steps we used to lay out concrete block. You can refer back to the previous lesson if you need a refresher. Now, let's apply those steps to an actual bricklaying job. Let's start with an 8-inch common brick wall.

Again, just as in laying concrete block, the next step is chasing the bond. To chase the bond you will have to:

1. Place your first brick on the foundation at a corner.
2. Use a rule or wood spacers to set the vertical joint thickness between the bricks.
3. Continue to lay bricks flush with your chalkline as you lay the first course.
4. Mark the head joint position on the foundation edge.

NOTE: If the job's not too big, you can chase the bond around the complete foundation (all outside walls).

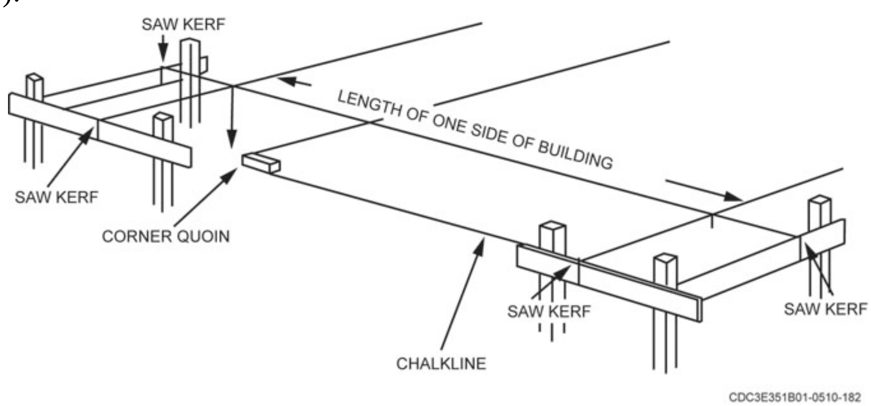


Figure 2–46. Locating the building corners.

Now you're ready to establish the leads. The corners (leads) are the first parts you lay. Raise leads at the corners and at several intermediate points if the walls are long. Build them up six or seven courses before you fill in the courses between them. Use the level to keep the corner leads and intermediate leads plumb. The first corner lead height depends on how many courses are in the wall and the bond you're using. A common-bond wall has a header course on the foundation and other headers every sixth course thereafter. We use two; three-quarter quoins with six headers on each side in the first course (fig. 2–47).

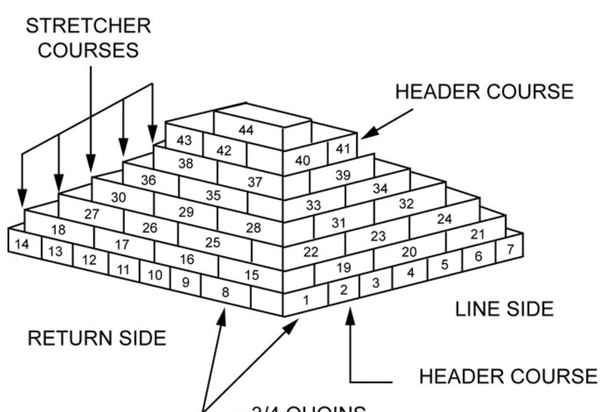


Figure 2–47. Brick laying sequence of (common-bond).

Applying the mortar

To keep the mortar from drying out, keep your pile round and well mixed according to step one in figure 2–48. To gather mortar, scrape a small amount from the main pile and slip your trowel under it trying not to disturb the basic mound shape (fig. 2–48, steps 2–4). As you "throw" the mortar onto a brick row, it must flow evenly from start to finish. To start the throwing stroke, bring the trowel (loaded with mortar) horizontal (top view, fig. 2–49) slightly ahead of where you want to start your mortar deposit. With a quick arm and wrist movement toward your body, turn the trowel vertical, depositing the mortar on the brick. Now grasp the trowel in the palm of your hand (center view, fig. 2–49) and turn it upside down to riffle the mortar as shown in the bottom of figure 2–49. Run the trowel point down the center to spread the mortar, and then run it down each center side to work the mortar toward the brick edges. Spread the mortar past the brick edges so that it hangs over the edges ensuring a full bed joint. You'll cut off the excess after you place the brick.

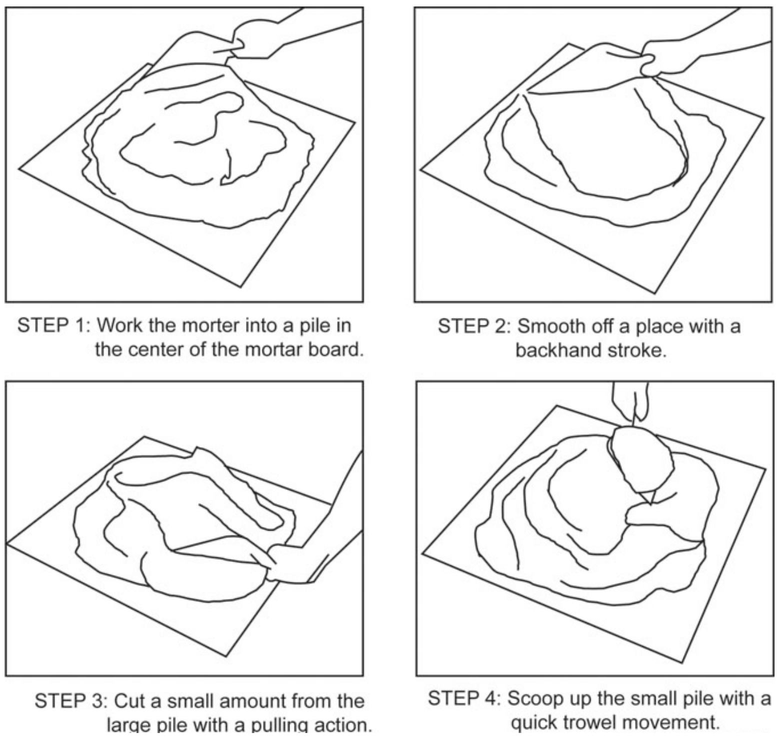


Figure 2–48. Working the mortar.

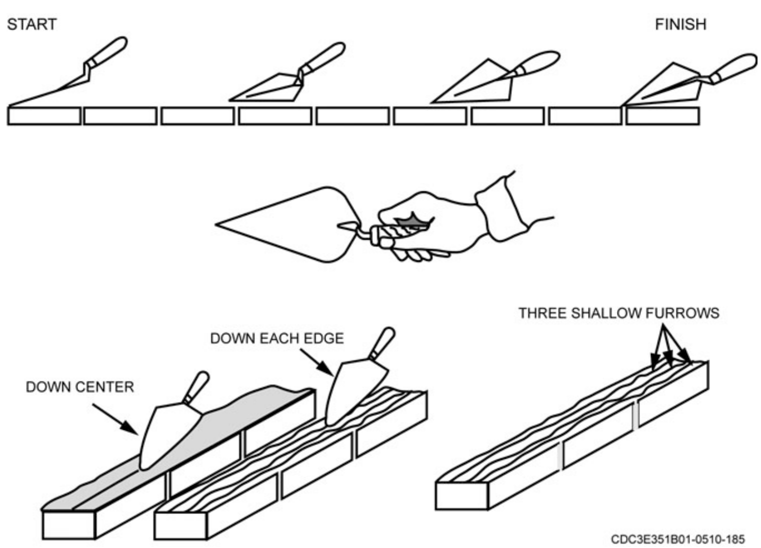


Figure 2–49. Applying the mortar.

Positioning the brick

Grasp a brick from the pile with whichever hand you don't use for the trowel. Place the corner brick of the first course on the mortar bed slightly away from its final position (fig. 2–50). As the brick touches the mortar bed, press and shove it downward to as near its final position as possible. Then force it down with your palm until mortar is squeezed out all around the edges and the bed joint is the right thickness. If the brick is exactly in place, you don't need to move it but that's not always the case; you may have to tap it into its final position with the trowel handle (fig. 2–50).

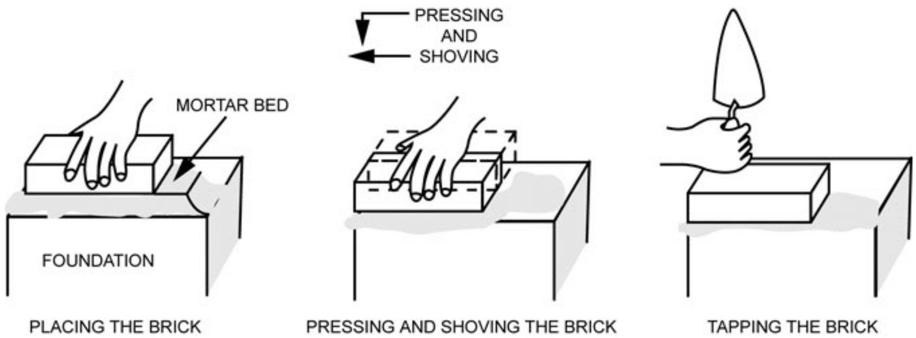


Figure 2–50. Positioning the first brick.

As you cut off the excess mortar (fig. 2–51), keep your trowel flush with both bricks or with the brick and the foundation, and be careful not to pull the mortar out of the joint.

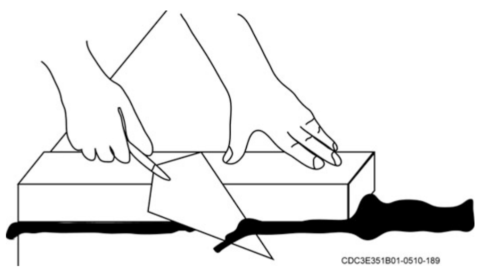


Figure 2–51. Cutting off the mortar.

Maintaining joint thickness

Common mortar joint thickness ranges from ⅛ to ½ inch with ¼- and ⅜-inch thicknesses being used most because they're the strongest and most water-resistant. Check the building plans and specifications for the job and lay out each course height to include bed joints on a story pole (fig. 2–52) so that you can check each course's height as you lay it. **NOTE:** As with block, only measure at the outside corners. You may also use a spacing or modular rule for maintaining joint thickness. The last whole brick in the wall should fit within the foundation's outer dimension. If it misses by one or two inches, you can adjust the head joint thickness; if it misses by four inches or more, use a whole brick on the corner and cut a brick to use as a closure. Place this cut brick two or three bricks away from the corner.

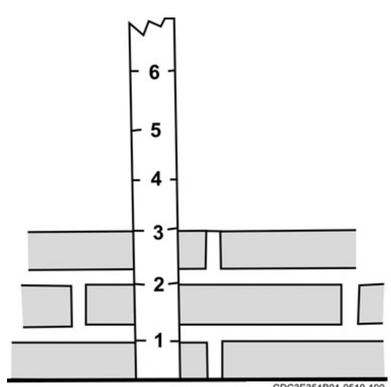


Figure 2–52. Using a story pole.

Leveling the brick

Continue building up the corner by laying the bricks in order (e.g., numbers 2, 3, 4, 5, 6, and 7 in fig. 2–47). Level the first course lead on the line side, if necessary, by tapping the brick. Then straightedge the headers to make sure they're in alignment with the chalkline on the foundation. Now you can throw and spread mortar on the foundation to lay the seven bricks on the return side, including the three-quarter quoin (number 8). Level, straightedge, and square the first course to eliminate any inaccuracies that develop during laying. Use your story pole to check the first course's height and make sure the joint is the right thickness. Cut off all overhanging mortar.

Now spread mortar on the first course's return side and lay the four stretchers numbers 15, 16, 17, and 18. Then spread mortar on the course's line side and lay the three stretchers numbers 19, 20, and 21. Lay the stretchers in the third course (i.e., numbers. 22, 23, 24, 25, 26, 27) the same way and check again to be sure the wall is plumb.

If you have to align a brick by tapping, be sure to do it while the mortar is still plastic or you'll break the bond. Once you've got it level, straightedge and square the corner cut off any overhanging mortar and tool the joints as needed.

Laying the stretcher course

Now you can lay the remaining stretcher bricks (i.e., numbers 28 through 39) in the corner. After spreading mortar on the sixth course, lay brick No. 40, a three-quarter quoin. This is the seventh course's corner brick, which is composed of headers. Make sure it's level, straight, and square with both corners.

Laying the header course

Lay the three-quarter closure (i.e., number 42 and the two header bricks, numbers 41 and 43) to form the seventh course in the corner lead. Then top the seventh course with the corner brick (i.e., number 44) for the eighth course. Strike and tool mortar joints as the work progresses and examine and touch up the joints from time to time as needed. Once the corner is completely raised, brush it down to eliminate the thin mortar fringes around the joint edges. Raise the second corner the same way and then fill in the stretcher courses between corners. Throw and spread mortar for as many bricks as you can lay and align before the mortar starts to set.

Laying stretcher courses

Lay your remaining stretcher courses and make sure to check and adjust for level and plumb as you progress. Before the mortar sets, touch up the joints and brush down the wall. Lay the bricks in the backup course the same way you laid the face brick up through the sixth course. Lay the headers in the seventh course the same way you laid the headers in the first course. The corner bricks in the eighth course help to hold the corner blocks and line in place when you lay the header course.

Use a tightly drawn line and secure it with pins, corner blocks, and so forth (fig. 2–53) to get a true wall surface. Fasten the line so that it's about $1/32$ inch outside the brick's top edge and level with it. Place bricks between corners without touching the line. **NOTE:** Disturbing the line with the bricks can cause the line to move and no longer give an accurate alignment. Figure 2–54 shows a line stretched between leads. If the distance is long, use an intermediate lead (e.g., twig) held in place by a brickbat to help support the line between corners (fig. 2–55).

To avoid disturbing the line, grasp the brick as shown in figure 2–56. The left view shows how to grasp the brick when you're standing outside the line and laying the brick across the line; the right view shows how to grasp it when you're standing inside the line. Now place the brick and press and shove it into place to get the right head joint or cross joint thickness. Release it and then press down once more to get the right bed joint thickness (fig. 2–57).

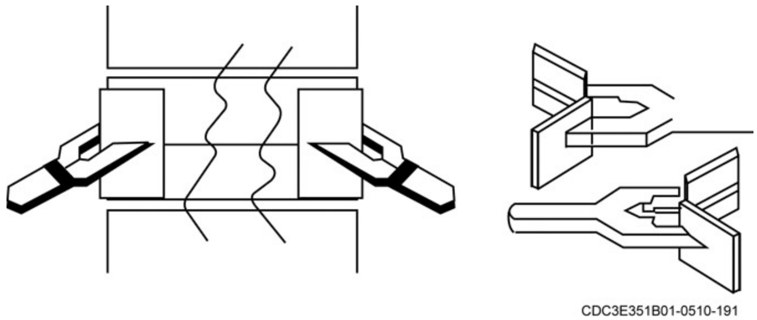


Figure 2–53. Corner blocks.

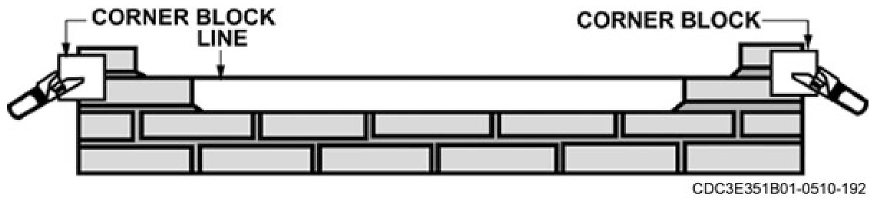


Figure 2–54. Using corner blocks to hold line.

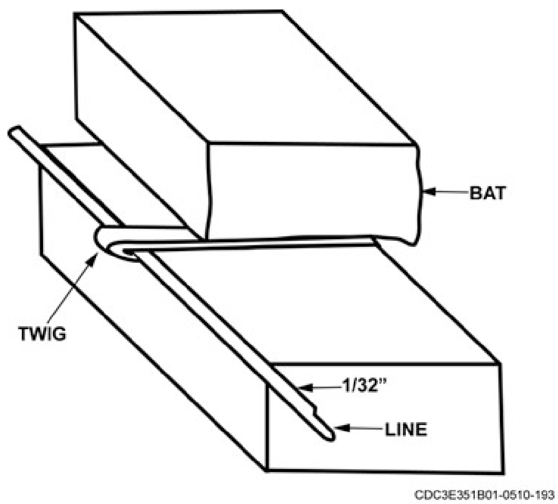


Figure 2–55. Using a line twig.

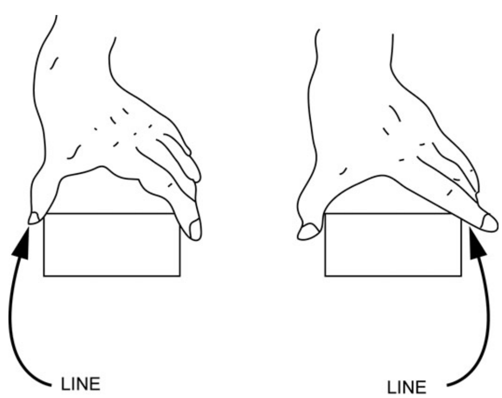


Figure 2–56. Grasping a brick.

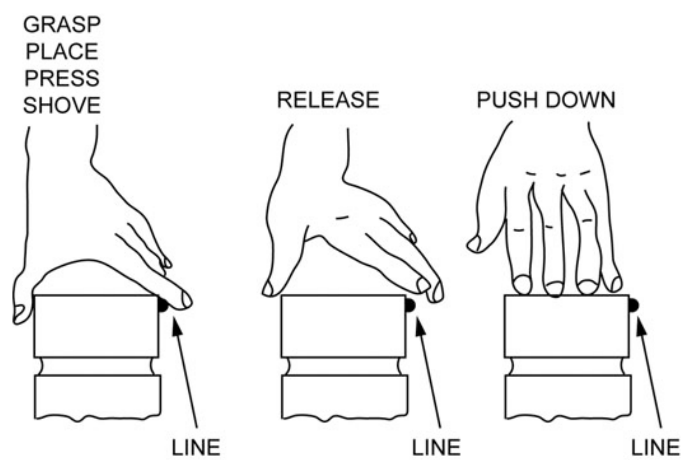


Figure 2–57. Laying brick to the line.

Laying rowlock and soldier bricks

To form rowlock courses, lay bricks on their edges; to form soldier courses, lay them on their ends on a mortar bed that is spread on the lintel. Be sure you apply mortar to the brick's whole face (fig. 2–58) and be sure you butter the brick's four edges to form a full complete cross-joint. Notice how the mortar inclines from the edges as seen in the right view of figure 2–58. You should apply the mortar this way to create a better bond and help prevent the mortar from slipping off the brick when you go to place it.

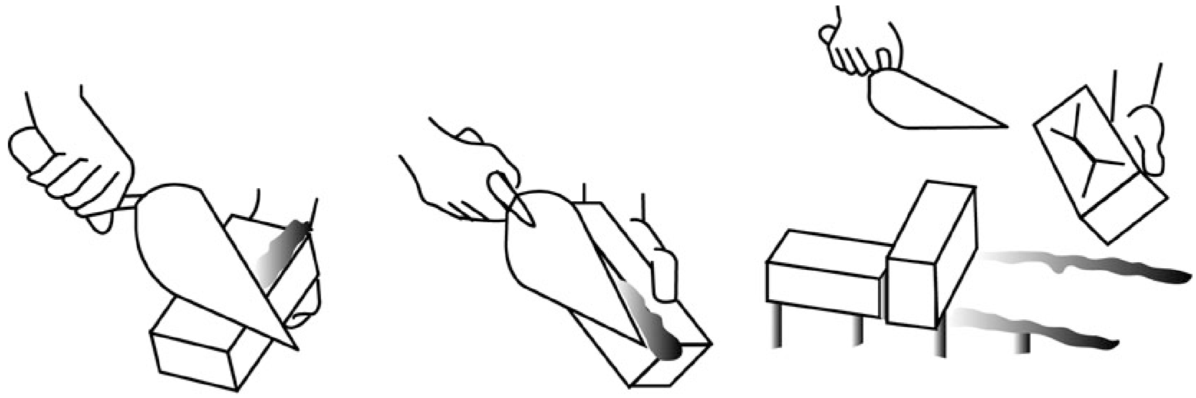


Figure 2–58. Completely buttering a brick side.

Finishing joints

As with block, brick joints must be tooled to make them attractive and waterproof. Each time you lay a few courses, pause to strike (i.e., finish or tool) the joints. Figure 2–59 shows some ways to tool the joints. To make a flat (i.e., struck) joint, cut off the overhanging mortar. You can hold the trowel's edge against the brick's edge and pull it along the joint or use a flat-edged jointer called a slicker. To form an inclined or weather-resistant joint, turn the trowel to a slight angle and strike the joint downward with the blade's top edge. To form a raked joint, rake some mortar from the joint with a flat jointer or use a skatewheel joint raker designed for that purpose. A skatewheel joint raker has two skatewheels, a handle and an adjustable depth hole in the center. You form a flush concave joint by compressing the mortar in the joint with a convex jointer. Use a brush to remove fine mortar particles from the brick face. The tools shown in figure 2–60 can be used to finish brick and block joints.

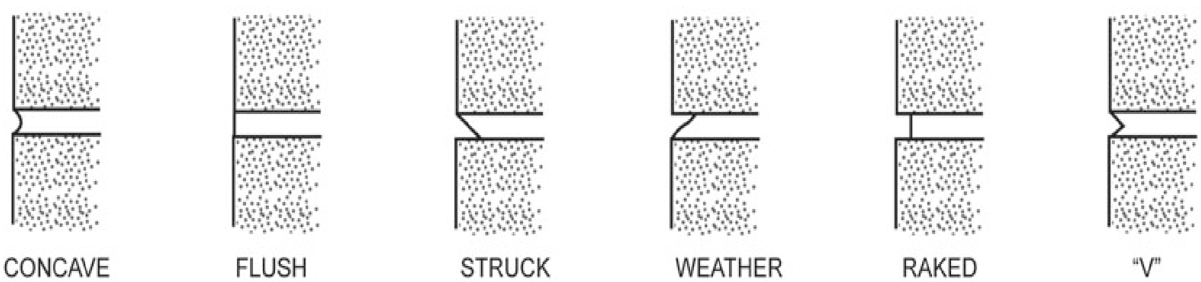


Figure 2–59. Mortar joints.

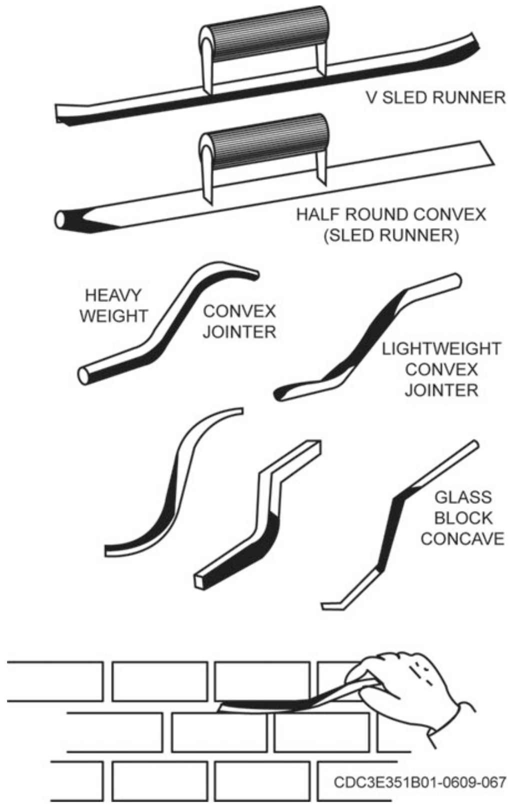


Figure 2–60. Joint tools.

Arches

A well-constructed brick arch can support a heavy load, mainly due to the way the weight is distributed over its curved shape. Brick arches require full mortar joints. The joint width is narrower at the bottom of the arch than at the top, but the joint should not be less than one-fourth inch at any point. Figure 2–61 shows two types of arches. **NOTE:** As laying progresses, make sure the arch does not bulge out of position.

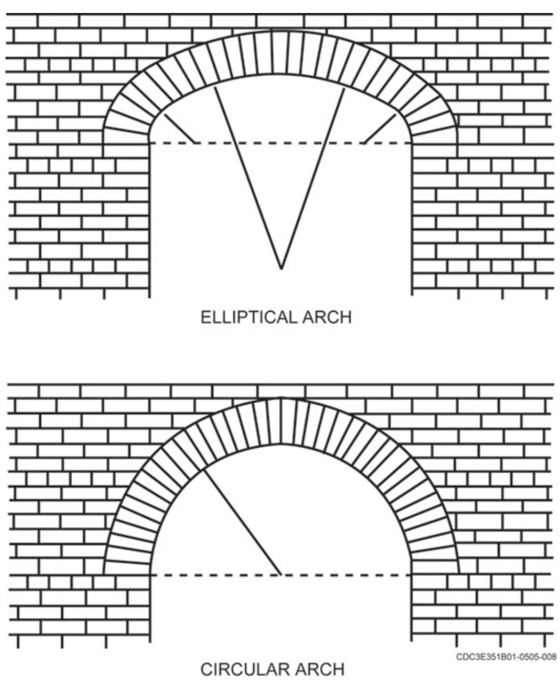


Figure 2–61. Common arch designs.

Template

It is impossible to construct an arch without support from underneath. These temporary wooden supports (i.e., templates) must not only be able to support the masonry during construction but also provide the geometric shape necessary for the proper construction and appearance of the arch.

Dimensions

Construct a brick arch over the template (fig. 2–62) that remains in place until the mortar sets. You can obtain the template dimensions from the construction drawings. For arches spanning up to six feet, use ¾-inch plywood to make the template. Cut two pieces to the proper curvature and nail them to 2 × 4 spacers to provide a surface wide enough to support the brick.

Positioning

Use wedges to hold the template in position until the mortar hardens enough to make the arch self-supporting. Then you can drive out the wedges.

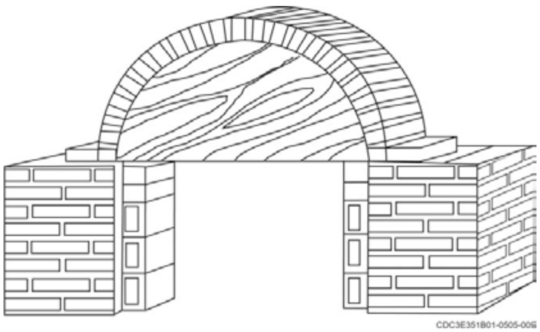


Figure 2–62. Arch template.

Layout

Lay out the arch carefully so that you don't have to cut any bricks. Use an odd number of bricks so that the key (middle brick) falls into place at the exact arch center (crown). The key brick is the last brick laid. To determine how many bricks an arch requires, lay the template on its side on level ground and set a trial number of bricks around the curve. Adjust the number of bricks and the joint spacing (not less than ¼-inch) until the key brick is at the exact center of the curve. Then mark the positions of the bricks on the template and use them as a guide when laying the brick.

411. Masonry maintenance and repair techniques

No matter the quality of workmanship on a masonry structure, there comes a time when it will probably require some type of maintenance and repair. Just like the construction techniques for clay masonry and concrete masonry units are similar, so is the maintenance and repair techniques. This section will provide you with the techniques used for each type.

Cleaning concrete masonry walls

When laying concrete masonry walls, be careful not to smear mortar on the masonry unit's surfaces. Once it hardens, these smears cannot be removed nor will paint hide them. Thus you should allow mortar droppings to dry and harden. You can then chip them off with a small piece of broken concrete block and/or brick or a trowel. A final wire brushing should remove the rest of the mortar.

Masonry stains

The two most common types of stains that develop on masonry surfaces are efflorescence and calcium carbonate. Efflorescence is a powdery salt substance; whereas, calcium carbonate stains appear as white stains that are hard and crusty. Other stains are the result of ordinary mud, dirt and soil.

Efflorescence

The leaching of soluble salts causes efflorescence to appear on exposed masonry surfaces. The salts are taken into solution through prolonged wetting. The solution moves to the surface as the wall begins to dry. The water evaporates and the salt is left behind on the surface. Thus efflorescence will not occur if the masonry units and the mortar do not contain any soluble salts and if there is not a lot of moisture present to cause the leaching.

Since moisture is necessary to carry soluble salts to the surface, efflorescence indicates defective construction. Wet walls may be caused by defective flashings, gutters, downspouts, copings, or improperly filled mortar joints. Efflorescence usually disappears with normal weathering if the source of moisture is stopped. Make the necessary repairs before you try to remove it or it will reoccur. You can dry brush, wash away with clean water or use a scrub brush to remove it.

Calcium carbonate

Although efflorescence is similar in appearance, calcium carbonate is distinguished with hard encrustations that can only be removed with acid cleaners. When mortar is saturated for an extended period of time, the hydration process is prolonged producing an excessive amount of calcium hydroxide, which eventually leaches to the surface. Once at the surface, it reacts with the carbon dioxide to form calcium carbonate. To prevent it from occurring, you need to protect the wall from saturation both during and after construction.

To remove the calcium carbonate, locate the source of moisture and repair it. Then saturate the stain and surrounding area with water and use a diluted acid solution. The solution should be one part acid to nine parts water.

CAUTION: Always add the acid to the water; acid reacts violently when water is added to it. Make sure you wear proper personal protective equipment and follow the precautions on the material safety data sheet.

NOTE: Muratic acid is suitable for cleaning clay masonry; however, it should not be used on concrete masonry units. The acid solutions dissolve the cement to remove the mortar smears. If used on the concrete masonry unit itself, it would also dissolve the cement matrix in each unit. Also, it should not be used on light-colored tan, buff, gray or pink brick because it sometimes reacts with minerals in the clay and causes green or brown stains.

Mud, dirt and soil

To clean away mud, dirt and soil, you can use a mild detergent such as ½ cup of trisodium phosphate and ½ cup of laundry detergent mixed with one gallon of water.

CAUTION: Regardless of the chemical used, you must make sure that you refer to the material safety data sheet for the product used and follow all prescribed safety precautions.

Pointing

Even though you may be a skilled mason, it is common to have to repair a damaged or defective masonry joint. You may also have to patch holes left by line pins. You do this by troweling mortar into the joints after the units are laid. This is referred to as pointing. You should try to do this while the mortar is still plastic and before the final tooling takes place. If you must make the repairs after the mortar has already hardened (repointing), be sure to rake or chisel the old mortar joints at least one-half inch deep.

Once the joints are clean, wet them with water and a brush and then apply mortar to the joint with a long, thin trowel that has a blade slightly narrower than the joint width. Before the mortar sets, strike it to produce the finish you want.

NOTE: Pointing and repointing are sometimes referred to as *tuckpointing*; however, tuckpointing is actually a decorative method of pointing masonry with a special surface mortar that is different than the mortar used to lay the masonry units.

Replacing damaged brick

Brick walls that have been exposed to structural shifting or building settlement often have broken or damaged brick. There are several ways to replace defective brick, but we only cover the following two in this course.

1. The first way is the same way you'd repoint a brick. The only difference is that you remove all of the mortar. Do not try to remove too much mortar at once. If you overwork the joint with your cold chisel, you can fracture adjacent brick joints.
2. The second way, you use a masonry blade in a portable power saw to cut out mortar in layers that are ¼-inch-thick. You must wear safety goggles, shields, and an apron to protect yourself from the sparks and debris. In both cases, exercise full safety precautions.

Once you remove the mortar and damaged brick, you can prepare the area for a replacement brick. It's good practice to dampen the new brick and the repair area immediately to keep the mortar from drying too fast. Now spread a thick bed of mortar, butter the brick and insert it into the joint (fig. 2–63). Cut off any excess mortar that squeezes out.

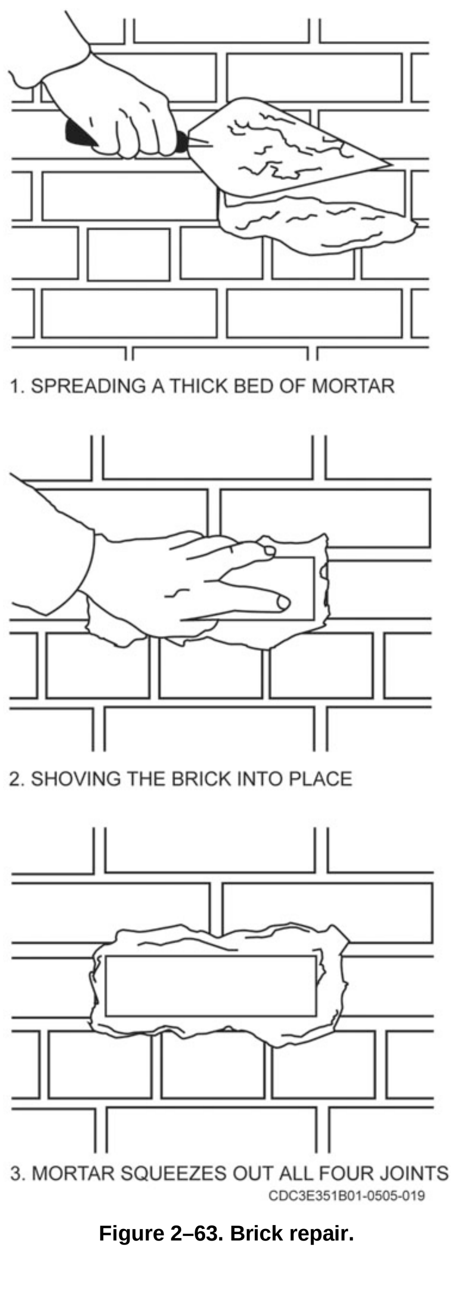


Figure 2–63. Brick repair.

Damp proofing and waterproofing

Masonry units are often porous and must be waterproofed to provide a dry wall. Below ground level (e.g., basements and retaining walls), they should always be damp proofed or waterproofed no matter how well they are laid. Some common ways include using waterproof paint, hot tar, hot asphalt with and without membranes and tile drains.

Painting concrete masonry units

Several finishes are possible with concrete masonry construction. The finish to use in any specific situation should be governed by the type of structure in which the walls will be used and the climatic conditions to which they will be exposed. Paints now commonly used on concrete masonry walls include Portland cement paint, latex paint, oil-based paint, and rubber-based paint. For proper application and preparation of the different types of paint, refer to the plans, specifications, or manufacturer's instructions.

Painting brickwork

Painting brickwork is an optional procedure that can be done on many brick surfaces without damaging the brick. We usually do it to improve a deteriorated appearance or simply change the color. Unfortunately once brick is painted it will have to be repainted often because it tends to scale and become unattractive. If you're trying to make the brickwork look better, you may want to consider whitewashing it.

Whitewashing brick

The basic whitewash solution is a combination of hydrated lime and regular table salt. A suggested mix ratio is 50-pounds of lime with 10 pounds of table salt. Add water to the mix until it resembles the consistency of pancake batter. Use a brush or a roller (brushes work best) to apply the mixture to the brick. Alternate the thickness of the whitewash to vary the surface appearance. The lightly applied areas will allow some of the brick color to show through.

To get an authentic old look, wash off some of the whitewash several hours after application or the next day to expose brick in various areas. You can even add a little tint to the mix to keep it from being too white.

Parging

We sometimes use parging, which we call back plastering, to improve water resistance. You simply plaster the bricks' back surface in the face tier with rich cement mortar at least ⅜-inch-thick before you lay the backing bricks (fig. 2–64).

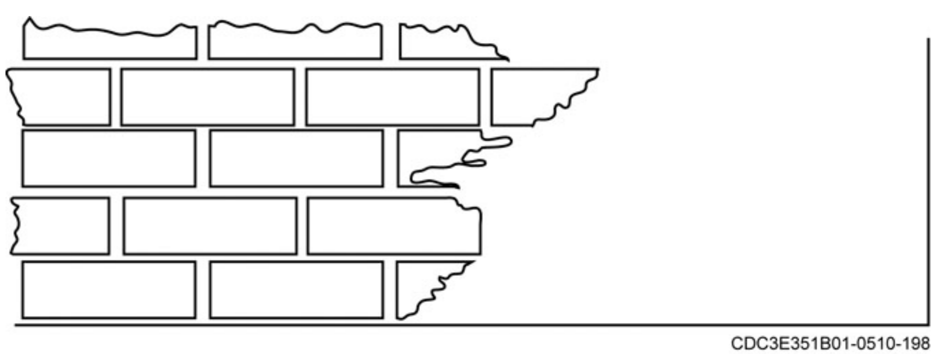


Figure 2–64. Parging method.

Hot tar or hot asphalt

Hot tar or asphalt is an economical method of waterproofing outside surfaces below ground level where there's not much water or where drainage is excellent. To use this method, you need a tar kettle to heat the tar or asphalt and a mop.

Hot tar or hot asphalt with membranes

Use hot tar or hot asphalt with membranes where there's excessive dampness (fig. 2–65). You apply the hot coal tar or hot asphalt coat with two or more membrane layers (i.e., roofing paper or asphalt saturated felt). Note that the joint where the wall attaches to the footing is filled with cement plaster to form a slope so that the moisture will drain away from the footing.

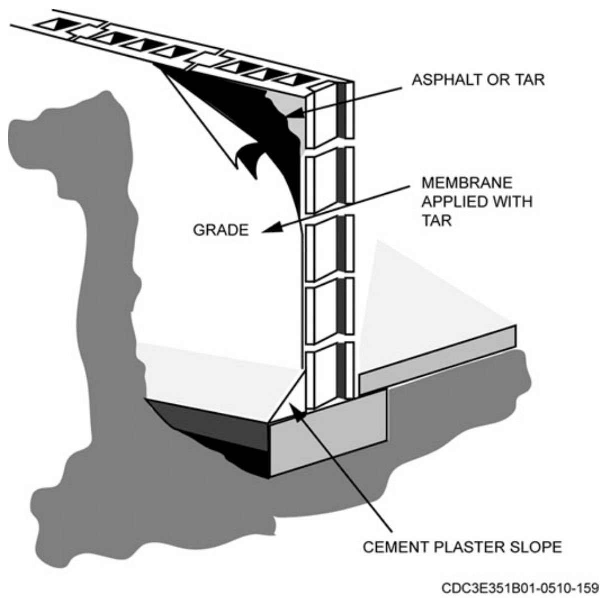


Figure 2–65. Membrane waterproofing.

Tile drain and French drain

Figures 2–66 and 2–67 show two similar methods used for tile drains. We use a tile drain or a French drain to control dampness in high-rainfall areas or where the surrounding soil allows water to gather around foundations and walls that are below ground. A basic way to install a tile drain is to have access to the foundation footers and the below grade walls. Next waterproof the wall area with hot tar with membranes or hot asphalt with membranes. Then place perforated pipe in a bed of crushed stone near the footers. Lay enough pipes to route the water away from your foundation. Backfill crushed stone over the pipe and against the below grade wall to just below the topsoil area. To make a French drain, follow the same procedures, except omit the pipe. For specific requirements, check the blueprint's plans or specifications.

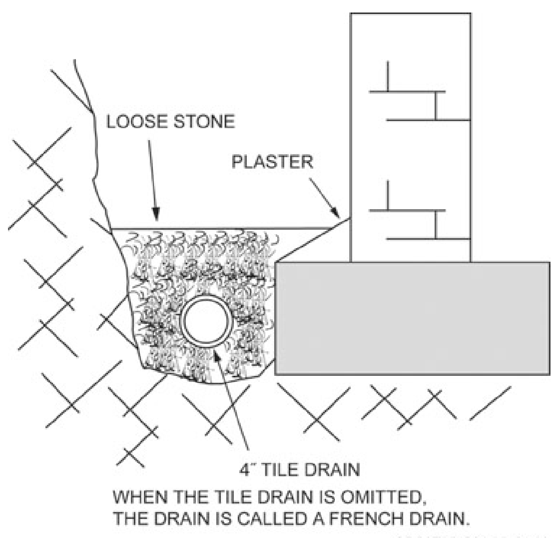


Figure 2–66. Tile drain for brick wall.

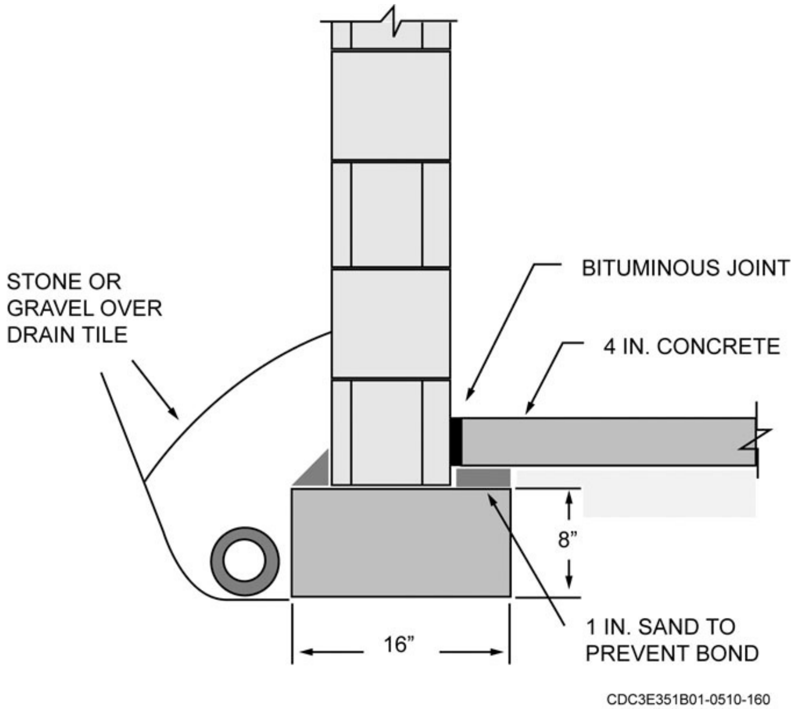


Figure 2–67. Tile drain adjacent to block wall.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

409. Concrete masonry unit construction

1. What is the concept behind modular planning?

2. After you locate the corners, what should you do if the slab is badly out of level?

3. Which part of the block is at the top when laid and why?

4. How many courses high are corner leads usually built?

5. In what sequence are the mortar joints tooled?

6. Describe the requirements when using anchor bolts.

7. Control joints divide a wall into sections that are usually no more than what length?

8. When installing a bond beam on top of a wall, you should lap all rebar splices at least what dimension?

9. What is a good rule of thumb for how much bearing should be provided for lintels placed above an opening?

10. Describe the requirements for vertical rebar installed in a block wall.

410. Clay masonry construction

1. If you must lay bricks in cold weather, what must you ensure?

2. What are three ways that you can achieve a structural bond with brick?

3. If you must use a special-sized brickbat as a spacer to make a course end properly, where should you place the bat?

4. At what slope (incline) are brick laid as sills?

5. At what intervals should weep holes be installed?

6. How many courses high should you build the leads before filling in between them?

7. What mortar joint thicknesses are the strongest and most water-resistant?

8. Describe how a line is installed for laying stretcher courses.

9. When constructing brick arches, what is the minimum thickness mortar joint allowed?

10. What material is used to make a template for arches spanning up to six feet?

411. Masonry maintenance and repair techniques

1. How should masonry with efflorescence be repaired?

2. How should clay masonry with calcium carbonate be repaired?

3. Describe how to replace a damaged brick using a masonry blade with a portable power saw.

4. At least what thickness should you apply plaster to brick using the parging method?

Answers to Self-Test Questions

408

1. Type N.
2. One part Portland cement, one part hydrated lime, and six parts masonry sand.
3. (1) Load ¾ amount of water.
   (2) Load ½ of the sand.
   (3) Add all masonry cement or Portland cement and lime.
   (4) Add the balance of sand and water.
   (5) Mix three (minimum) to five (maximum) minutes until the mortar is completely mixed and a uniform mixture is obtained.
4. Add half the sand, followed by all of the cement and lime (if used), and then the remaining amount of sand.
5. 2 ½ hours.
6. 5¼ cubic feet of Portland cement, 6½ cubic feet of lime, and 26¼ cubic feet of sand.

409

1. Making maximum use of full- and half-length concrete masonry units to minimize cutting and fitting.
2. Complete the entire first course before you begin working on the other courses.
3. The thicker side (web) is at the top to provide a larger mortar-bedding area.
4. Five or six courses high.
5. Tool horizontal joints with a long jointer first, then tool the vertical joints using an S-shaped jointer next.
6. Place pieces of metal lath in the second horizontal mortar joint from the top of the wall under the cores that will contain the bolts. Place ½ × 18-inch long anchor bolts spaced no more than four feet apart into the cores of the top two courses and fill the cores with concrete or mortar.
7. 20 feet long.
8. 40 times the bar diameter.
9. Allow one inch of bearing for every foot of clear space (minimum of six inches).
10. Place rebar at each corner and at both sides of each opening. Space a maximum of 32 inches on center and lap the bars 40 times the bar diameter.

410

1. That they do not get wet.
2. (1) Overlapping (interlocking) the masonry units.
   (2) Embedding metal ties in connecting joints.
   (3) Using grout to adhere adjacent Wythes of masonry.
3. One or more bricks from the end.
4. ¼ inch per 6 inches of run.
5. 18 to 24 inches.
6. Six or seven courses high.
7. ¼- and ⅜-inch.
8. Stretch a tightly drawn line and secure it with pins, corner blocks, and so forth. Fasten the line so that it's about $^{1}/_{32}$ inch outside the brick's top edge and level with it.
9. No less than ¼ inch at any point.
10. ¾-inch plywood.

411

1. (1) Stop the source of moisture and dry brush.
   (2) Wash away with clean water or use a scrub brush to remove it.
2. Make the necessary repairs and then saturate the stain and surrounding area with water and use a diluted acid solution of one part acid to nine parts water.
3. (1) Cut out mortar in ¼-inch-thick layers and remove the damaged brick.
   (2) Dampen the new brick and the repair area immediately to keep the mortar from drying too fast.
   (3) Now, butter and insert new brick.
4. ⅜-inch-thick.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

37. (408) Which type of mortar should you choose for general use work, specifically for below-grade masonry that contacts the earth, such as foundations?
    a. Type K.
    b. Type M.
    c. Type N.
    d. Type S.

38. (408) What is the *minimum/maximum* time you should mix the mortar when machine mixing?
    a. 1 to 2 minutes.
    b. 3 to 5 minutes.
    c. 4 to 6 minutes.
    d. 5 to 7 minutes.

39. (408) When hand-mixing mortar, which method allows the blending process to take place easier and quicker?
    a. Add one-fourth the sand, followed by all the cement and lime, and then the remaining amount of sand.
    b. Add half the sand, followed by all of the cement and lime, and then the remaining amount of sand.
    c. Add one-fourth the sand, followed by half the cement and lime, and then the remaining amount of sand and cement.
    d. Add half the sand, followed by half the cement and lime, and then the remaining amount of sand and cement.

40. (408) As a practical guide, you should discard any mortar not used within how many hours?
    a. 1½.
    b. 2.
    c. 2½.
    d. 3 .

41. (408) Using Rule 38, estimate approximately how much cement and sand is needed for a 1:4 mix ratio.
    a. 5 cubic feet of cement; 20 cubic feet of sand.
    b. 6 cubic feet of cement; 32 cubic feet of sand.
    c. 7.6 cubic feet of cement; 30.4 cubic feet of sand.
    d. 9.5 cubic feet of cement; 28.5 cubic feet of sand.

42. (409) When constructing a concrete masonry wall, which action should you take after you locate the corners?
    a. Chase the bond.
    b. Build the corner leads.
    c. Measure the diagonals.
    d. Check the footing or slab for level.

43. (409) How do you chase the bond for a concrete masonry wall?
    a. Build up the corners four courses high.
    b. Lay out a story pole with ⅜-inch joints.
    c. Spread a full mortar bed on the first course.
    d. Place the first course of blocks without mortar.

44. (409) How high should you build the corner leads once the first course is laid?
    a. Two or three courses.
    b. Three or four courses.
    c. Four or five courses.
    d. Five or six courses.

45. (409) How should you tool mortar joints on a concrete masonry wall?
    a. Tool vertical joints with a long jointer first, then the horizontal joints with an S-shaped jointer.
    b. Tool vertical joints with an S-shaped jointer first, then the horizontal joints with a long jointer.
    c. Tool horizontal joints with a long jointer first, then the vertical joints with an S-shaped jointer.
    d. Tool horizontal joints with an S-shaped jointer first, then the vertical joints with a long jointer.

46. (409) Which of the following procedures is used to make a Michigan control joint in a concrete masonry wall?
    a. Cut a ½-inch-deep line into the block face.
    b. Lay half- and full-size tongue and groove blocks.
    c. Connect stretcher blocks with a Z-shaped bar placed across the joint.
    d. Curl a strip of felt into the end core to cover the end of the block on one side of the joint.

47. (409) When installing lintels, what is the *minimum* amount of bearing that you should provide at each end?
    a. 2 inches.
    b. 4 inches.
    c. 6 inches.
    d. 12 inches.

48. (410) Which action can you take to *ensure* that *all* the face bricks received at the job site are uniform in quality, size and color?
    a. Request the same style.
    b. Specify the correct size.
    c. Keep a sample from the first load.
    d. Order them from the same manufacturer.

49. (410) What do you do to bricks if you *must* lay them in cold weather?
    a. Keep them dry and warm.
    b. Soak them in warm water.
    c. Sprinkle them with cool water.
    d. Heat them with a propane torch.

50. (410) Which type of course is used when laying a brick windowsill?
    a. Coping.
    b. Soldier.
    c. Header.
    d. Rowlock.

51. (410) To protect the tops of walls and other brickwork exposed to the weather, you should install
    a. lintels.
    b. headers.
    c. copings.
    d. rowlocks.

52. (410) When laying the corner leads on a brick wall, the *first* lead height is determined by how many
    a. courses are needed and the bond type.
    b. courses are needed only.
    c. brick bats are needed and the bond type.
    d. brick bats are needed only.

53. (410) What size mortar joints should you use when laying brick to produce the *strongest* and *most* water-resistant joints?
    a. ⅛ and ¼ inch.
    b. ¼ and ⅜ inch.
    c. ½ and ⅝ inch.
    d. ¾ and ⅞ inch.

54. (411) Which action will usually result in efflorescence disappearing with normal weathering?
    a. Spray with bleach.
    b. Coat with lime putty.
    c. Mist with acid solution.
    d. Stop the source of moisture.

55. (411) If you *must* make repairs to mortar joints after the mortar has already hardened (i.e., repointing), you *must* rake or chisel the old mortar joints at least how deep?
    a. ⅛ inch.
    b. ½ inch.
    c. 1 inch.
    d. 1½ inch.

56. (411) Before you insert a replacement brick, you should dampen the new brick and the repair area immediately to
    a. create an elastic effect.
    b. allow the mortar to flow.
    c. distribute the mortar more evenly.
    d. keep the mortar from drying too fast.

57. (411) How should you waterproof outside masonry surfaces below ground level where there's *not* much water or where drainage is excellent?
    a. Parging.
    b. French drain.
    c. Hot asphalt only.
    d. Hot asphalt with membranes.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Masonry Wall and Floor Tile Construction

WE CAN FINISH walls and floors with different masonry materials. An interior wall could have a low-cost plaster finish or an expensive ceramic tile finish. A floor's finish could range from ordinary concrete to ceramic tile. We begin with a brief look at plaster and stucco and give a more detailed look at ceramic tile. Become familiar with the basic masonry finishes that are used on walls and floors, particularly with their specifications, shapes, sizes, and tile setting methods.

3–1. Plaster and Stucco

Plaster and stucco are economical masonry materials that provide various finishes on walls. We mix both with water to a smooth consistency (e.g., plastic state) and apply it to a wall where it hardens in place. The main difference between the two is that we use plaster for interior walls and stucco for exterior walls. The term plaster can be used interchangeably with stucco when discussing tools, ingredients, and application techniques.

412. Identifying plastering tools and materials

In this lesson, you'll learn the basic principles for plastering. We will also discuss the materials used, along with mix ratios, and the tools needed to apply it.

NOTE: The tools used for plastering are the same for stuccoing.

Tools

Plastering requires the use of a number of tools, some specialized, including various trowels, hawks, floats, straight and featheredges, Darbys, scarifiers, and plastering machines.

Trowels

Steel trowels are used to apply, spread, and smooth plaster. The shape and size of the trowel blade are determined by the purpose for which the tool is used and the manner of using it.

Hawk

The hawk (fig. 3–1) is a square, lightweight sheet metal platform with a vertical central handle, used for carrying mortar from the mortarboard to the place where it is to be applied. The plaster is then removed from the hawk with the trowel.

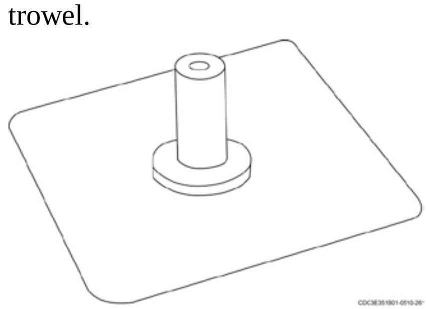


Figure 3–1. Hawk.

Float

A wood or sponge float (fig. 3–2) is used to fill voids and hollows, to level bumps left by previous operations, and to add texture to the surface.

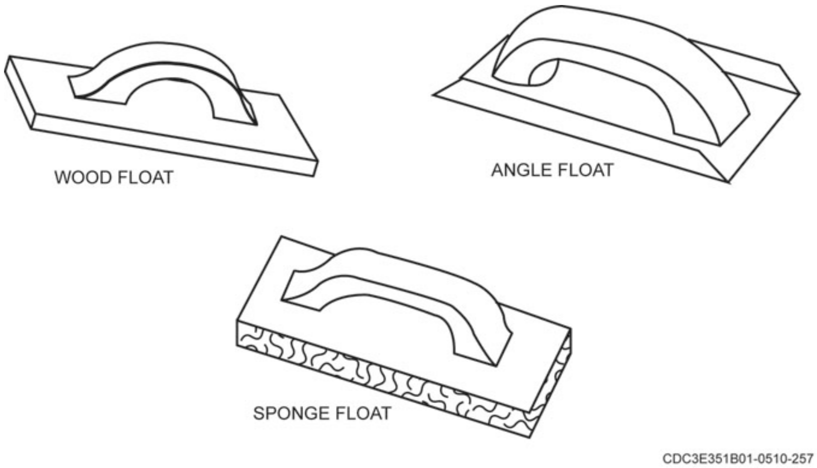


Figure 3–2. Floats.

Straightedge and featheredge

The rod or straightedge consists of a wood or lightweight metal blade usually 6 inches wide and 4 to 8 feet long; however, it may be as long as 10 to 16 feet (fig. 3–3). You use this tool to level and straighten the plaster and/or stucco between the grounds.

The featheredge is similar to the rod except that the blade tapers to a sharp edge. It is used to cut in inside corners and to shape sharp straight lines at outside corners where walls intersect.

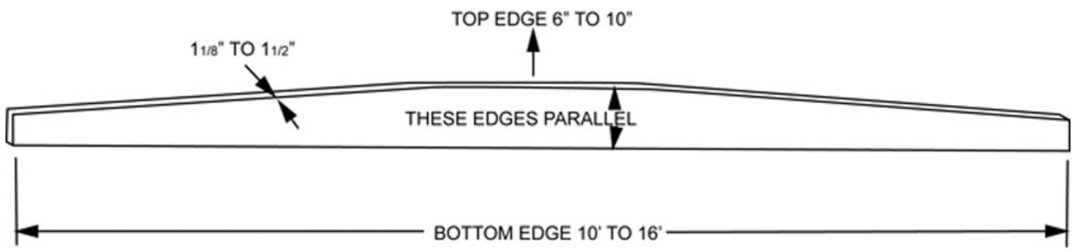


Figure 3–3. Straightedge.

Darby

The Darby (fig. 3–4) is used for further base coat straightening after rodding is completed and to level plaster screeds and finish coats. When using the Darby, hold the blade nearly flat against the plaster surface and at an approximate 45 degrees angle in the direction of travel.

NOTE: When leveling a plaster surface, be sure to move the leveling tool over the plaster smoothly. Moisten the surface if it’s too dry. You can dash or brush water onto the plaster and/or stucco for base coat operations.

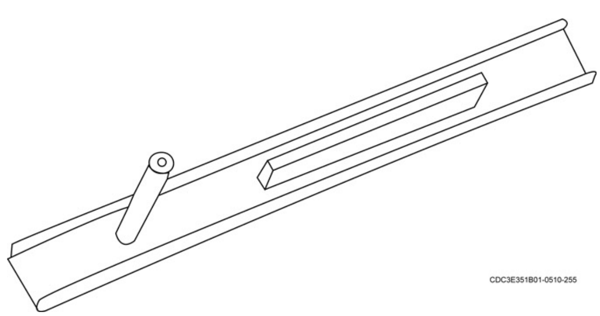


Figure 3–4. Darby.

Scarifier

The scarifier (fig. 3–5) is a raking tool that leaves furrows approximately ⅛ inch deep, ⅛ inch wide, and ½ to ¾ inch apart. The furrows improve the bond between the scratch coat and the brown coat.

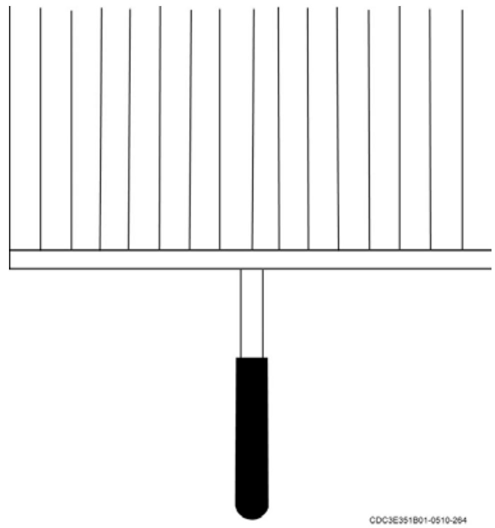


Figure 3–5. Scarifier.

Plastering machines

There are two types of plastering machines: wet mix and dry mix. The wet-mix pump type carries mixed plaster from the mixing machine to a hose nozzle. The dry-mix machine carries dry ingredients to a mixing nozzle where water under pressure combines with the mix and provides spraying force. Most plastering machines are of the wet-mix pump variety.

Plaster

A plaster mix, like a concrete mix, is made plastic by the addition of water to dry ingredients (i.e., binders and aggregates). Also, like concrete, a chemical reaction of the binder and the water, called hydration, causes the mix to harden. The binders most commonly used in plaster are gypsum, lime, and Portland cement; however, you should not expose gypsum plaster to water or severe moisture conditions. Thus it is only used for interior surfaces. Lime and Portland cement plaster may be used for both interior and exterior construction.

Gypsum plaster

Gypsum is a naturally occurring sedimentary gray, white, or pink rock. The natural rock is crushed, and then heated to a high temperature (e.g., calcining). Additives are used to control set, stabilization, and other physical or chemical characteristics.

Lime plaster

Lime plaster is mainly used for interior finish coats. Lime putty is also often added to other less workable plaster materials to improve plasticity. For lime plaster, lime is mixed with sand, water, and a gauging material.

Portland cement plaster

Portland cement plaster is similar to Portland cement mortar used in masonry. It usually contains only cement, sand, and water; although, lime is usually added for plasticity. You can apply Portland cement plaster directly to exterior and interior masonry walls and over metal lath but *never* apply it over gypsum plasterboard or over gypsum tile. Portland cement plaster is recommended for use in plastering walls and ceilings of large walk-in refrigerators and cold-storage spaces, basements, toilets, and showers.

Aggregates

The three main aggregates used in plaster are sand, vermiculite, and perlite.

Sand

Sand used for plaster must not have more than the specified amounts of organic impurities and harmful chemicals. If the sand is too fine, the strength is reduced. If the sand is too coarse, the mix will be hard to apply. Having an excess of either fine or coarse aggregate can cause plaster shrinkage during drying. Basically any sand retained on a #4 sieve is too coarse to use in plaster and only a small percentage of the material (about 5 percent) should pass a #200 sieve.

Vermiculite

Vermiculite is a micaceous mineral; each particle is laminated or made up of adjoining layers. For ordinary plasterwork, vermiculite is used only with gypsum plaster. **NOTE:** Its use is generally restricted to interior applications.

Perlite

Raw perlite is a volcanic glass that when flash-roasted expands to form irregularly shaped frothy particles containing innumerable minute air cells. Perlite is used with calcined gypsum or Portland cement for interior plastering.

Water

As with concrete, there is a maximum quantity of water required to complete hydration. Any excess reduces the plaster strength. As a general rule, you should add only the amount of water required to attain workability. The water should be potable and contain no dissolved chemicals that might accelerate or retard the set.

Bases

For plaster bases, you must install a base material, called lath, to form a continuous surface spanning the spaces between the structural members.

Wood lath

Wood lath is made of white pine, spruce, fir, redwood, and other soft, straight-grained woods. The standard size of wood lath is $^{5}/_{16}$ inch × 1½ inch × 4 feet.

Board lath

Board lath is manufactured from mineral and vegetable products and is available in standard dimensions for easy application onto framing members. The most commonly used gypsum board lath is ⅜-inch × 16 inches × 48 inches (solid or perforated). Long lengths of gypsum lath are primarily used for furring the interior side of exterior masonry walls. It is available in sizes 24 inches wide, ⅜-inch-thick, and up to 12 feet in length.

Board lath has numerous advantages:

- It is rigid, strong, stable, and reduces the possibility of dirt filtering through the mortar to stain the surface.
- It insulates and strengthens the framework.
- Gypsum board lath is fire resistant.

NOTE: Using board lath reduces the amount of plaster needed to cover the surface.

There are two main groups—gypsum board and insulation board. Each type is used for a specific purpose or condition.

NOTE: Only gypsum mortar can be used over gypsum lath. *Never* apply lime mortar, Portland cement, or any other binding agent to gypsum lath.

Metal lath

Metal lath is perhaps the most versatile of all plaster bases. Keys are formed when the plaster is forced through the openings to create the bond. As the plaster hardens, it becomes rigidly interlocked with the metal lath.

Three types of metal lath are commonly used: diamond mesh (e.g., expanded metal), expanded rib, and wire mesh (e.g., woven wire).

- Diamond mesh lath is also made in a large mesh used for stuccowork and concrete reinforcement. Self-furring lath has little dimples that hold the lath approximately one-fourth inch away from the wall surface. You can nail it to smooth concrete or masonry surfaces. Another form of diamond mesh lath is paper-backed. It has a waterproof or Kraft paper glued to the back of the sheet to act as a moisture barrier and plaster saver.

- Expanded rib lath is like diamond mesh lath except that various size ribs are formed in the lath to stiffen it. Ribs run lengthwise of the lath.

- Woven wire lath resembles “chicken wire.” It is made of various gauges of galvanized wire that are woven or twisted together to form either squares or hexagons. It is commonly used as a stucco mesh where it is placed over tarpaper on open-stud construction or sheathing.

Lath accessories

Manufacturers produce a wide variety of metal accessories for use with gypsum and metal lathing. Lathing accessories are usually installed before plastering to form true corners, act as screeds, reinforce possible weak points, provide control joints, and provide structural support. Lathing accessories consist of structural components and miscellaneous accessories.

Structural components

The principal use of structural components is in the construction of hollow partitions. A hollow partition is one that does not have any framing members (i.e., studs and plates). Structural components are lathing accessories that take the place of the missing framing members that would normally support the lath. These include prefabricated metal studs and floor and ceiling runner tracks. The runner tracks take the place of missing top and bottom plates. They usually consist of metal channels used for furring and bracing.

Miscellaneous accessories

Miscellaneous accessories consist of components attached to the lath at various places. They define and reinforce corners, provide dividing strips between plaster and the edges of baseboard or other trim, and define plaster edges at unframed openings.

Corner beads

Corner beads fit over the outside corners on gypsum lath to provide a true, reinforced corner. They are available in either small-nose or bullnose types with either solid or perforated metal flanges.

Casing beads

Casing beads are similar to corner beads and are used both as finish casings around openings in plaster walls and as screeds to obtain true surfaces around doors and windows. They are also used as stops between a plaster surface and another material such as masonry or wood paneling. Casing beads are available as square sections, modified-square sections, and quarter-rounds.

Screeds

Base or *parting* screeds are used to separate plaster from other flush surfaces, such as concrete. A *ventilating expansion* screed is used on the underside of closed soffits and in protected vertical surfaces to help ventilate enclosed attic spaces. *Drip* screeds act as the termination point along concrete foundation walls when using exterior Portland cement plaster. They are also used on external horizontal corners of plaster soffits to prevent drip stains on the underside of the soffit. A *metal base* acts as a flush base at the bottom of a plaster wall and also serves as a plaster screed.

413. Applying and repairing plaster and stucco

Now that you are familiar with the tools and materials needed to apply plaster and stucco, we will discuss the installation methods for the bases and the application techniques for the plaster and stucco. We will also discuss common repair methods that you may encounter.

Base lath installation

In the previous lesson, we discussed the different types of bases used for plaster and stucco. Now we will discuss the basic installation procedures for plaster bases and their accessories.

Wood lath

Nail each lath to the studs or joists with 3d blued-lathing nails. Nail the laths six in a row, one above the other leaving a ⅜-inch space between each piece (fig. 3–6). Nail the next six rows of lath above the first set but stagger the end joint two stud places (leave a ¼-inch space between the lath ends). Repeat this procedure for each successive set of six rows.

NOTE: The lath joints are staggered in an attempt to prevent cracks.

You must make sure that wood lath is damp when you apply the mortar. If not, the dry lath will pull the moisture out of the mortar preventing proper setting. The best method to prevent dry lath is to wet it thoroughly the day before plastering, this lets the wood swell and reach a stable condition ideal for plaster application.

Gypsum (board) lath

You should fasten gypsum lath horizontally with staggered end joints using lath nails or staples (fig. 3–7). The fasteners should penetrate into the framing members at least ¾ inch. Leave a small gap between boards, so the board is not under compression before the plaster is applied.

NOTE: Never place lath joints over openings at the jamb line, this will likely result in stress cracks along this joint.

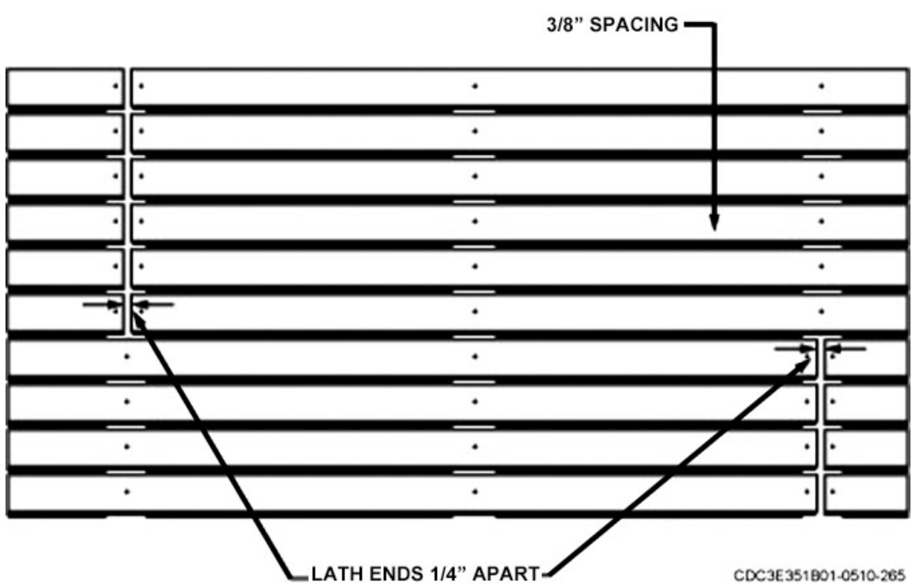


Figure 3–6. Wood lath.

Place at least four fasteners on each support for 16-inch-wide lath and five fasteners for 2-foot-wide lath when framing members are spaced 16 inches on center. Use five fasteners when framing members are spaced 24 inches on center.

NOTE: Some fire ratings require more fasteners. Start fastening ½ inch from the edges of the board. To keep the board from buckling, fasten the center of the board first, and then work toward the ends.

NOTE: When installing insulating lath, use the same installation procedures as gypsum lath except the nails used should be slightly longer.

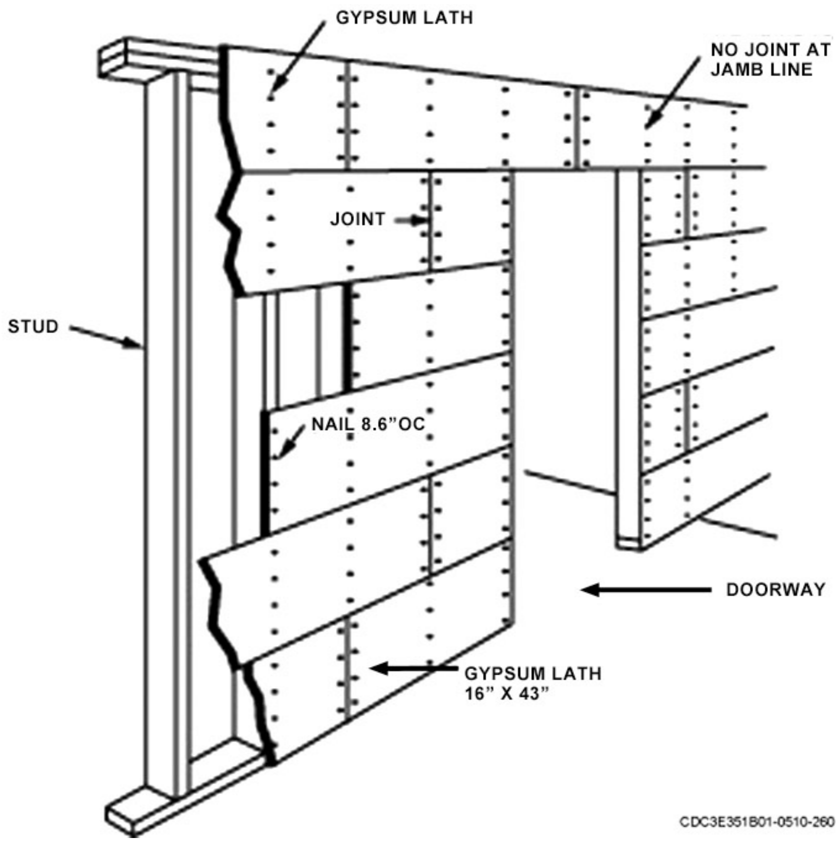


Figure 3–7. Gypsum board lath.

Metal lath

Install metal lath with the long length at right angles to the framing members (i.e., supports) and with the sides and ends lapped over each other. Secure (i.e., tie) the laps with 18-gauge tie wire. Place rib lath with the ribs against the supports and the ribs nested where the lath overlaps.

Lap

Lap the metal lath and wire lath at least 1 inch at the ends (vertical lap) and ½ inch at the sides (horizontal lap); however, refer to the project or manufacturer's specifications for specific lap requirements. Some wire lath manufacturers specify up to 4½-inch end laps and 2-inch side laps.

Fastening

There are various fastening methods; the list below provides a sampling:

- Nail or staple the lath to the supports at 6-inch intervals. You can use 1½-inch barbed roofing nails with $^{7}/_{16}$-inch heads or 1-inch 4-gauge staples for flat lath on wood supports.
- For ribbed lath, heavy wire lath and sheet lath, use nails or staples that penetrate the wood at least 1⅜ inches for horizontal application and at least ¾ inch for vertical application.
- To fasten metal lath onto metal channel supports, use 18-gauge tie wire or hog ties (i.e., heavy wire ring installed with a special tool) at 4-inch intervals.

Stretch the lath tight so that no sags or buckles occur. Start tying or nailing at the center and work toward the ends. Rib lath should have ties looped around each rib at all supports as the main supporting power for rib lath is the rib.

When you install metal laths at both inside and outside corners, bend the lath to form a corner and carry it at least 4 inches in or around the corner. This provides the proper reinforcement for the angle or corner.

Joint reinforcing

Some shrinkage results as wood-framing members dry. This may cause cracks to develop around openings and corners. To reduce the possibilities of cracks, you can place strips of expanded metal lath (i.e., strip reinforcement) in key positions over the base material to act as reinforcements. Tack a 10- to 20-inch strip diagonally across each upper comer of the opening. Strip reinforcement should also be used under flush ceiling beams to prevent plaster cracks.

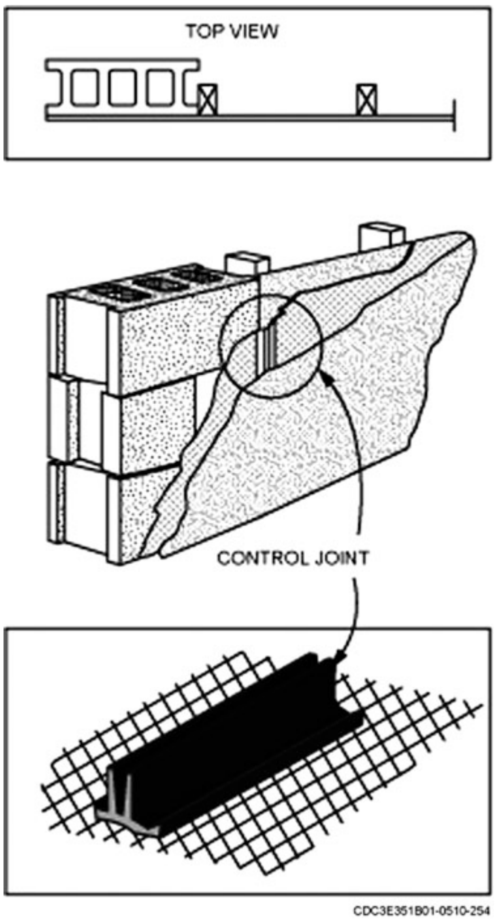


Figure 3–8. Control joint.

Install corner beads on all outside corners ensuring they are plumb and level. Each bead acts as a leveling edge when walls are plastered and reinforces the corner. Reinforce the inside corners at the juncture of walls and ceilings with metal lath to minimize plaster cracks.

Place control joints at intermediate locations, per the job specifications, to minimize cracking and to maintain proper plaster thickness. Control joints are formed metal strips that relieve stresses and strains in large plaster areas and at junctures of dissimilar materials on walls and ceilings (fig. 3–8). **NOTE:** Control joints are extremely important when Portland cement plaster is used.

Plastering grounds

Plastering grounds (fig. 3–9) are strips of wood used as plastering guides and are located around window and door openings to include at the base of the walls. For interior door openings, they are 5¼ inches wide, which coincides with the standard jamb width for interior walls with a plaster finish. They are removed after the plaster has dried.

In window and exterior door openings, the frames are normally in place before the stucco is applied. Thus, the inside edges of the side and head jamb often serves as grounds. The edge of the window can be used as a ground, or you can use a narrow ⅞-inch-thick ground strip nailed to the edge of the 2 × 4-inch sill. These are normally left in place and covered with the casing.

Use a narrow ground or screed at the bottom of the wall to control the thickness of the gypsum plaster and to provide an even surface for the baseboard and molding. This screed is left in place after the plaster has been applied.

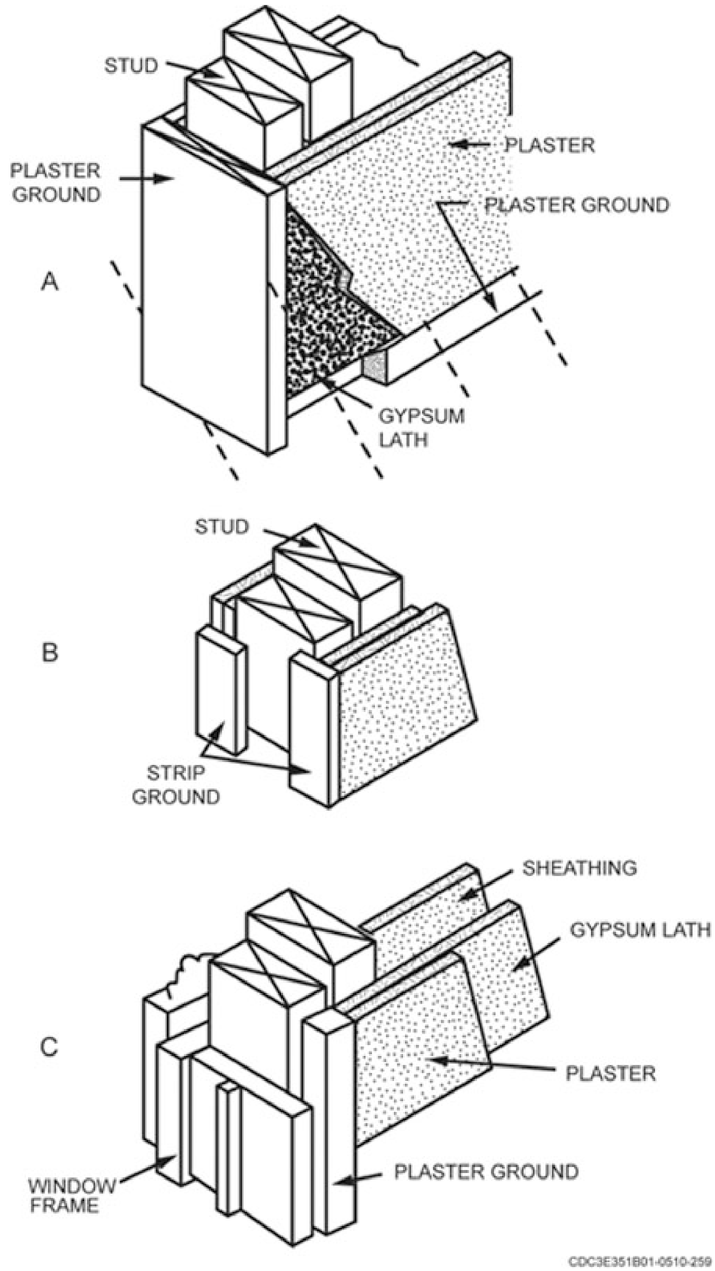


Figure 3–9. Plastering grounds.

Mix ratios

Some plaster comes ready-mixed, meaning you only need to add water to attain the minimum required workability. To mix it yourself, tables are available that provide the recommended proportions for base and finish coats on various types of laths.

In the following discussion, one part of cementitious material means 100 pounds (e.g., one sack) of gypsum or 94 pounds (e.g., one sack) of Portland cement. One part of aggregate means 100 pounds of sand or 1 cubic foot of vermiculite or perlite. The first number in the mix is the cementitious material and the second number is the aggregate. **NOTE:** The aggregate parts given for gypsum or Portland cement plaster may refer to sand, vermiculite, and/or perlite.

Base coat proportions

Two-coat plasterwork consists of a single base coat and a finish coat. Three-coat plasterwork consists of two base coats (i.e., the scratch coat and the brown coat) and a finish coat. Refer to the table below for some common mix ratios:

INGREDIENT	PROPORTION
Two-coat masonry work[1]	
Gypsum plaster	1:3
Three-coat work on a masonry or metal lath base	
Gypsum plaster	Both coats 1:3
Portland cement plaster	Both coats 1:3 to 1:5
Three-coat work on gypsum lath using gypsum plaster	
Scratch coat	1:2
Brown coat	1:3

[1] Portland cement plaster is not used for two-coat work, and two-coat work is not usually done on metal lath.

Finish coat proportions

A lime finish can be applied over a lime, gypsum, or Portland cement base coat. Other finishes should be applied only to base coats containing the same cementitious material. Finish coat proportions vary according to whether the surface is to be finished with a trowel (smooth finish) or with a float (textured finish). Thus you should always refer to the job specifications.

Mixing methods

The two methods used to mix plaster or stucco is hand mixing and machine mixing. **NOTE:** Be sure to wear personnel protective equipment when handling cement and lime.

Hand Mixing

To hand-mix plaster, you will need a flat, shallow mixing box and a mortar hoe. The three steps below provide direction on performing hand mixing.

1. Place the dry ingredients in a mixing box and thoroughly mix until a uniform color is obtained.
2. Cone the pile and add water to the mix. Begin mixing by pulling the dry material into the water with short strokes.
3. Continue mixing until the materials have been thoroughly blended and proper consistency has been attained.

NOTE: After the materials have been thoroughly blended, continue mixing for *only* 10 to 15 minutes.

Machine mixing

A typical plaster-mixing machine consists primarily of a metal drum containing mixing blades, mounted on a chassis equipped with wheels for road towing. Use the following steps to properly operate a machine mixer.

1. Add the water first, and then add about half of the sand.
2. Next add the cement and any admixture desired.
3. Last add the rest of the sand.
4. Mix until the batch is uniform and has the proper consistency—usually 3 to 4 minutes.

NOTE: Most mixers operate at top capacity when the mortar is about two inches above the blades—do not overload.

Base coat application

Specifications usually require that plaster be finished within ⅛-inch tolerance within 10 feet and not have waves, cracks, or imperfections. It is very important to adhere to the recommended minimum thickness for the plaster. The thicker the plaster gets over the minimum recommended thickness, the more rigid it becomes. As a result, the tendency to crack increases as thickness increases.

Gypsum

Below is the sequence in three coat gypsum plastering:

1. Install the plaster base.
2. Attach the grounds.
3. Apply the scratch coat approximately $^{3}/_{16}$-inch-thick.
4. Before the scratch coat sets, rake and cross rake.
5. Allow the scratch coat to set firm and hard.
6. Apply plaster screeds (if required).
7. Apply the brown coat to a depth of the screeds.
8. Using the screeds as guides, straighten the surface with a rod.
9. Fill in any hollows and rod again.
10. Level and compact the surface with a Darby; then rake and cross rake to receive the finish coat.
11. Define angles sharply with an angle float and a featheredge. Trim back the plaster around the grounds so the finish coat can be applied flush with the grounds.

Portland cement

Portland cement plaster is actually cement mortar. It is usually applied in three coats, the steps being the same as those described for gypsum plaster. Minimum recommended thicknesses are usually ⅜ inch for the scratch and brown coats, and ⅛ inch for the finish coat.

Portland cement plaster should be moist-cured similar to concrete. The best procedure is fog-spray curing. The scratch coat and the brown coat should both be fog-spray cured for 48 hours. The finish coat should not be applied for at least seven days after the brown coat. It too should be spray-cured for 48 hours.

Finish coat application

You can use the troweling, floating, or spraying techniques to finish interior plaster. Troweling makes a smooth finish; whereas, floating and spraying makes various surface textures.

Smooth finish with gypsum gauging plaster

Gypsum gauging plaster is the most widely used material for smooth finish coats. A team of two or more is usually needed to apply this coat. When you apply gypsum gauging plaster complete these steps.

1. One person applies plaster at the angles.
2. Another person follows immediately, straightening the angles with a rod or featheredge.
3. The remaining surface is covered with a skim coat of plaster. Pressure on the trowel must be sufficient to force the material into the rough surface of the base coat to ensure a good bond.
4. The surface is immediately doubled back to bring the finish coat to final thickness.
5. All angles are floated with additional plaster added if required to fill hollows.
6. The remaining surface is floated, and all hollows filled. This operation is called drawing up. The hollows being filled are called cat faces.

7. Allow the surface to draw for a few minutes. As the plaster begins to set, the surface-water glaze disappears and the surface becomes dull. Begin troweling at this point. The plasterer holds the water brush in one hand and the trowel in the other, so troweling can be done immediately after water is brushed on.
8. Water is brushed on lightly, and the entire surface is rapidly troweled with enough pressure to compact the finish coat fully. The troweling operation is repeated until the plaster has set.

Other types of plaster

The sequence of steps for trowel finishes for other types of finish plasters is about the same. Preliminary finishing of Portland cement-sand is done with a wood float, after which the steel trowel is used.

Float finish

The steps in float finishing are about the same as those described for trowel finishing, except the final finish is done with a float. A surface is usually floated twice: a rough floating with a wooden float first, then a final floating with a rubber or carpet float.

Special textures

Some special interior-finish textures are obtained by methods other than or in addition to floating. A few of these are listed below.

Stippled

After the finish coat has been applied, additional plaster is daubed over the surface with a stippling brush or roller.

Sponge

By pressing a sponge against the surface of the finish coat, you get a very soft, irregular texture.

Dash

The dash texture is obtained by throwing plaster onto the surface from a brush. It produces a fairly coarse finish that can be modified by brushing the plaster with water before it sets.

Travertine

The plaster is jabbed at random with a whiskbroom, wire brush, or other tool that will form a dimpled surface. As the plaster begins to set, it is troweled intermittently to form a pattern of rough and smooth areas.

Stucco

Stucco is the term applied to plaster whenever it is applied to the exterior of a building or structure. Stucco is hard strong, fire resistant, weather resistant, does not deteriorate after repeated wetting and drying, resists rot and fungus, and retains colors.

Composition

Stucco is a combination of cement or masonry cement, sand and water, and frequently a plasticizing material. Color pigments are often used in the finish coat, which is usually a factory-prepared mix. The material used in a stucco mix should be free of contaminants and unsound particles. Type I normal Portland cement is generally used for stucco, although Type II, Type III, and air entraining may be used. The plasticizing material added to the mix is hydrated lime. Mixing water must be potable. The aggregate used in cement stucco should be well-graded, clean, and free from dirt, clay, or vegetable matter. Follow the project specifications as to the type of cement, lime, and aggregate to be used.

Application

Metal reinforcement should be used whenever stucco is applied on wood frame, steel frame, flashing, masonry, or any surface not providing a good bond. Stucco may also be applied directly on masonry.

Two-coat work applied directly to masonry

On masonry where no reinforcement is used, two coats are usually sufficient (fig. 3–10). Apply the rough-floated base coat approximately ⅜-inch-thick. Follow with a ¼-inch-thick finish coat.

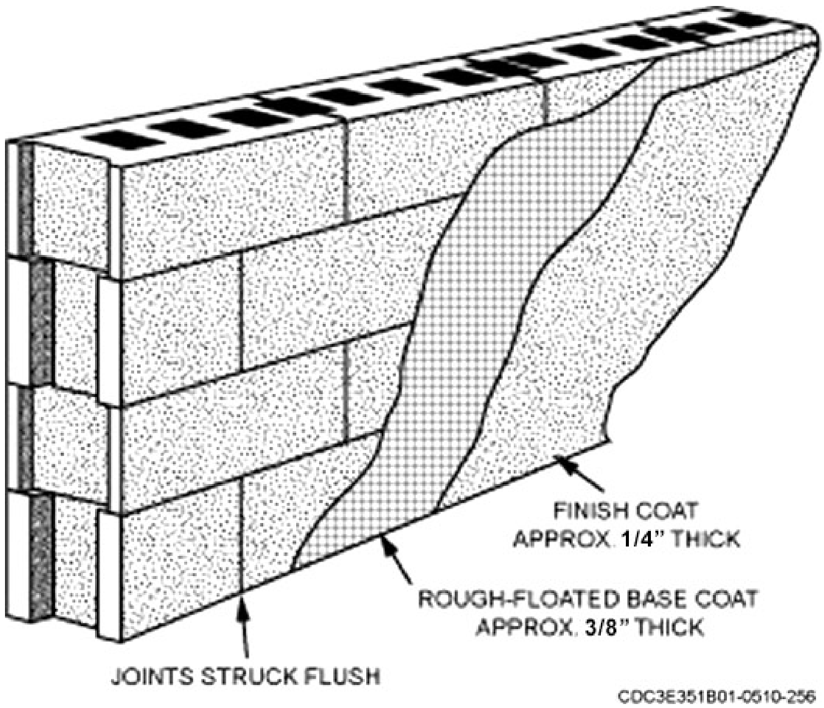


Figure 3–10. Stucco applied to masonry.

Three-coat work applied to open-frame construction

To prepare an area to receive the metal lath, drive nails one-half of their length into the framing members. Space the nails 5 to 6 inches on center from the bottom and place them on all corners and openings throughout the entire structure. Once the area is prepared you're ready for the next three steps:

1. Place (i.e., stretch) wire on the nails (fig. 3–11). This is called installing the line wire.
2. Apply a layer of waterproof paper over the line wire. Lap three to four inches and nail with roofing nails.
3. Install wire mesh (e.g., stucco netting) over the paper using furring nails (fig. 3–12). Furring nails are used to hold the wire ⅜ inch away from the paper.

Stucco or sheathed frame construction is the same as open frame except no line wire is required.

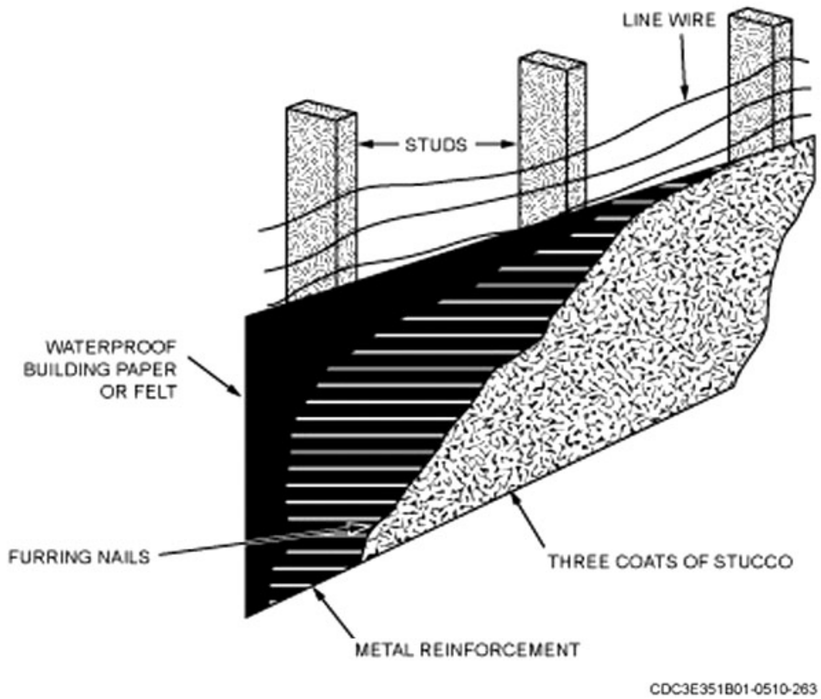


Figure 3–11. Preparing framing members for stucco.

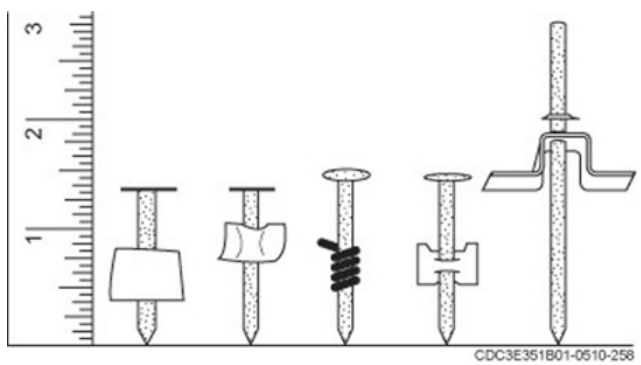


Figure 3–12. Furring nails.

Three-coat application procedures

The open and sheathed frame construction requires three coats—a ⅜-inch scratch coat (e.g., horizontally scored or scratched), a ⅜-inch brown coat, and a ⅛-inch finish coat (⅞ inch total thickness). Start at the top and work down the wall. This prevents mortar from falling on the completed work. The following list contains features of the three-coat process:

1. The scratch coat should be pushed through the mesh to make sure the metal reinforcement is completely embedded for mechanical bond.
2. The brown coat should be applied as soon as the scratch coat has setup enough to carry the weight of both coats (usually 4 or 5 hours). The brown coat should be moist-cured for about 48 hours and then allowed to dry for about five days. Dampen the brown coat uniformly just before the application of the finish coat.
3. The finish coat is frequently pigmented to obtain decorative colors. Although the colors may be job-mixed, a factory prepared mix is recommended. The finish coat may be applied by hand or machine and mist-cured for 48 hours.

Mixing

Mixing procedures for stucco are similar to those for plaster.

Maintenance and repair

The material presented here refers to both stucco and plaster. Cracks, holes, and looseness in plastered surfaces are signs of excessive internal or external stresses. They may be caused by poor workmanship, excess moisture inside a building or building settlement. External stresses that cause damage should be corrected before repairs are made to the plastered surfaces themselves.

Structural cracks

Structural cracks are usually large and well defined, extending across the surface and entirely through the plaster. They generally develop during the first year after construction and, in most cases, can be permanently repaired. However before repairs are begun, the cause should be determined and necessary precautions taken to prevent recurrence.

Structural cracks may extend diagonally from the corners of door and window openings, run vertically in corners where walls join, run horizontally along the junction of walls and ceilings, or occur in walls where two unlike materials join. To repair structural cracks follow the next three steps:

1. Cut out and remove the loose material. Form a V-shape in the crack to provide a key. Widen the crack only enough to ensure a good bond between patching plaster, old plaster, and lath.
2. Clean the expanded metal or wire lath to form a key. Break out the key between wood laths so that a new key can be formed. Thoroughly wet wood lath before patching. Brush out all loose material, remove all grease or dirt from surrounding surface areas, and thoroughly wet the edges of the groove.
3. Press the first coat of patching plaster firmly into place, filling the groove nearly to the surface; allow it to set until nearly dry but not hard; then complete the patch by applying a finish coat, strike off flush, and trowel smooth.

In applying the patching plaster, you should pay special attention to the edges of the patch to ensure a firm, solid bond between old and new plaster.

Loose plaster

Large areas of plaster surfaces with cracks indicate loose plaster. To determine the extent of loosened plaster, lightly tap the surface with a small hammer. Loose plaster may result from excessive moisture caused by leaks in the roof, seepage through an exterior wall, plumbing leaks, or heavy condensation. This excessive moisture causes the plaster to become soft, which destroys the bond to the base.

In some cases, moisture causes the fastenings holding the lath to the structural frame to corrode, permitting both the lath and plaster to bulge or sag. In localities where high humidity is prevalent, moisture causes a continued hydration of the lime that weakens the plaster and destroys the bond between plaster and base. This condition usually occurs in the spring and summer months, starting from the first to third year after plastering and continuing indefinitely.

Before the damaged plaster is repaired, it is necessary to locate and eliminate any source of moisture. To prevent the loose plaster from falling until permanent repair can be made, temporarily secure the loose plaster with a section of wallboard nailed securely over the affected area. You should make the following two permanent repairs as soon as possible.

1. Remove all loose plaster around the break, working well back in the surrounding area to a point where solid plaster is obtained.
2. Remove the defective lath and replace it with suitable plaster backing, such as metal lath or plasterboard, and securely refasten all laths that have become loosened.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

412. Identifying plastering tools and materials

1. Match the tools in Column B with their uses in Column A. Items in Column B may be used once, more than once or not at all.

Column A	*Column B*
____ (1) Used to apply, spread and smooth plaster.	a. Float.
____ (2) A square lightweight sheet metal platform used for carrying mortar from the mortarboard,	b. Hawk.
____ (3) Used to fill voids or hollows, to level bumps and to add texture to the surface.	c. Darby.
____ (4) Used to level and straighten the plaster and/or stucco between the grounds.	d. Trowel.
____ (5) Used to cut inside corners and to shape sharp straight lines at outside corners where walls intersect.	e. Scarifier.
____ (6) Used to level plaster screeds and finish coats.	f. Featheredge.
____ (7) A raking tool used to leave furrows in the plaster and/or stucco.	g. Straightedge.

2. What type of plaster is only used on interior surfaces?

3. What are the most commonly used aggregates for plaster?

4. What are the two main groups of board lath?

5. List the types of commonly used metal lath.

413. Applying and repairing plaster and stucco

1. How is wood lath installed?

2. How is gypsum board lath installed?

3. What does each number in a mix ratio for plaster represent?

4. Specifications usually require that plaster be finished within what tolerance?

5. How thick is each coat when three-coat stucco is applied to open and sheathed frame construction?

6. When applying patching plaster to a damaged area, why should you pay special attention to the edges of the patch?

3–2. Wall and Floor Tile

Before you set ceramic tile, you need to become familiar with the different classes, types, shapes, and sizes that are available. You must also know the proper tools and materials needed to properly lay the tiles. Imagine spending countless hours laying ceramic floor tiles in an outdoor area, just to find out they all cracked. In this section, we will discuss the different types of tools and materials used along with general installation procedures used for wall and floor tile.

414. Tile tools and materials

In this lesson, we will discuss some of the tools that you will need to install wall and floor tiles. We will also discuss some of the different materials used to make and lay these tiles. It's very important that you use the right tools and materials for the project you are working on. An oversight in one area could result in lost man-hours and thousands of dollars.

Tools

You will need some special tools when laying ceramic tile. A primary tool is a notched trowel. It must be notched to the depth recommended by the manufacturer of the adhesive you are using. Some craftsmen prefer to use a trowel with notches on one side and smooth on the other. Different sized trowels are available.

A tile cutter is the most efficient tool for cutting ceramic tile. There are two types used—electric and manual. The manual tile cutter uses a scribe on the cutter that has a tungsten carbide tip. An electric tile cutter uses a diamond-tipped cutting blade and water to keep the blade cool.

Use tile nippers when trimming irregular shapes. Nip off very small pieces of the tile you are cutting. Attempting to take big chunks at one time can crack the tile. Some craftsmen use a 4½-inch grinder with a diamond-tipped blade to cut irregular shapes.

A rubber-surfaced grout float is used to force grout into the joints of the tile.

Types of ceramic tile

We call any clay tile baked in a kiln *ceramic tile*. Ceramic tile is used extensively where sanitation, stain resistance, ease in cleaning, and low maintenance is desired. They are often found in bathrooms, laundry rooms, showers, kitchens, locker rooms, and swimming pools. There are many ways to identify them. Ceramic tile is usually classified according to its exposure rating (i.e., interior or exterior) and location (i.e., walls or floors).

Exposure

Ceramic tile is classified as interior or exterior based on its water absorption rate. If you use ceramic tiles on exterior areas, the tiles must be able to withstand freeze and/or thaw conditions. Thus, they should have an absorption rate of three percent or less. The four tile types are nonvitreous, semivitreous, vitreous, and impervious. Nonvitreous and semivitreous are for interior use and vitreous and impervious are suitable for exterior use.

PEI Ratings

There are not any industry standards for ceramic tile; however, the Porcelain Enamel Institute (PEI) has rated most tiles with an abrasion test Class 1 – 5.

Class 1

No foot traffic. This tile is recommended for interior residential and commercial walls only.

Class 2

Use this tile for light traffic. This tile is recommended for interior residential and commercial walls. It is also recommended for use on bathroom floors for residential areas only.

Class 3

This tile is recommended for light to moderate traffic areas. Its recommended use is for commercial walls and residential floors, walls and countertops.

Class 4

Class 4 tiles are recommended for use in moderate to heavy traffic areas. Its suggested use is for all residential, medium commercial, and light institutional floor and wall areas.

Class 5

This class is recommended for heavy to extra heavy traffic areas. Use this class tile for areas that will be subjected heavy usage.

Tiles

Clay tiles are dried in a kiln. There are many types available, but the types you'll probably use most are glazed tile, quarry tile, and mosaic tile.

Glazed interior tile

This nonvitreous tile is normally 4¼ inches × 4¼ inches or 6 inches × 6 inches square. We often use it on bathroom walls and floors. Manufacturers add aluminum oxide powder to glazed floor tiles to provide a nonslip surface.

Glazed exterior tile

Glazed exterior tile is weatherproof and similar to glazed interior tile in appearance. The main difference is that this tile has an impervious or vitreous body that can withstand freezing. We use it to cover building fronts, swimming pools, and so forth. It's available in the same sizes and shapes as glazed interior tile to include a selection of many colors.

Quarry tile

Quarry tile is unglazed and made of less expensive clay. It's normally in earth tone colors (i.e., orange, red, or brown). Quarry tile is made with extruded clay that is cut to shape with a wire and then fired in a kiln (oven). It is usually ½ to 1 inch thick, underscored on the bottom, and 6 × 6 inches or 12 × 12 inches (fig. 3–13). Laid with their smooth side up, they're ideal for floors in kitchens, entranceways, and so forth, where traffic is heavy. They also resist moisture absorption.

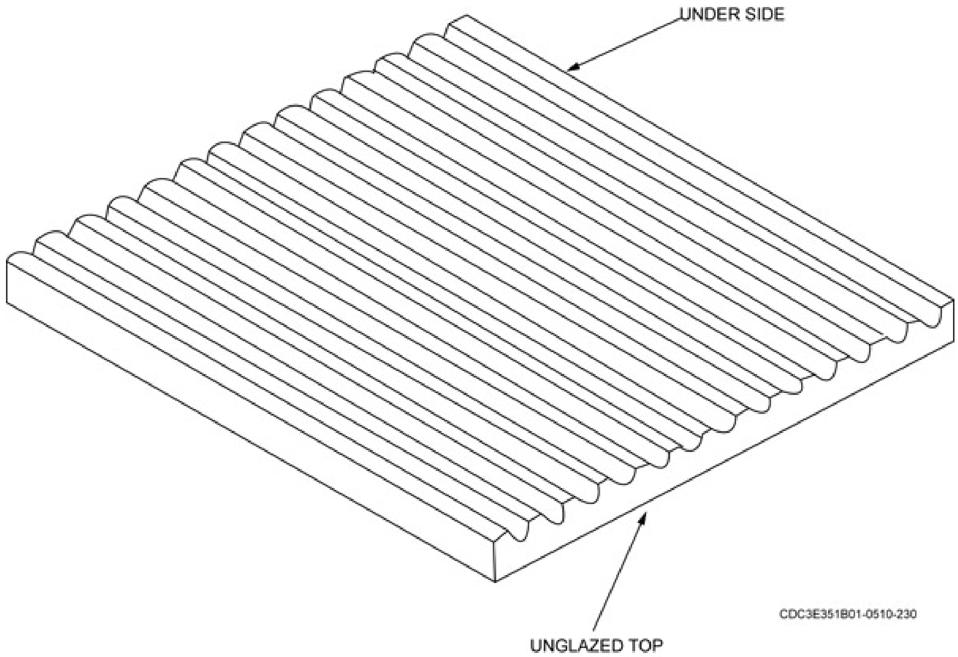


Figure 3–13. Underscored quarry tile.

Ceramic mosaic tile

Ceramic mosaic tile is a vitreous tile that is popular for floors in bathrooms, shower rooms, countertops, tabletops, and so forth. These tiles are small, multicolored squares, rectangles, and other shapes pasted in position on paper sheets to form a pattern. Mosaic tiles are set using the same procedures as ceramic tile.

Tile sizes and shapes

There are many ceramic tile sizes and shapes available. The tile used throughout the main area is called *field* tile; whereas the tile used around the borders or with special shapes or designs is called specialty tile. The most common size field tile used on walls is 4¼-inch × 4¼-inch.

Specialty tile

Specialty tiles made for the first row are called base tile. There are three basic types: 1) cove base, 2) sanitary base, and 3) base angle. Base angle tiles are used in corners and are usually marked "R" for right and "L" for left for use in opposite corners. Several other specialty tile (i.e., bullnose tile) styles give a rounded appearance.

There are many different shapes available for particular purposes. You can purchase tiles (i.e., cap or curb) that fit very easily around a lavatory or kitchen sink; figure 3–14 shows some different tile types. From left to right, they are wall tile, down corner, edging cap, cove base, and cove base corner and edging cap.

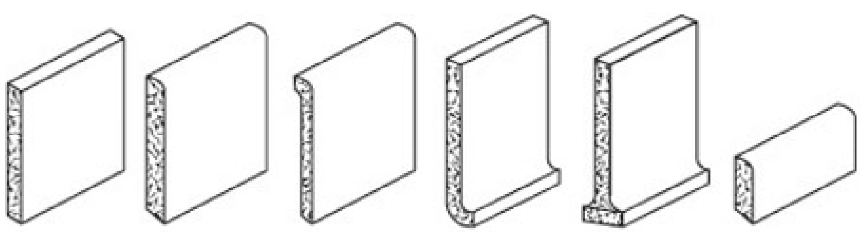


Figure 3–14. Types of tiles.

Mortars and adhesives

Ceramic tile's resistance to traffic depends primarily on base and bonding material rigidity, grout strength, hardness, and the accurate leveling and smoothness of the individual tiles in the installation. The four basic installation methods are cement mortar, which is the only thick bed method, thinset mortar, epoxy mortar, and organic adhesives (mastic).

Cement mortar

This was the traditional method used to install tile. It's also known as thick-bed or mortar-bed installation. Cement mortar used for setting ceramic tiles is made of a Portland cement and sand mixture. The mix proportions for floors vary from a 1:3 to 1:6. For walls, a Portland cement, sand and hydrated lime mix varies from 1:3:1 to 1:5½:1.

To use this method, a ¾- to 1-inch-thick layer of mortar is spread on the walls and a ¾- to 1¼-inch-thick layer is spread on the floors. A neat cement bond coat is applied over it while the cement mortar is fresh and plastic. The tiles are soaked in water for at least 30 minutes and then installed over the neat cement bond coat. This type of installation, with its thick mortar bed, permits wall and floor surfaces to be sloped. A waterproof backing is sometimes required, and the mortar must be damp-cured.

Thinset mortar

Originally termed dry-set mortar, thinset mortar is a thin-bed mortar of premixed Portland cement, sand and admixtures that control the mortar's setting time. When applied with a ⅜-inch-thick notched trowel, the bed is usually no more than $^{3}/_{16}$-inch-thick. You may use it over many bases, such as concrete, block, brick, and unpainted dry cement plaster. While typical thinset mortar is not recommended for use over wood or wood products, there are various types of modified thinset mortars manufactured today that can be applied over wood, linoleum, and vinyl. This method has excellent water and impact resistance and may be used on exteriors. The tiles do not have to be presoaked, but some mortars must be damp-cured. **NOTE:** A sealer coat is often required over gypsum plaster.

Epoxy mortar

Epoxy mortar can be applied in a bed as thin as ⅛ inch. When the epoxy resin and hardener are mixed on the job, they harden into an extremely strong, dense setting bed. This mortar has excellent resistance to the corrosive conditions often encountered in industrial and commercial installations. It may be applied over bases of wood, plywood, concrete, or masonry. This type of mortar is nonshrinking and nonporous.

Organic adhesives

Organic adhesives (i.e., mastics) are applied in a thin layer with a notched trowel. They are solvent-based, rubber material. Porous materials should be primed before mastic is applied to prevent some of the plasticizers and oils from soaking into the backing. Suitable surfaces include wood, concrete, masonry, gypsum wallboard, and plaster.

Grouts

The joints between the tiles must be filled with a grout selected to meet the tile requirements and exposure. Tile grouts may be a Portland cement base, epoxy base, furans, or latex.

Cement grout consists of Portland cement and admixtures. This is better than plain cement in terms of waterproofing, uniform color, whiteness, shrink resistance, and fine texture. It may be colored and used in all areas subject to ordinary use.

Drywall grout has the same characteristics as thinset mortar and is suitable for areas of ordinary use.

Epoxy grout consists of an epoxy resin and hardener. It produces a joint that is stain proof, resistant to chemicals, hard, smooth, impermeable, and easy to clean. It is used extensively in counters that must be kept sanitary for foods and chemicals. It also has the same basic characteristics as epoxy mortars.

Furan resin grout is used in industrial areas requiring high resistance to acids and weak alkalies. Special installation techniques are required with this type of grouting.

Latex grout is used for a more flexible and less permeable finish than cement grout. This grout is made with a latex additive introduced into the Portland cement grout mix.

NOTE: With all of these grouts, be sure to follow the manufacturer's instructions for mixing, applying and curing. You must also be familiar with the material safety data sheets and follow all safety precautions associated with the products use and disposal.

415. Wall tile installation

After you select the correct materials and gather the required tools, you are ready to prepare the wall surface and lay out the tile. In this lesson, we cover some common installation methods used throughout the field.

Preparing the wall's surface

Before you start the tile installation project, remove as many items as needed to provide professional results. Some common items to remove include baseboard, shoe molding, towel bars, shower curtain rods, soap and toilet tissue holders, and switch and outlet plates. If plumbing fixtures such as faucets are in the way, remove the faucet handles and the escutcheon plates from the pipes. Where required wrap pipe threads with masking tape to protect them. To keep any objects from going down drains, place a cloth over the drain in the sink and tub.

Check the walls for loose plaster and paint. If walls have been painted but the paint isn't bonded very well, you'll need to wash the walls with detergent and rinse them thoroughly. Fill all holes and cracks with patching plaster and sand the surface smooth. You should also check the walls to see if they are extremely rough or out of plumb. If the walls are plaster, check if it is badly deteriorated (e.g., cracked or loose). If so, you will have to either remove the old plaster and replaster or cover the walls. You can use ½-inch-thick water resistant gypsum wallboard, commonly called green board, or cement board.

Cement board

Cement board (i.e., backer board) is designed for use in high moisture areas. It resists water penetration and will not deteriorate if it becomes wet. These boards are made from aggregate and Portland cement that is reinforced on both sides with vinyl-coated glass fiber mesh. The usual size is 3 feet × 5 feet × ½ inch thick; however, larger sizes are available. You can also use $^{5}/_{16}$-inch-thick boards as an underlayment for floors and countertops.

In many cases, you'll have to install a water barrier (not a vapor barrier) behind the cement board. If required, the water barrier must be grade D building paper, No. 15 asphalt felt or an equivalent product. To install the backer board follow the three steps below:

1. Measure and precut the cement board by scoring the surface with a utility knife and snapping along the score. You can make irregular cuts with a rod saw, which is a hacksaw handle with a tungsten-carbide blade. For extensive cutting, use a circular saw with a masonry blade. **NOTE:** Be sure to wear personal protective equipment when cutting.
2. Nail or screw it to the studs every eight inches along the seams and throughout the board's center (6 inches on center for ceilings). Place the nails ⅜ to ⅝ inch from the edges using 1½-inch galvanized roofing nails or 1¼-inch galvanized wood screws. Be sure to use steel screws when fastening to a metal framing. The studs cannot be spaced more than 16 inches on center the nail heads should be flush with the surface, *not* countersunk. Countersinking could cause the concrete board to crack.
3. Caulk all joints around pipes and seal all seam joints with an alkali-resistant tape designed for use with the backer board. This ensures added protection from moisture absorption into the base material.

NOTE: The cement board should have a smooth and a rough side. The side facing the tile depends on the bonding method used; smooth side for mastics (e.g., adhesives) and rough side for mortars.

Priming the surface

When the wall you're going to tile is in satisfactory condition, your preparation is fairly simple. Prime the walls with two coats of a good quality wall primer to help the tile "grab" or adhere to the base material and to seal the surface. The only time you have to prime an area is for the adhesive method, *not* for the mortar method (i.e., thin setting). Brush or roll the first coat on vertically or horizontally. When the first coat is dry; brush or roll the second coat on opposite to the previous coat. Make sure all joints, cracks, and corners are sealed. If primer isn't available, use good-quality shellac.

Wall tile layout

Using a layout stick will aid you in laying out the walls. You can make a layout stick from any straight board. Cut the stick to the desired length and mark off the tiles on the stick (leave $^{1}/_{16}$-inch spaces for the grout joints [fig. 3–15]). Your successful tile job depends largely on your ability to keep the tile level and plumb. You'll need to establish a level (horizontal) and plumb (vertical) reference line. We'll begin our discussion with the plumb line.

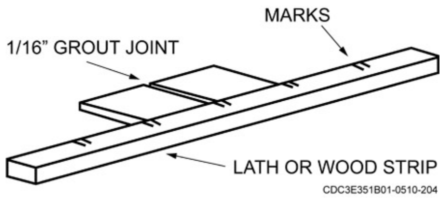


Figure 3–15. Marking a layout stick.

Plumb line

The basic principle behind establishing the plumb line is to layout the wall where the full tiles are in the most visible areas and the cut tiles in the less visible areas. You should treat each wall as a separate layout.

When you want an even width border tile on each side of the wall, such as the back of bathtub, the first step is to find the center of the wall. Mark this point and draw a plumb line on the wall. There are two ways to layout the wall tile—you can place the tile's edge on the centerline (fig. 3–16, view A) or straddle the centerline (fig. 3–16, view B). Choose the method that will give you the largest border tile. In most cases, the border tile should not be less than ½ the width of the tile.

On walls where only one side is visible and the other side is hidden, strike your plumb line so that you are starting with a full tile leaving the cut tiles hidden.

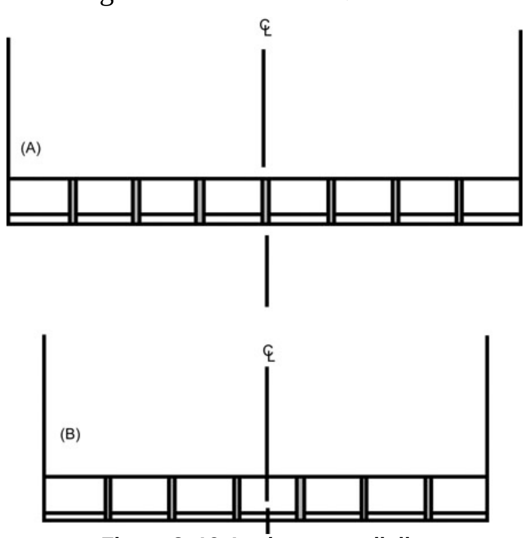


Figure 3–16. Laying out wall tile.

Horizontal line

There are two ways to begin a wall-tiling project. The first way is to use base tile. The second way is to begin with regular field tile. Let's begin with the first method.

Base tile method

With the base tile method, your first step in laying out the wall is to make sure the floor is level using a level and layout stick. To keep rows straight and level, you must make certain that the first row *(cove base row)* is level. To do this, check the floor with the level. Place a mark on each wall at the cove base row height (fig. 3–17). If the floor is uneven, you must repair, fill in, or replace it to get a good tile job. You can use floor-leveling compound to get the floor level. Follow the manufacturer's specifications for the product you have.

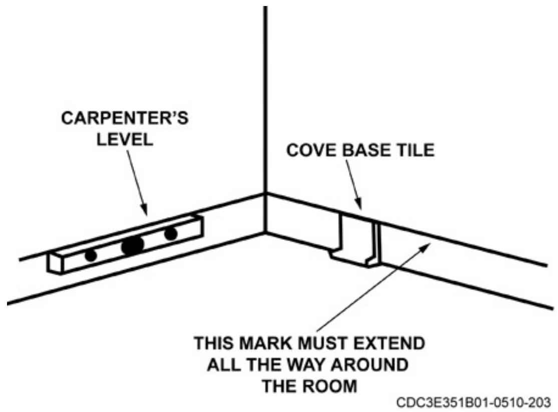


Figure 3–17. Laying out for cove base tile.

Alternative method

If the floor is not level, you cannot use base tile. In this case, you'll begin by finding the *lowest point* on the floor. From this point, draw a horizontal (level) line one full tile height around the entire room. It's a good idea to tack a straightedge to the wall with the top of the straightedge resting on this line. The tiles are then laid to the straightedge. Once you're done, remove the straightedge and cut the tiles for the first (base) row to fit the floor.

Miscellaneous information

Tile the area around the bathtub at least one row higher than the showerhead. Tile the walls around the sink at least two courses higher than the sink. Ordinarily we tile sidewalls to about 50 inches (10 courses plus the edging cap and the cove base).

Cutting and fitting tile

Seldom are walls laid out where the tiles can be set without cutting them. This cutting normally requires a straight cut, which you can get in two ways. If a tile-cutting machine is available, mark the tile with a pencil where you want it cut and place it in the machine (fig. 3–18). After you place it in the machine, score the tile (fig. 3–19).

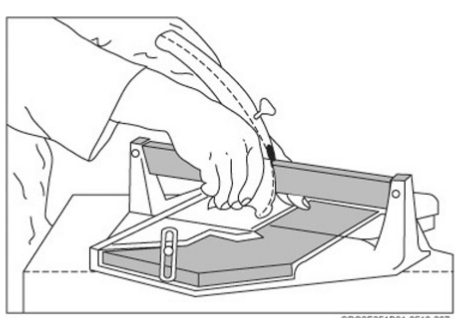


Figure 3–18. Tile placed on the tile cutter.

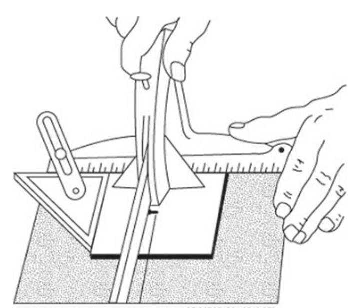


Figure 3–19. Scoring the tile.

After you score the tile, press down on the tile machine's handle (fig. 3–20) to break it. If a tile cutter is not available, you can score the tile with a glasscutter and break it over a close hanger. Other cuts that are usually needed are around pipes or other fixtures and where you join tiles at a corner. An easy and fast way to cut difficult shapes and curves is to use a rod saw. Just drill a hole in the tile with a ½-inch carbide masonry drill bit, slip the blade through the hole, and reattach the blade to the hacksaw frame. When you saw along the pencil line, apply even pressure allowing the saw to do the work. If you force the cut too fast, the tile may break.

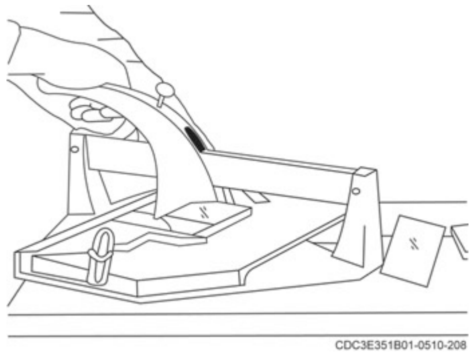


Figure 3–20. Snapping the tile.

You can also use a hole puncher to cut a hole in ceramic tile. A hole puncher is a clamp that holds the tile securely on all four sides. The pressure used to hold the tile keeps the tile from shattering when you use a tile hammer to punch out a hole (fig. 3–21). You can also make holes or notches for pipes or other irregular cuts by marking the area with a pencil and scoring the tile freehand with a glasscutter (fig. 3–22). Use tile nippers to nibble away small tile bites inside the scored lines. *Don't* take large bites or the tile could break in the wrong place. Figure 3–23 shows a cut tile and a pair of tile nippers.

Figure 3–21. Hole puncher.

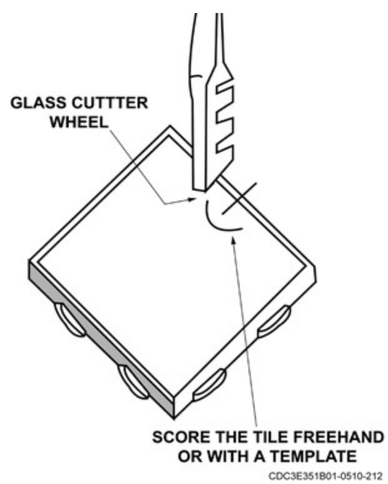


Figure 3–22. Scoring tile with a glasscutter.

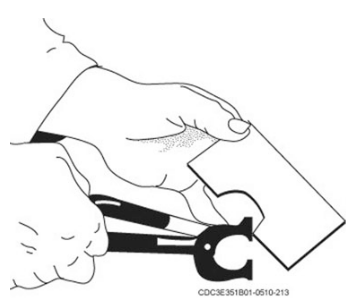


Figure 3–23. Using tile nippers.

When you get close to the scored lines, you can smooth the cut with a Carborundum stone (fig. 3–24) or electric grinding wheel. Always wear goggles or a face shield when you use the grinding wheel, as tile chips easily. Be sure to make the hole about ⅛ inch larger than the pipe on all sides to allow for vibration and for contraction and expansion of the materials. Caulk around the pipe with putty or caulking compound before you install the escutcheon plate.

Mounted fixtures also present challenges. Many times removing them can make your tile work easier and neater. If you cannot remove them, you'll have to cut and fit tile around them.

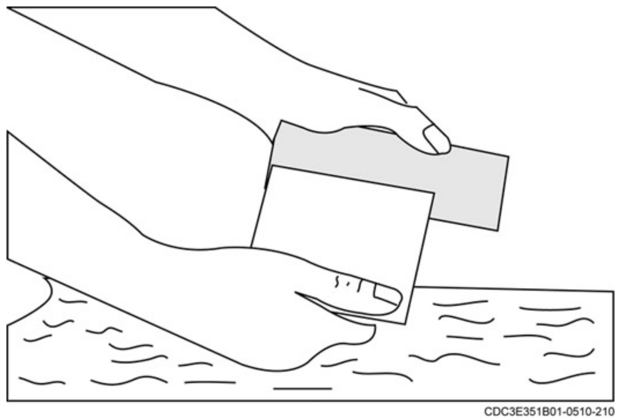


Figure 3–24. Smoothing tile edges with a Carborundum stone.

Fitting tile around obstacles

After you set the cove base row, use the layout stick to locate the first full tile row above a tub. Use the level to draw a line at this height on all tub sides that fit against a wall. Cut the tile to fit between this level line and the bathtub. Leave a ⅛-inch clearance between the tile and the tub for contraction and expansion. *Don't* forget the $^{1}/_{16}$-inch grout joint between the tiles (fig. 3–25). **NOTE:** Some tile layers will cut the row directly above the cove base row, so the first tile row above the tub will be full size. Use whichever method that provides the best finish appearance.

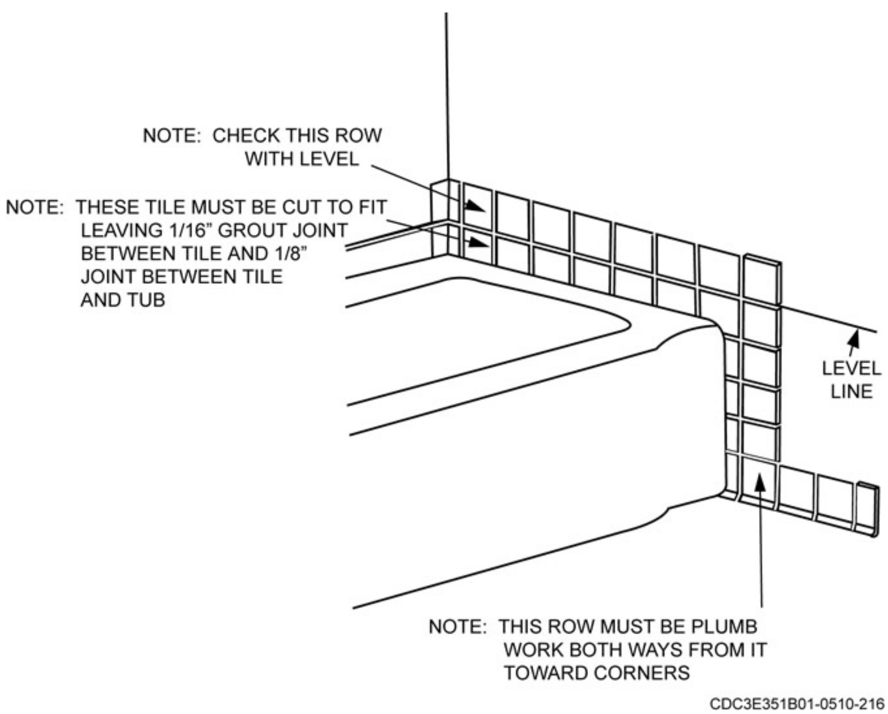


Figure 3–25. Fitting tile around a tub.

Setting tile with adhesive

An easy and fast way to set (i.e., install) wall tile is to use adhesive. Be sure to carefully follow the manufacturer's instructions for the adhesive used.

Preparing the tile

The tiles must be thoroughly dry or the adhesive *won't* adhere to them. If possible, keep the tiles at room temperature for at least 24 hours before installing them to minimize expansion and contraction.

Adhesive methods

There are two ways to install tile with adhesives: buttering and floating. In the buttering method, we apply adhesive at least $^{1}/_{16}$-inch-thick over 60 percent of a tile's backside. This is especially useful for small repair sections, setting trim tile or setting the border tile. In the floating method, you apply the adhesive to the wall and set the tile in the adhesive.

Applying the adhesive

In the adhesive floating method, spread the tile adhesive on the wall with a notched trowel. Be sure to follow the adhesive manufacturer's specifications for the correct size notched trowel to use—usually $^{1}/_{16}$-inch. Hold the trowel at about a 45 degree angle to deposit the adhesive to the proper depth. When you apply adhesive to the wall, *don't* leave any bare spots on the surface. Most tile adhesive will set up in about 30 minutes; so don't apply the tile adhesive to a larger area than you can finish within that time. Adhesives vary, so follow the manufacturer's instructions that are printed on the container.

Pick up the tile one at a time and set them in a horizontal row. Make sure the friction bars (i.e., ridges) on the tile's back are perpendicular to the adhesive lines. Tap the tile lightly with the handle of your trowel as you set it on the wall. This sets the tile firmly enough to keep it in place.

Spacing the tile

Continue setting the wall tile until you have one row that extends the length of the wall that you want covered. After you complete the first row, check the joints to make sure they're all the same width—adjust as needed. Most wall tiles are manufactured with lugs to give you the proper spacing; however, some are not. You can space these tiles with small rubber or wooden tile spacers (fig. 3–26).

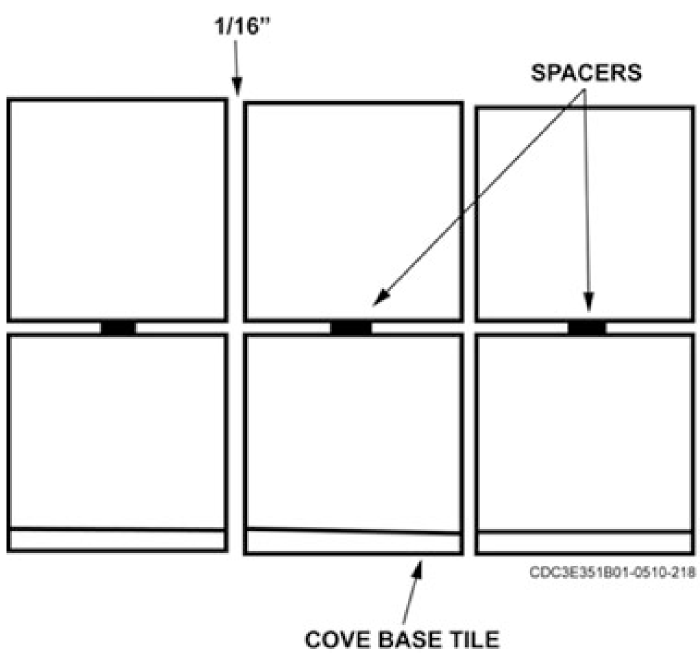


Figure 3–26. Tile spacers.

After you lay one complete row, place a level on top of the tiles to make sure they're level (fig. 3–27). Depending on the length, you may need to level sooner. Just make sure the tile is level before the adhesive sets. If the tiles aren't level, raise them against the level until you get a level reading.

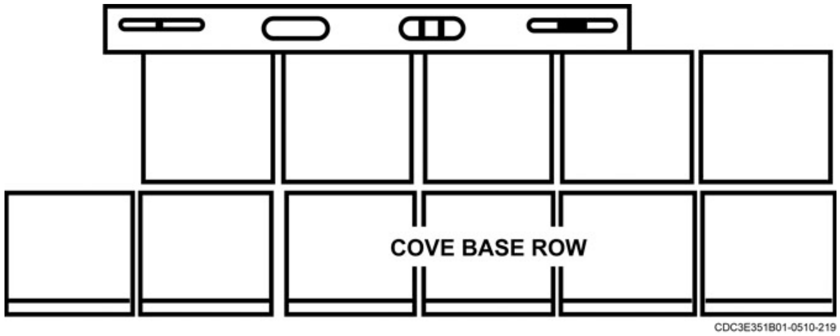


Figure 3–27. Leveling wall tile.

After the first row is level use the same procedure to set a few more rows. Level the rows as you complete them, unless the row is too long to level them before they set. After you have laid all of the rows, butter and set the *bullnose cap* above the top row, then visually align the vertical joints.

Setting tile with cement mortar

It's best to set ceramic wall tile with mortar where strength and heavy exposure to water is expected.

Preparing the surface

Preparing a wall surface to receive tile is almost the same as preparing it to be plastered. Just as in the adhesive method, you can butter the tiles or float them. **NOTE:** Depending on the ceramic wall tile, you may have to wet them with water to keep from extracting moisture from the mortar.

Setting the tile

Spread the thinset on the wall with a notched trowel. Be sure to follow the thinset manufacturer's specifications for the correct size notched trowel to use. Hold the trowel at about a 45 degree angle to deposit the thinset to the proper depth—do not leave any bare spots. Only spread enough mortar that can be covered in the amount of time recommended by the thinset manufacturer.

In the floating process, snap the tile into place to force out the air from behind the tile to get a good bond. In the buttering process, you apply a $^{1}/_{16}$-inch-thick mortar skim coat to the tile's backside. Cover at least 90 percent of a tile's backside with mortar, then set and tap it into place. The suction assures a good bond between the tile and surface. Always use the buttering process to set ceramic wall tile trim.

The cove base tiles are usually set first. Use your trowel handle to tap the tile and spread the mortar evenly behind it. Set the remaining cove base tiles the same way. The layout and alignment are the same as for tile set using the adhesive method. Use either the floating or the buttering process to install the wall tile in level rows on top of the cove base. After you set the tiles, you must beat them before you grout the joints.

Beating the tile

After you set the tiles, *beat* them into place to get a smooth wall surface. Variations in individual thickness and differences in depth to which the tiles have been set make it necessary to bring the whole surface into a uniform, smooth plane. The only tools you need are a hammer and a wooden block. It's easy to crack several tiles when you *beat* them, so take great care. Actually the term "beating" is misleading—*tapping* is a better term. To beat the tile into a smooth surface, hold the block at one end with the flat side against the tile's surface. Then move the block along the wall and beat (e.g., tap) the wood block with your hammer to set the tiles even with one another.

Grouting the tile

Grouting seals the joints between the tiles and gives the surface a finished appearance. Your skill at grouting gives the tile a final finishing touch. To mix grout, pour about 1 inch of water into a clean bucket and add about 2 or 3 handfuls of white Portland cement or a manufactured grout. Add enough grout to make a thick paste. Mix the paste thick because the tiny lumps mix easier when the mix is thick. After the grout is thoroughly mixed, add enough water to give the mix a thin creamy consistency. **NOTE:** Some grout manufacturers recommend that you spray a mist of water along the tile surface to keep from extracting too much moisture from the grout.

Apply the grout to the tile joints with a rubber float. Run the float diagonally to the tile joints until the grout is flush with the tile surface. This keeps the float from catching on the tile corners. If the joints aren't taking the grout properly, add a little more water. Just thin the grout enough that it penetrates into every joint.

Washing the tile

Wash the tile with a clean sponge and water. Wet the sponge in a bucket of water and wash the surplus grout from the tile. After going over the surface a couple of times with the wet sponge, wipe the surface thoroughly with a squeegee or cloth (fig. 3–28). After nearly all the grout is removed from the surface of the tile, finish smoothing off the joints by gently rubbing over them with a damp cloth.

Try to bring all joints to a $^{1}/_{32}$-inch depth below the tile's surface. As the tile joints dry (i.e., cure), work the joints over lightly with a damp cloth or sponge to keep them from drying too fast, which would cause the grout to crack. As long as you rub the joints with a damp cloth or sponge, there will be a thin grout film on the tiles. When the tile joints are properly cured, clean the tiles by rubbing them with a soft dry cloth.

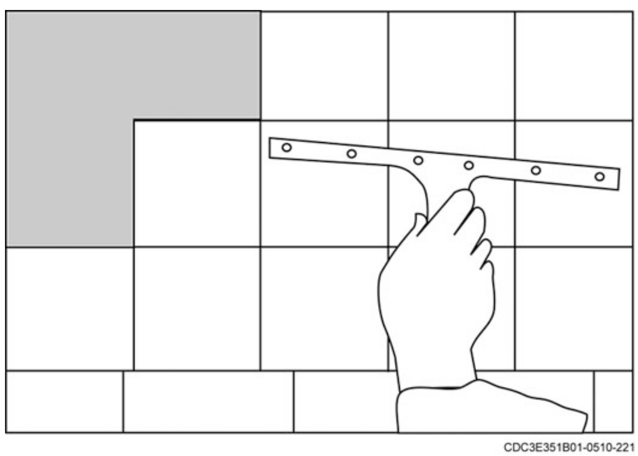


Figure 3–28. Cleaning tile with a squeegee.

Installing fixtures

The tiling job is not finished until you reinstall any fixtures that were taken down, such as towel bars or toilet paper holders. You may have to use either toggle bolts or plastic anchors to secure the items. Regardless the fastener, the first objective is to drill through the tile. You must use a carbide-tipped masonry bit because regular twist drill bits can't cut through the tile.

The following four steps provide a trick that you can use to keep the bit from slipping off the smooth tile surface:

1. Place two strips of masking tape (e.g., overlapped to form an "X") on the tile. This strengthens the tile around the hole and keeps the bit from slipping.
2. Mark the exact centerline location for the hole on the tape. Ensure that the measurement is at the specified height and level. Toilet paper holders are usually installed 20 to 24 inches off the finished floor; however, always refer to the job specifications for the exact placement.

3. Begin drilling through the tape. You will be able to feel the bit grind as it drills through the glazing. Drill completely through the tile and into the drywall or backer board. Be sure to lighten the pressure at the end to ensure a clean hole.
4. Use whichever fastener you have chosen and install the mounting brackets.

Replacing tile

There may come a time when you'll have to replace a broken tile. To do so, you must first remove the grout from between the tiles. You can use a utility knife, hawkbill blade or other suitable tool. Be careful not to hit the edges of the adjacent tiles. Try to remove as much grout as possible to relieve pressure from around the tile—at least the spacer lugs.

Once the grout is removed, make a hole in the center of the tile to be removed. Use a small cold chisel and hammer to chip away small portions of the tile. Be sure to work from the center of the tile out toward the edges. Be very careful not to damage the surrounding tiles.

After the tile is removed, you must remove the setting material—adhesive or mortar. If this isn't removed, the replacement tile will not be flush with those around it.

Depending on the opening, you may have to remove some or all of the spacer lugs on the new tile. There are minor variances in each ceramic tile. You can use a grinder or tile nippers. You can also file them down with course sandpaper.

Install the replacement tile using the buttering method. Follow the procedures previously mentioned to grout around it.

416. Floor tile installation

As with wall tile, the success of your floor tiling project depends largely upon the surface preparation, proper layout, and application. In this lesson, we will discuss common methods for how to prepare floors, doors, and door casings for floor tile. We will also discuss how to layout and complete a top quality floor tile job.

Preparing the floor

When tiling a floor, it's best to have the room as empty as possible. Start by removing the furniture and then any removable fixtures. This gives you room to work and is especially useful during layout. Next, check, repair, and level the floor. When tiling a bathroom, you should remove the commode to save time and to produce a neater job. Remember to leave a ⅛-inch grout joint space for expansion and contraction around items that you must tile around, such as the bathtub. **NOTE:** Lay the floor up to ½ inch of the toilet floor flange (fig. 3–29).

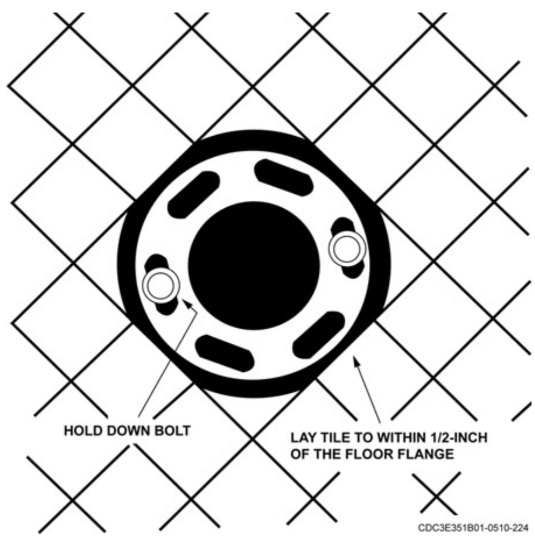


Figure 3–29. Tiling around commode flange.

After you remove the fixtures, check the floor for possible repairs. A primary concern is to have a firm base for the tiles to attach to. Floor tiles without a firm base can work loose and crack. In new construction, concrete is sometimes poured to serve as the firm base. The subfloor is lowered so that the ceramic tile on top of the concrete base is flush with the finished floor (fig. 3–30). Oftentimes you lay tile on concrete, such as this with the plaster (i.e., mortar) method especially in bathroom construction, to prevent water from being a problem.

To install ceramic floor tile over a concrete surface, roughen the surface for a good bond between the tile and the concrete. Fill in any low spots with floor leveling compound. Follow the manufacturer's directions for a satisfactory job.

To repair a wood floor, you may need to cut out the damaged flooring and install new lumber or plywood that matches the existing floor's thickness. Other times you may need to overlay the floor to get a smooth base for your tile. You can use either a wood underlayment or cement board. Keep in mind that your underlayment must be rigid and stable to resist movement.

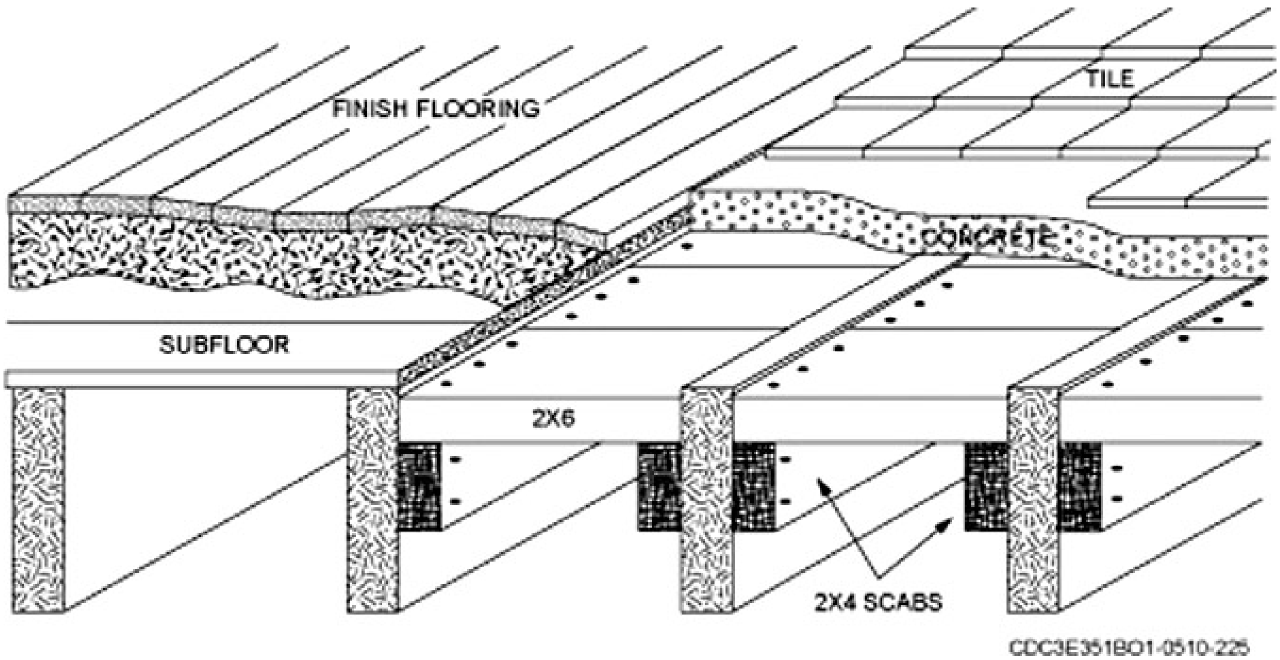


Figure 3–30. Details for a concrete base.

Underlayment

Wood underlayment materials consist of plywood, strandboard, hardboard or particleboard; however, only plywood is acceptable for use with ceramic tile. It is available in ¼- to ¾-inch thicknesses. For ceramic floor tile, the combined thickness of the subfloor and underlayment should be at least 1⅛-inch-thick. Also interior-grade plywood is not considered strong enough for this application.

Install the underlayment with the face grain perpendicular to a board lumber subfloor. If the subfloor is not board lumber, install the underlayment perpendicular to the floor joists. To attain a strong, stiff, squeak-free floor, install more fasteners than used with ordinary subfloors. For ¼-inch plywood, install 1¼-inch ring-shank nails 3 inches on center along the panel edges and 6 inches on center throughout the panel. For ⅜- or ½-plywood, install 1¼-inch ring-shank nails 6 inches on center along the edges and 8 inches through the panel; ⅝- and ¾-inch plywood panels follow the same spacing (6 and 8 inches), except 1½-inch ring-shank nails are used instead. Be sure to stagger the end joints of successive rows. **NOTE:** For expansion and contraction, leave a ½-inch space along the walls and ⅛-inch space between sheets.

Once the underlayment is installed, it's a good idea to give it a prime coat before you apply the tile adhesive (fig. 3–31). Since the overlayment area is higher than other floor areas, you must install a transition between the different floor heights. There are many materials that you can use as a transition; they include bullnose tile, trim tile and marble strips. These transitions are commonly used as doorway thresholds (fig. 3–32).

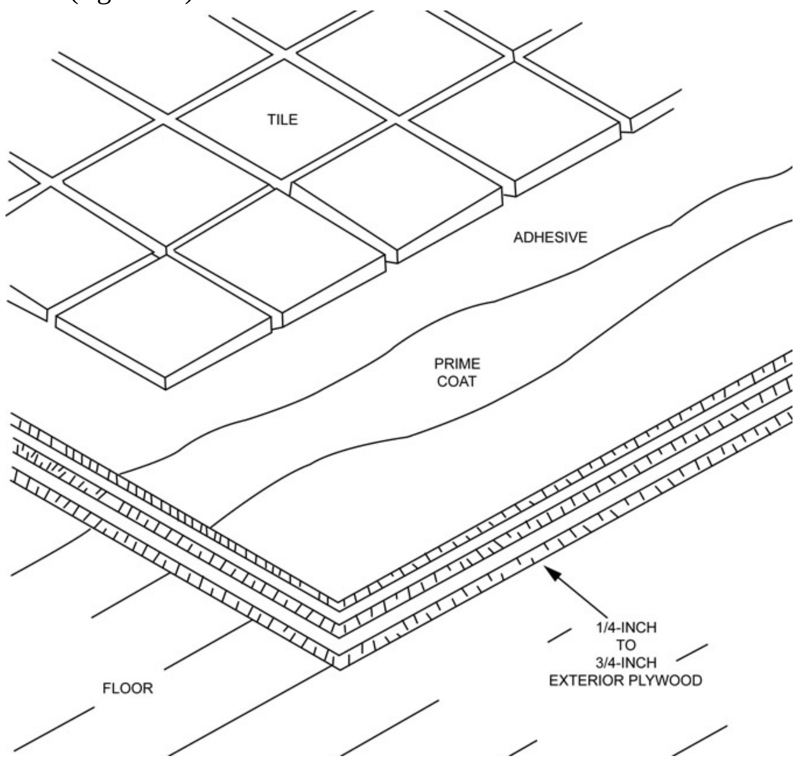


Figure 3–31. Tile laid on plywood.

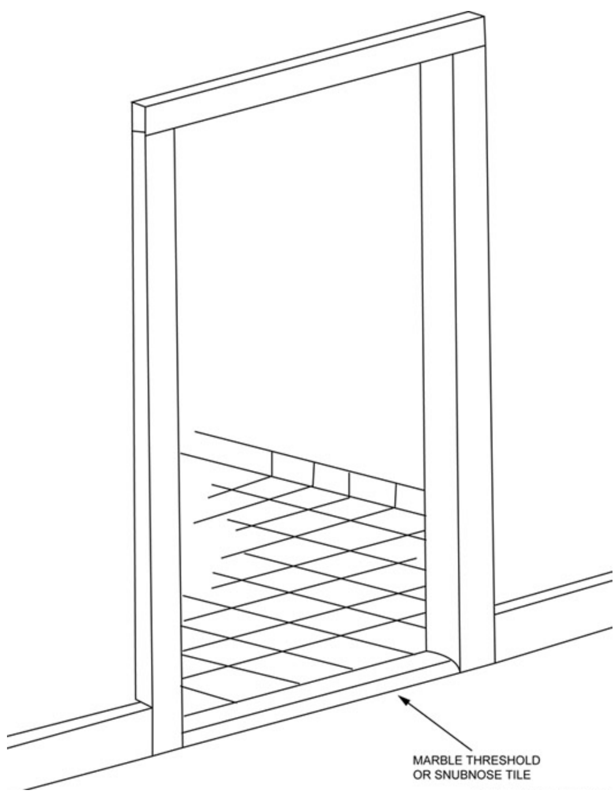


Figure 3–32. Tile transition at a doorway.

Cement board

Cement board is the best choice for ceramic floor tile. It provides a completely stable surface even when wet. You should use it in areas likely to get wet such as bathrooms. Cement board is usually available in $^{5}/_{16}$-inch-thick sheets to reduce the variation between the ceramic tile floor and the surrounding wood or carpet floors.

For new construction, install a ¾-inch exterior grade plywood subfloor. Use a construction adhesive on top of the floor joist for added strength. For renovation projects, make sure the subfloor is firmly attached to the joist.

To install the cement board, laminate (adhere) it to the subfloor with a Type 1 organic adhesive or a latex-fortified mortar suitable for this type of work. Use a ¼-inch square-notched trowel to apply the mortar or a $^{5}/_{32}$-inch V-notched trowel for the mastic. Place the cement board with the joints staggered from the subfloor. Use either 1¼-inch galvanized wood screws or 1½-inch galvanized roofing nails spaced eight inches on center to fasten it to the subfloor. The fasteners must be at least ⅜ to ⅝ inch from the ends and edges. After the board is fastened in place, fill the joints with tile-setting mortar or adhesive and embed fiberglass mesh tape and smooth the joints.

NOTE: The cement board should have a smooth and a rough side. The sides facing the tile depend on the bonding method used—smooth side for mastics (i.e., adhesives) and rough side for mortars.

Preparing doors and door casings

If you change the floor height by adding tile, cut the inside door casing and remove the lower section before you lay the tile. If you're laying tiles directly on the floor, place a tile against the casing (fig. 3–33) and mark it with a pencil. If you're covering the floor with plywood, mark the casing with a tile on top of a scrap plywood piece. When you cut the casing, don't saw through the casing's other side. Mark the door by placing the saddle against it (fig. 3–34). You normally allow at least a ½-inch clearance between the tile and the bottom of the door (interior doors only).

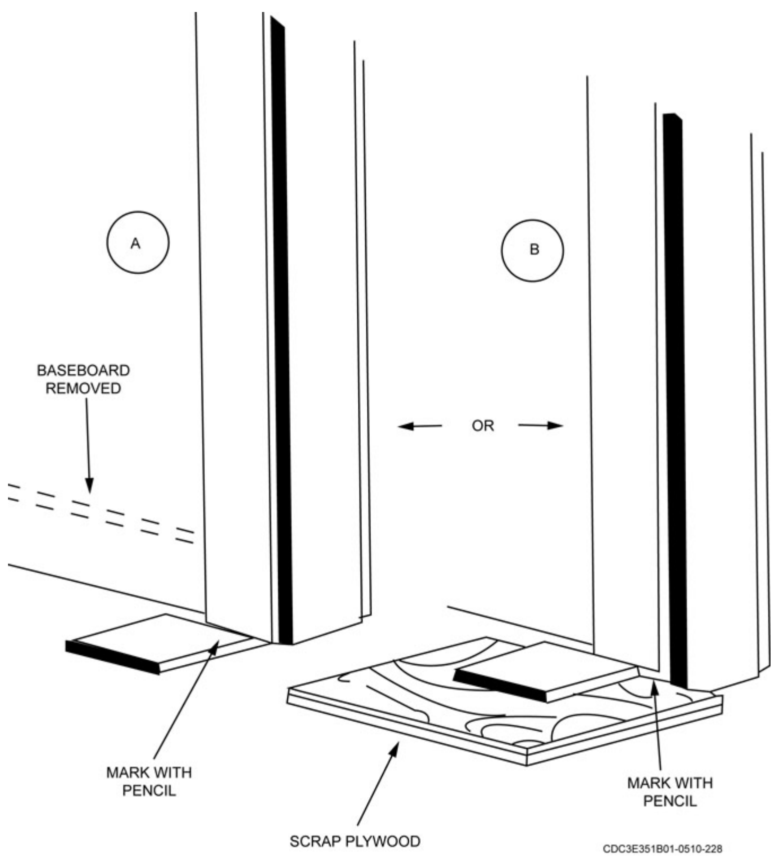


Figure 3–33. Marking a door casing.

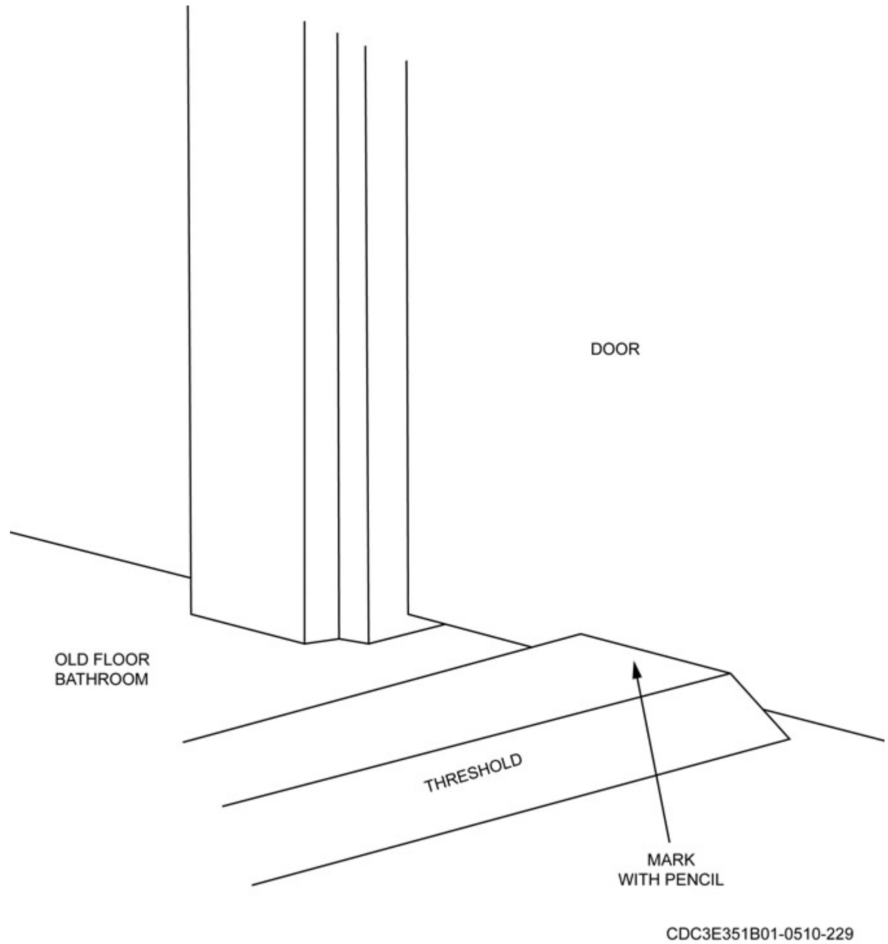


Figure 3–34. Marking the door bottom for clearance.

Mosaic tile layout and installation

Before you start to set floor tile, check the room for square. Lay the tile out in the right pattern before you apply mortar or adhesive to see if any tiles will need to be cut. If the room is not square, try to plan your tile so the angle cuts are not very noticeable, such as in a corner or behind a toilet. When your layout work is done, you're ready to set the tile. Take the time to read the general installation procedures when using a thinset mortar.

1. Mix the thinset mortar per the manufacturer's instructions.
2. Ensure that you have the correct size notch trowel per the manufacturer's specifications for the size tile you are installing. Spread only enough mortar that will allow you to install the tile, remove the paper if applied and realign the tile before the mortar sets—usually 4 – 10 square feet.
3. Install the tile face-side up. Some tiles manufacturers distribute their tiles face-mounted to Kraft paper. If so, install the tiles paper side up.
4. Press each sheet into the mortar and beat (e.g., gently tap) the tile with a hammer and 2 × 4 block to get a smooth, flat surface.
5. Remove the paper if applied after the mosaics start to set but before they are fully bonded. Follow the manufacturer's instructions for paper removal.
6. Finally grout the tile. You'll need to follow the thinset mortar manufacturer's instructions for the specified cure time before you grout. If you grout too soon, the mortar won't cure properly. Remember if the instructions call for 24 hours, they mean 24 hours not sometime the next day.

Quarry tile installation

Setting quarry tile is like setting other ceramic floor tile; the methods discussed here apply to both types. Like other ceramic tiles, you can set quarry tiles using the mortar or adhesive method. The first step is to lay them out.

Layout

The concept behind floor and wall tile layout is similar. If all the walls in the room are equally visible, you'll want equal-sized border tile. If only one end is visible, it may be best to start with a full tile. Next let's discuss the method for equally sized border tiles by going over established reference lines, thinset mortar method, and the adhesive method.

Establish reference lines

Find the center of the most visible wall. Strike a 90-degree line from this mark to the opposite wall. Next find the center of that line and strike another line at 90 degrees to the two remaining walls. Layout the tiles along the lines to check your border tile size. The border tiles should be at least one-half the width of the tile. If they are less than one-half the width of the tile, move your reference line over exactly half the tile's width and strike a new reference line.

NOTE: Some tile layers prefer to layout small grid sections based on the initial set of reference lines. They measure off from the first two lines and layout small sections (2 to 3 square feet) to help them keep the tile straight and square.

Installing the tile

As you've previously learned, you can use either thinset mortar or adhesive to set floor tile.

Thinset mortar method

Before you start to set tile on a concrete surface or cement board, you need to dampen the surface with water to keep the concrete from absorbing water from the mortar. Continue to wet the surface at intervals if the surface tends to dry out. It's also a good idea to soak quarry tile but not other types of ceramic floor tiles.

You usually butter, sometimes called back buttering the tile for small repair sections (fig. 3–35) for setting trim tile or for setting the border tile. In each instance, only a few tiles are involved. To butter, spread the mortar on the back of the tile with a notch trowel. Then turn the tile over, set it on the slab, and tap it lightly with the handle of your trowel or a mallet; this will spread the mortar evenly over the tile's bottom surface. **NOTE:** Use the size notched trowel that the tile and/or thinset mortar manufacturer recommends.

To install the main field tiles, you should float them in. It's usually best to start in the center of the room. Spread the mortar over one section using a notched trowel—be sure not to cover up your reference lines. Lay the first tile where the two reference lines intersect. Set the remaining tiles on the reference lines working out from the first tile. You need to keep an even space between each tile. Normally, we use ½-inch-thick joints between quarry tiles. So set the remaining tile in the first row one-half inch apart using tile (plastic) spacers.

NOTE: Depending on the type or size tile, you may have a smaller space in between the tiles. Use the size that is more appealing. For instance, many people choose to use either a ¼- or ⅜-inch space between 12 × 12-inch floor tile.

Once the first row is in place, you should *beat* (i.e., gently tap) the tiles with a hammer and 2 × 4 to set the tile into the mortar and get an even height across the tiles. After setting the tile, remove any mortar that may have been forced from between the joints. Repeat the process for each row.

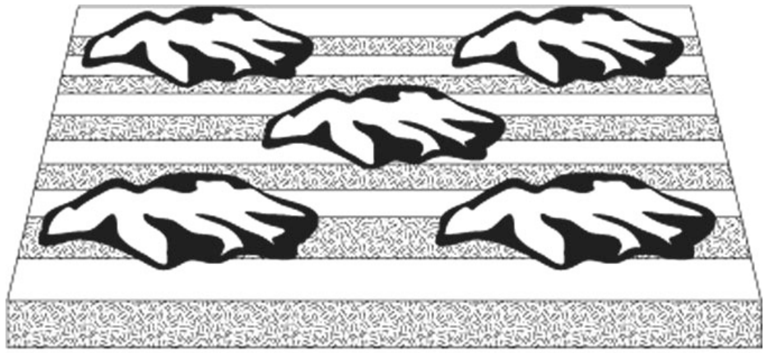


Figure 3–35. Buttered quarry tile.

Adhesive method

You use tile adhesive to set quarry tile on wood. Seal wood floors, such as plywood, before you set the tiles. Apply two primer or shellac coats and let them dry thoroughly before you set the tile. Apply the adhesive with a notched trowel. Follow the layout and installation methods previously mentioned. Remember that excess adhesive on any tile can squeeze up between tiles and cause grouting problems.

Grouting the tile

As with mosaic tile, you need to follow the manufacturer's instructions of the adhesive and/or mortar used for the specified cure time before you grout. If you grout too soon, the mortar won't cure properly. Some thinset mortars require up to 24-hour curing period.

When you grout quarry tile, you can prepare the grout mixture with the same ingredients as the cement mortar you used to set the tile or with white Portland cement grout. You may also add color to your grout for a more appealing color combination. The usual grout mixture for quarry tile is one part Portland cement to 2½ parts sand. Add enough water to get a creamy consistency. Before you grout the tile, remove the tile spacers. Apply the grout with a rubber float moving it diagonally along the tile. This keeps the float from catching the corners of the tile. After you grout a few joints, rub them with a rubber squeegee or float to force the grout into the joints so that they are filled just below the tile surface; continue this until you grout all joints.

Washing quarry tile

After the grout has set, wash the tile with a wet cloth to remove any cement spots. Then rub over the tile with a dry cloth. Allow at least 30 minutes for the grout to set before you wash the tile.

Curing quarry tile joints

To keep the joints from cracking, you can cure them with wet burlap bags placed over the surface for at least 24 hours. When you remove the burlap bags, wash the tile with water once again. If the cement grout discolors the tile, you can restore the true color by applying linseed oil with a cloth.

Tile maintenance

Tile maintenance includes checking for cracks in the tile joints and making sure the tile has not become loose. You may have to regrout and seal the area several times a year. If you need to regrout, take time to clean the area with a suitable cleaning detergent to provide a better bond. **NOTE:** Many tile manufacturers recommend using a mixture of vinegar and water to clean the grout.

The best way to remove old grout from ceramic and mosaic tile is with some type of specialty grout removal tool. After you remove the grout, make sure the grout joints are clean and regrout using the same procedures that we discussed earlier. After the grout sets for 72 hours, you may apply a silicone sealer to the grout lines to reduce water penetration.

To repair quarry tile grout joints, use a ½-inch chisel to clean out all loose grout or a grout removal tool. To allow the new grout to have a durable bond, we recommend that you remove half of the existing grout depth. In some cases, you may have to remove all of the grout. Before you regrout, remove all grout debris and dampen the surface. This ensures a better bond and prevents cracking. You can also use a silicone sealer on quarry tile grout joints.

To replace ceramic, quarry, or mosaic tile on the wall or floor you should follow the next three steps:

1. Use a hammer and cold chisel to break the old tile out. Always start from the center of the tile and work out to keep from breaking adjacent tiles. You can also use a drill with a carbide-tipped bit to make a series of holes to simplify tile removal.
2. Ensure that you remove the original adhesive and/or mortar from the surface. If it is not removed, the new tile may not be flush with the surrounding tiles.
3. Replace the tile, using the same adhesive that you use to install it. You must butter each tile piece that you repair separately.

NOTE: Always remember to observe all safety precautions and use gloves, eye protection, and hearing protection while removing the tiles.

Shower pans

A shower pan (i.e., receptor pan) in the bottom of a shower stall helps it hold water. Fiberglass is the most common material, but acrylic, terrazzo, and enameled-steel models are available. These pans are square or rectangular and about four inches deep with a drain hole in the middle to receive a plumbing flange. Shower pans are secured through a flange to a stud wall. Other pans used today are lead and vinyl. They come in sheets and are easily fitted to accommodate any size shower stall. These pans are installed directly to the floor and stud walls before the mortar or concrete bed is placed.

If there’s a problem with a shower leaking, first check the grouting and caulking material. If it’s defective, you’ll have to regrout and caulk. If the leak persists, the pan may have deteriorated.

Remove shower pan

Before removing the pan, place a rag in the drain so debris will not clog it. Remove the first two rows of wall tile for access. To remove the fiberglass, acrylic, terrazzo, or steel models, remove the screws or nails and pull the unit out. Keep in mind that each unit is different, but the procedures are similar. To remove the lead and vinyl pans, use a hammer and cold chisel to break out the tile and mortar or concrete bed. You can also use an electric jackhammer or rotary hammer to remove the shower pan. Remember to wear protective equipment. **NOTE:** You need to follow local environmental regulations when handling and disposing of lead materials.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

414. Tile tools and materials

1. Which tool is used to force grout into the tile joints?

2. What are the four types of tiles?

3. Which class tile is recommended for use in moderate to heavy traffic areas?

4. What are the four basic tile installation methods?

5. What action is often required when using thinset mortar over gypsum plaster?

415. Wall tile installation

1. What do you do if the plaster wall you are to cover with ceramic wall tile is badly deteriorated?

2. What is the maximum stud spacing when installing cement board?

3. When you want to prime a wall before applying ceramic tile to it, what do you use, how do you apply it, and what can you use as a substitute?

4. How are tiles installed in relation to the showerhead and sink?

5. When you're cutting ceramic tile, what tool do you use and what may you use if that tool is not available?

6. In cutting a hole in ceramic tile, what tools may you use?

7. When pipes protrude through a ceramic wall tile, how much space do you leave around them, why do you leave it, and what do you do to make the seal watertight?

8. Briefly explain the two adhesive methods of applying ceramic tile.

9. At any one time, how much adhesive do you apply for wall tile installation?

10. What purpose do lugs on ceramic wall tile serve?

11. List the procedures for grouting ceramic wall tile.

12. When drilling a hole through ceramic wall tile, how can you strengthen the tile and keep the bit from slipping?

13. What steps are involved to replace wall tile?

416. Floor tile installation

1. Within what distance should you lay tile to the toilet floor flange?

2. For ceramic floor tile, what should be the combined thickness of the subfloor and underlayment?

3. For expansion and contraction, how much space should you leave along the walls and between the plywood underlayment sheets?

4. What is the difference in sides of cement board?

5. If the mosaic tile you are installing is face-mounted to Kraft paper, when should you remove the paper?

6. When establishing reference lines for quarry tile installation, what action should you take if the border tiles are less than one-half the width of the tile?

7. How can you remove cement grout discoloration from quarry tile?

8. When removing a shower pan, what action should you take to keep debris from clogging the drain?

Answers to Self-Test Questions

412

1. (1) d.
   (2) b.
   (3) a.
   (4) g.
   (5) f.
   (6) c.
   (7) e.
2. Gypsum plaster.
3. (1) Sand.
   (2) Vermiculite.
   (3) Perlite.
4. (1) Gypsum board.
   (2) Insulation board.
5. (1) Diamond mesh (expanded metal).
   (2) Expanded rib.
   (3) Wire mesh (woven wire).

413

1. (1) Nail each lath to the studs or joists with 3d blued-lathing nails.
   (2) Nail the laths six in a row, one above the other leaving a ⅜-inch space between each piece.
   (3) Nail the next six rows of lath above the first set but stagger the end joint two stud places (leave a ¼-inch space between the lath ends).
2. Fastened horizontally with staggered end joints. The fasteners should penetrate into the framing members at least ¾ inch. Leave a small gap between boards.
3. The first number in the mix is the cementitious material and the second number is the aggregate.
4. Within ⅛ inch within 10 feet (without waves, cracks or imperfections).
5. (1) ⅜-inch scratch coat.
   (2) ⅜-inch brown coat.
   (3) ⅛-inch finish coat.
6. To ensure a firm, solid bond between old and new plaster.

414

1. Rubber-surfaced grout float.
2. (1) Nonvitreous.
   (2) Semivitreous.
   (3) Vitreous.
   (4) Impervious.
3. Class 4.
4. (1) Cement mortar.
   (2) Thinset mortar.
   (3) Epoxy mortar.
   (4) Organic adhesives.
5. Apply a sealer coat over the plaster.

415

1. You will have to either remove the old plaster and replaster or cover the walls. You can use ½-inch-thick water resistant gypsum wallboard, commonly called *green board* or cement board.
2. 16 inches on center.
3. Use a good-quality wall primer. Apply the first coat with a brush or roller horizontally or vertically; after the first coat is completely dry, apply the second coat using either a brush or roller but in the opposite direction. You may use shellac if a primer is unavailable.
4. Tile the area around the bathtub at least one row higher than the showerhead. Tile the walls around the sink at least two courses higher than the sink.
5. A ceramic-tile-cutting machine. A glasscutter.
6. (1) A hole punch.
   (2) Tile hammer.
   (3) Rod saw or glasscutter.
   (4) Tile nippers and Carborundum stone.
   (5) Electric grinding wheel.
7. Leave about a ⅛-inch space around all pipes to allow for vibration and contraction and expansion. Make the area around the pipes watertight by caulking.
8. (1) Buttering. With the buttering method, you apply the adhesive to the tile's backside.
   (2) Floating. With the floating method, you apply the adhesive to the wall to be tiled and set the tile in it before it sets.
9. No more than you can cover before it sets depending on the manufacturer, usually about one-half hour.
10. To give the proper spacing.
11. (1) With a rubber float, apply the grout in diagonally to the joints until the grout is flush with the tile surface.
    (2) Using clean water, sponge the surplus grout from the tiles and wipe surface thoroughly with a squeegee.
    (3) Gently rub the tile with a damp cloth.
    (4) Keep the joints damp to prevent them from drying too fast and cracking.
    (5) After the joints have cured, wipe the tiles down with a clean, soft dry cloth.
12. Place two strips of masking tape (overlapped to form an "X") on the tile.
13. (1) Remove the grout from between the tiles.
    (2) Make a hole in the center of the tile to be removed.
    (3) Remove the setting material—adhesive or mortar.
    (4) Depending on the opening, you may have to remove some or all of the spacer lugs on the new tile.
    (5) Install the replacement tile using the buttering method.
    (6) Grout around it.

416

1. ½ inch.
2. 1⅛-inch-thick.
3. ½ inch along the walls and ⅛-inch space between the sheets.
4. The side facing the tile depends on the bonding method used—smooth side for mastics (adhesives) and rough side for mortars.
5. Remove the paper after the mosaics start to set, but before they are fully bonded.
6. Move the reference line over exactly half the tile's width and strike a new reference line.
7. By applying linseed oil with a cloth.
8. Place a rag in the drain.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

58. (412) Which tool is used for further straightening after rodding is completed and to level plaster screeds and finish coats?
    a. Hawk.
    b. Darby.
    c. Trowel.
    d. Featheredge.

59. (412) Which material can you add to other less workable plaster materials to *improve* plasticity?
    a. Perlite.
    b. Lime putty.
    c. Gypsum plaster.
    d. Portland cement plaster.

60. (412) Which of the following accessories are used both as finish casings around openings in plaster walls and as screeds around doors and windows?
    a. Metal base.
    b. Drip screeds.
    c. Corner beads.
    d. Casing beads.

61. (413) Which ingredient does the *first* number in the plaster mix ratio represent?
    a. Perlite.
    b. Aggregate.
    c. Vermiculite.
    d. Cementitious material.

62. (413) How many *minutes* is the usual time needed to mix a batch of plaster to the proper consistency using a mixing machine?
    a. 3 to 4.
    b. 6 to 8.
    c. 10 to 12.
    d. 12 to 15.

63. (413) To repair a structural crack in plaster, you cut out and remove the loose material to form which type of shape in the crack?
    a. V-shape or concave.
    b. V-shape only.
    c. Right angle or concave.
    d. Right angle only.

64. (414) When selecting ceramic tiles for *interior* use, which of the following tiles are suitable?
    a. Vitreous and impervious.
    b. Vitreous only.
    c. Nonvitreous and semivitreous.
    d. Nonvitreous only.

65. (414) When selecting ceramic tile, if a *class* 4 tile is suggested for use, its *best* suited for
    a. bathroom floors for residential areas only.
    b. interior residential and commercial walls only.
    c. commercial walls and residential floors, walls and countertops.
    d. all residential, medium commercial and light institutional floor, and wall areas.

66. (415) How do you repair a badly deteriorated plaster wall before you apply ceramic wall tiles?
    a. Cover it with soft fiberboard only.
    b. Remove the old plaster and replaster only.
    c. Remove the old plaster and replaster or cover it with soft fiberboard.
    d. Remove the old plaster and replaster or cover it with water resistant gypsum wallboard or cement board.

67. (415) Before installing ceramic tile, apply a prime coat to the wall when you are using
    a. the epoxy method.
    b. the mortar method.
    c. the adhesive method.
    d. any installation method.

68. (415) When installing ceramic wall tiles around the bathtub, place the tiles at least
    a. one row below the showerhead.
    b. two rows below the showerhead.
    c. one row higher than the showerhead.
    d. two rows higher than the showerhead.

69. (415) When installing ceramic tiles around a bathroom sink, place the tiles at least
    a. even with the sink.
    b. one course higher than the sink.
    c. two courses higher than the sink.
    d. three courses higher than the sink.

70. (415) When laying ceramic tile, how much clearance should you leave between the tile and the tub for contraction and expansion?
    a. ⅛-inch.
    b. ¼ inch.
    c. ½ inch.
    d. Do not leave a space.

71. (415) When drilling through ceramic wall tile to mount wall fixtures, how can you keep the drill bit from slipping off the smooth tile surface?
    a. Center punch the tile or place two strips of masking tape (form an "X") on the tile.
    b. Place two strips of masking tape (form an "X") on the tile only.
    c. Center punch the tile or prick punch with carbide rod.
    d. Prick punch with carbide rod only.

72. (416) When you're installing ceramic floor tile in a bathroom, lay the tile to within how many inches of the toilet floor flange?
    a. ¼ inch.
    b. ½ inch.
    c. ¾ inch.
    d. 1 inch.

73. (416) To attain a strong, stiff, squeak-free floor when you're installing wood underlayment for ceramic tile, how should you install fasteners in comparison to installation of ordinary subfloors?
    a. Less fasteners.
    b. More fasteners.
    c. Longer fasteners.
    d. Thicker fasteners.

74. (416) When planning for mosaic floor tile in a room that is *not* square, you
    a. start laying tile in the center of the room.
    b. square the room before beginning to lay the tile.
    c. lay the tile on the floor as if the floor were square.
    d. plan any unnecessary cuts for areas that are less noticeable.

75. (416) Normally what joint size do you use when laying quarry tile, and how do you maintain the space?
    a. 1 inch; with tile spacers.
    b. ½ inch; with tile spacers.
    c. 1 inch; using tiles manufactured with lugs.
    d. ½ inch; using tiles manufactured with lugs.

76. (416) When using a hammer and cold chisel to break the old tile out for replacement, *always* start from the
    a. lower edge and work up.
    b. upper edge and work down.
    c. center of the tile and work out.
    d. corners and work towards the center.

Student Notes

Glossary

Terms

Additives—Added to concrete to improve certain characteristics. By using the correct additive, you can improve appearance, workability, strength, watertightness, wear resistance, freeze resistance, and also reduce set time.

Aggregate—Materials added to concrete and mortar to add strength. Aggregates include rock, gravel, and sand.

Air-entrained concrete—An additive that causes air bubbles to form in freshly mixed concrete so that it improves workability and increases frost resistance.

Alumina cement—Manufactured from bauxite ore, it has a rapid hardening rate and is high in alumina content. It has two advantages for cold weather operations; rapid hardening rate and considerable chemical heat produced while it is developing its set.

Bond beam—Reinforced block courses that bond and integrate a concrete masonry wall into a stronger unit. They are usually found at the top of walls to stiffen them.

Building paper—Asphalt impregnated paper that serves as a vapor barrier.

Buttering—Putting a contoured mortar layer on a brick or block with a trowel before laying.

Concrete—Artificial stone made from sand and gravel or crushed stone, bonded together with cement and water.

Construction joint—A joint made at a concrete slab's edge when a single pour can't complete the job. It allows the separately poured slabs to be bonded together.

Control joint—A joint made in a concrete slab to reduce cracks during expansion and contraction. They are made by cutting a hardened slab with a concrete saw or jointing the concrete before it sets. The usual depth is 1—4 to 1—3 the thickness of the concrete that has been placed. Also called expansion or contraction joint.

Curing—The process of keeping concrete damp and at favorable temperatures to ensure complete hardening. Its purpose is to prevent water loss or replenish the water lost during the early, relatively rapid hydration stages.

Efflorescence—Salt deposits that are carried to a masonry surface by water. It is seen as a white powder or crystallization on the surface of concrete block walls, caused by the evaporation of water carrying water-soluble salts. Since moisture is necessary to carry these salts to the surface of the masonry, this is evidence of faulty or defective construction, usually in the flashing, gutters, downspouts, copings, or improperly filled mortar joints.

Expansion joint—A bituminous felt strip placed between new and old concrete such as in a diveway. It is designed to allow independent movement during freeze and thaw cycles. It extends completely through the concrete and has no load transfer devices built into them. Also called an isolation joint.

Face—Brick, block, or stones exposed surface.

Ground Fault Interrupter—An electrical outlet that trips (stops electrical flow) when too much current flows in the circuit, such as when the circuit is exposed to water. This function prevents electric shock.

Grout—Sand, cement, and water mixture that is commonly used to fill the joints between ceramic tiles.

Honeycomb—Voids in a concrete mix caused by coarse aggregate particles settling to the bottom and the water rising. The result is a honeycomb shape formed in-between.

Isolation joint—See expansion joint.

Keyway joint—A concave or contoured surface made into freshly poured concrete to make a mechanical bond with additional concrete pours.

Monument—A stationary reference point or permanently located object (can be man made or natural) sometimes called a horizontal control point; they reference a building's construction location with the necessary dimensions and other information to locate building lines with precision.

Mortar—A masonry mixture that contains sand, water, and cementing material that bonds masonry units such as block or brick together.

Parging—Method used to apply mortar onto a masonry wall that is below ground level for waterproofing.

Portland cement—Made from silica, lime, iron, and alumina that has been heated, cooled, and pulverized into a fine powder. It is then mixed with water and aggregates and allowed to harden into a solid mass.

Potable water—Water that has been tested and determined to be safe for human consumption.

Quoin—A brick serving to form an exterior structural angle on a masonry wall.

Retentivity—The power of retaining.

Slump test—A test to measure consistency and workability of freshly mixed concrete. The mix should never be so stiff that excessive labor is required to work it.

Workability—Refers to the ease with which a certain concrete mix can be placed in a particular position.

Abbreviations and Acronyms

CMU concrete masonry unit

GFI ground fault interrupter

MSDS material safety data sheet

WWF welded wire fabric

PEI Porcelain Enamel Institute

psi per square inch

Student Notes

Student Notes

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