Residential masonry construction involves the laying of brick, concrete block, or stone in beds of mortar, the installation of accessory items, and sometimes reinforcement. One of the most important operations is mixing mortar batches that are correctly and consistently proportioned to produce mortar with adequate strength and durability. The functional and financial success of a project, however, are often determined before construction begins—based on proper planning and estimating.

5.1 Planning and Estimating

The design of buildings with masonry foundations, basements, and veneers must take into consideration the size of the units involved. The length and height of walls as well as the location of openings and intersections will greatly affect both the speed and cost of construction as well as the appearance of the finished masonry. The use of a common module in determining dimensions can reduce the amount of field cutting required to fit the masonry units together and to coordinate the integration of masonry elements with the size and dimensions of other systems such as concrete slabs or foundations and wood framing.
5.1.1 Modular Planning

Brick and concrete block walls are typically laid out based on a 4-in. or 8-in. module, respectively. The nominal length of one modular brick plus one mortar joint is 8 in. Three bricks laid one on top of the other with three mortar joints is also equal to 8 in. If the height and length of brick veneer walls are multiples of 4 in. and doors and windows are located and sized on a 4-in. module, only whole and half-length modular brick will be needed and a minimum amount of cutting and fitting will be required. For example, a brick wall should be 6 ft.-8 in. long rather than 6 ft.-6 in. because 6 ft.-8 in. (80 inches) is a multiple of 4 in. A brick sidewalk should be 3 ft.-0 in. wide rather than 2 ft.-6 in. because 36 in. is a multiple of 4 in. Concrete blocks have nominal face dimensions of 8 in. × 16 in., including one head and one bed joint. If the height and length of concrete block walls are multiples of 8 in. and doors and windows are located and sized on an 8-in. module, only whole and half-length blocks will be needed (Figure 5-1). In construction of brick veneer over concrete-block backing walls, modular sizes facilitate the coursing and anchorage as well as the joining and intersecting of the two types of units (Figure 5-2). When the brick and block units work together in both plan and section, it increases the speed with which you can lay up a wall and improves the general quality, workmanship, and appearance of the job. Figure 5-3 lists the heights and lengths for various brick and block courses. Corners and intersections in masonry walls can be critical both structurally and aesthetically, and proper planning can facilitate construction of these elements while maintaining proper coursing (Figure 5-4).

A brick that is laid lengthwise in the wall is called a stretcher (Figure 5-5). Standing upright with the narrow side facing out, it is called a soldier—with the wide side facing out, a sailor. A stretcher unit that is rotated 90° in a wall so that the end is facing out is called a header. If the unit is then stood on its edge, it’s called a rowlock. With modular brick, no matter which way you turn the units, they will work to a 4-in. module. Turning a brick stretcher crosswise in a two-wythe wall to make a header is also easy if the units are modular. The header unit is exactly the same width as a wall built of two rows of brick with a 3/8-in collar joint in between. Two header units
Modular layout of openings in masonry walls. (adapted from NCMA, TEK 14, National Concrete Masonry Association, Herndon, VA).

**Figure 5.1**
or three rowlock units are the same length as one stretcher brick. One soldier course is the same height as three stretcher or header courses. Two rowlock courses are the same height as three stretcher courses or one soldier course, and so on (Figure 5-6). Using alternating stretcher and header units, you can easily create patterns and designs in a wall (Figure 5-7). In contemporary veneer wall construction where the masonry is only 4 in. thick, half-rowlocks and half-headers may be used to create the aesthetic effects of different pattern bonds on the exterior without the unit actually penetrating the full thickness of the wall (Figure 5-8).
<table>
<thead>
<tr>
<th>Number of brick and mortar bed joint courses</th>
<th>Number of concrete block and bed joint courses</th>
<th>Wall height</th>
<th>Number of brick and head joint courses</th>
<th>Number of concrete block and head joint courses</th>
<th>Wall length</th>
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</thead>
<tbody>
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<td>2' 11/16&quot;</td>
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<td>1</td>
<td>0'-8&quot;</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5 5/16&quot;</td>
<td>2</td>
<td>1</td>
<td>1'-4&quot;</td>
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<tr>
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<td>1</td>
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<td>72</td>
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Modular brick and block coursing.
5.1.2 Estimating Materials

Estimate the number of bricks needed by multiplying the number of units in the wall length times the number of courses in the wall height, or figure 7 modular bricks for every square foot of wall area. For brick paving, estimate 4-1/2 modular bricks for every square foot when the units are laid flat on their broadest face and will be set with mortar joints, 5-1/2 units per square foot if laid tightly abutted without mortar joints. Estimate the number of concrete blocks needed by multiplying the number of units in the wall length times the number of courses in the wall height, or figure 1-1/4 units per square foot of wall area.

Stone is sold by the ton or by the cubic yard at quarries and stone suppliers. Cut stone will naturally be more expensive than rubble stone. To estimate how much stone will be needed, multiply the length \( \times \) the height \( \times \) the width of the wall in feet to get cubic feet, then divide by 27 to get cubic yards. To translate from cubic feet to tons, figure limestone and sandstone at about 140 lbs./cu. ft. and granite at 160 lbs./cu. ft. A stone supplier should be able to provide accurate conversions for each type of stone they sell. If the stone is sold by the ton, estimate 45–50 square feet of wall area from each ton for most types of stone. For cut ashlar stone, add about 10% extra for breakage and waste, and for rubble stone, add at least 25% extra. For flagstone to build a patio or walk, figure the square footage by multiplying length \( \times \) width. The stone supplier will be able to estimate the amount of stone based on this figure and the type of stone selected.

Mortar should be estimated by the cubic yard for large projects. The amount of mortar required will depend on the type of masonry unit or stone. Figure 5-9 shows the approximate cubic yardage of mortar.
required for different types of masonry. Various mix proportions for both portland cement and lime mortars and for masonry cement mortars are included in Chapter 4, but for residential work, a Type N mortar is the most appropriate. The typical mix proportions for a portland cement and lime mortar are 1:1:6 (1 part portland cement : 1 part hydrated mason’s lime : 6 parts masonry sand). To make one cubic yard of a Type N portland cement and lime mortar will require 4-1/2 sacks of cement, 4-1/2 sacks of lime, and 1-1/2 tons of sand. The typical mix proportions for a masonry cement mortar are 1:3 (1 part masonry cement : 3 parts sand). To make one cubic yard of Type N masonry cement mortar will require 9 sacks of Type N masonry cement and 1-1/2 tons of sand.

5.2 Construction Preparation

Before beginning construction, materials must be properly stored and protected from the weather and supporting elements inspected for completion and accuracy.

5.2.1 Material Delivery, Storage, and Handling

The methods used to store and handle materials affect both the performance and appearance of the finished masonry. Weather should not
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FIGURE 5-6

Modular versatility and brick orientation.
affect properly stored and protected materials, but improper procedures can result in physical damage to units and accessories, or contamination of mortar ingredients. As a general rule, materials should always be stored high and dry and protected from weather.

The color, texture, and size of units delivered to the job site should be verified before the shipment is accepted. Masonry units should be delivered and stored on wooden pallets to prevent moisture absorption from the soil, and covered with water-repellent tarps or plastic

**Figure 5-7**

Masonry bonding patterns. (from Technical Note 30, Brick Industry Association, Reston, VA).
Masonry units that are kept dry but subjected to freezing temperatures while stored may be used in construction without damage to the units or to the masonry. Masonry units that have absorbed moisture from rain or snow and are then frozen, however, must be thawed before they can be used, so it is always easiest to keep the units covered and dry. Aggregates should be protected against contamination from rain, ice, and snow and from blowing dust and soil during construction so that they do not contribute to staining or reduced mortar bond strength. Different aggregates should be stored in separate stockpiles and all aggregate stockpiles covered with a waterproof tarp or plastic covering when not

![Diagram of masonry construction](image)
in use. This will prevent evaporation of moisture from sand aggregates as well as excessive wetting, both of which affect how much mixing water will be needed in the mortar. Packaged mortar ingredients such as cement, lime, admixtures, and pigments should be stored on pallets and covered with waterproof tarps or plastic covers to prevent moisture intrusion and damage.

5.2.2 Inspecting Surfaces to Receive Masonry

Concrete supporting elements should be inspected before starting the masonry work to assure correct layout and dimensions. Footings should be cleaned to remove laitance, loose aggregate, dirt, and other substances which would prevent mortar from bonding to the concrete. In veneer walls, the masonry is laid on flashing rather than directly on the concrete, but the concrete surface should be relatively smooth and clean to avoid puncturing the flashing.

5.2.3 Layout and Coursing

The laying up of unit masonry walls is a very ordered and controlled process. Units must remain in both vertical and horizontal alignment throughout the height and length of a wall in order to maintain structural stability and for the coursing to work out with opening locations, slab connections, anchorage to other structural elements, and so on.

<table>
<thead>
<tr>
<th>Type of masonry</th>
<th>Mortar quantity, cu. yds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-⅞&quot; × 2-¾&quot; × 7-⅜&quot; modular brick with ⅝&quot; mortar joints</td>
<td>0.515 per 1000 brick</td>
</tr>
<tr>
<td>Nominal 8&quot; × 8&quot; × 16&quot; concrete block with ⅝&quot; mortar joints</td>
<td>1.146 per 1000 block</td>
</tr>
<tr>
<td>4&quot; × 1-½&quot; × 8&quot; paving brick ⅛&quot; mortar joints 1&quot; thick mortar setting bed</td>
<td>0.268 per 1000 pavers 0.820 per 1000 pavers</td>
</tr>
<tr>
<td>Cut stone</td>
<td>0.04 to 0.10 per cu.yds. of stone</td>
</tr>
<tr>
<td>Fieldstone</td>
<td>0.15 to 0.40 per cu.yds. of stone</td>
</tr>
</tbody>
</table>

Estimating required mortar quantities. *(Adapted from Kolkoski, Masonry Estimating.)*
Laying out the first course is critical, since mistakes at this point would be difficult, if not impossible, to correct later. The first course must also provide a level and stable base on which the remainder of the walls can rest. It is important to coordinate the dimensions of concrete slabs and footings so that the masonry lays out properly with full and half-size units.

Before beginning work, the horizontal coursing can be checked by laying out a dry course of masonry units without mortar. Chalk lines are used to establish location and alignment of masonry on a concrete footing. A concrete slab will typically have a dropped brick ledge along its outer perimeter so that the bottom of the brick veneer is slightly lower than the finished floor height. A dry course layout should start from the wall ends or corners and work from both ends toward the middle. A piece of \( \frac{3}{8} \)-
in. plywood or the tip of a finger can be used to evenly space between units. If necessary, the size of the head joints between units can be adjusted to take up slight variations in brick size, footing length, or brick ledge dimensions. Each concrete block and head joint should measure 16 in., each modular brick and head joint should measure 8 in., and every three bricks with head joints should be 24 in. The size of “antiqued” Type FBA brick will vary more than those of smoother FBS brick, so the head joint width will also have to vary more to maintain the modular dimensions of a wall. The wall length should lay out using only whole and half-length units. Half-size brick units should be cut where needed for openings, wall ends, and corners. After the head joints are adjusted for even coursing, a few joint locations or opening locations or other critical dimensions can be marked along the chalk line on a footing or on the face of a brick ledge so that they can be used to check the spacing of the first course when the units are later laid in mortar.

5.2.4 Masonry Units

When brick is manufactured, it is fired in a high-temperature kiln which drives virtually all of the moisture out of the wet clay. Fired bricks are extremely dry until they absorb enough moisture from the air to achieve a state of moisture equilibrium with their surroundings. Brick that is very dry when it is laid causes rapid and excessive loss of mixing water from the mortar, which results in poor adhesion, incomplete bond, and water-permeable joints of low strength. Brick that is very dry and absorptive is said to have a high initial rate of absorption.
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To test a brick for excessive absorption, draw a circle the size of a quarter on the bed surface using a crayon or wax pencil. With a medicine dropper, place twelve drops of water inside the circle and time how long it takes to be absorbed (Figure 5-11). If the water is completely absorbed in less than one minute, the brick is too dry.

5.2.5 Reinforcement, Connectors, and Accessories

Reinforcement and accessories should be checked for correct size and configuration and for adequate quantities to complete the work. Before placing reinforcing steel or metal accessories in the wall, oil, dirt, ice, and other contaminants should be removed so that a good bond can be achieved with the mortar or grout.

5.3 Mixing Mortar

Mortar is the cementitious material that bonds units, connectors, and reinforcement together for strength and weather resistance. Although it contributes to the compressive strength of the masonry, mortar’s primary functions are in providing bond strength and in sealing the joints between units against the passage of air and water. To perform these
functions, it must be properly mixed and placed to achieve intimate contact with the unit surface and form both a mechanical and chemical interlock.

Mortar mixes must be carefully controlled at the job site to maintain consistency in performance and appearance. Consistent measurement of mortar ingredients should ensure uniformity of proportions, yields, strengths, workability, and mortar color from batch to batch. Volume rather than weight proportioning is most often used because it is simpler. Ingredient proportions for the various types of conventional mixes are shown in Figures 5-12 and 5-13. Portland cement, mason’s lime, and masonry cement are packaged and labeled only by weight. Each bag of portland cement or masonry cement equals one cu. ft. regardless of its labeled weight, and each bag of hydrated mason’s lime equals 1-1/4 cu. ft. regardless of its weight. Cement and lime are generally charged into the mixer in whole or half bags, depending on the mixer size and the batch size needed.

Volume measurements of sand are often miscalculated because of variations in the moisture content of the sand. Common practice is to use a shovel as the standard measuring tool for sand, but moisture in the sand causes a bulking effect. Wet sand occupies more volume than the same weight of dry sand. This often causes over- or undersanding of the mix, which affects both the strength and bonding characteristics of the mortar. Oversanded mortar is harsh and unworkable, provides a weak bond with the masonry units, and performs poorly in freeze-thaw conditions. The simplest method of consistently measuring and batching sand by volume is by

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<th>Mortar Type</th>
<th>Portland Cement</th>
<th>Lime</th>
<th>Sand</th>
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<td>1/4</td>
<td>3-1/2</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
<td>1/2</td>
<td>4-1/2</td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>O</td>
<td>1</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>3</td>
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</tr>
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</table>

**FIGURE 5-12**

*Proportions for portland cement and lime mortars. (from ASTM C270 Standard Specification for Mortar for Unit Masonry, American Society for Testing and Materials, West Conshohocken, PA).*

<table>
<thead>
<tr>
<th>Mortar Type</th>
<th>Masonry Cement</th>
<th>Mortar Cement</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>S N Sand</td>
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</tbody>
</table>

**FIGURE 5-13**

using a one-cubic-foot measuring box made of plywood or lumber. The person at the mixer can then determine the exact number of shovels of sand which equal one cubic foot. Since the moisture content of the sand will vary constantly because of temperature, humidity, and evaporation, it is good practice to check the volume measurement at least twice a day and make adjustments as necessary to the number of shovels of sand being used. Some mechanical mortar mixers are equipped with a measuring box which is convenient to use because it is hinged to dump directly into the mixer.

Bond strength is an important physical property of masonry mortar, which depends on many things, including workability and water content. Unlike concrete, which is mixed with as little water as possible to produce acceptable workability, masonry mortar requires the maximum amount of water consistent with good workability. Mortar requires more mixing water than concrete because excess water is rapidly absorbed by the masonry units, immediately reducing the water-cement ratio to normal levels and providing a moist environment for curing. Unlike concrete, masonry mortar is never specified by water-cement ratio or slump limits. Optimum water content is best determined by the mason’s feel of the mortar on the trowel. Dry mixes do not spread easily, produce poor bond, and may suffer incomplete cement hydration. Mixes that are too wet are also difficult to trowel and allow units to settle after placement. A mortar with good workability is mixed with the proper amount of water. Mortar with good workability should spread easily, cling to vertical unit surfaces, extrude easily from joints without dropping or smearing, and permit easy positioning of the unit to line, level and plumb. Thus, water content is essentially self-regulating—what is good for the mason on the scaffold is also good for the mortar itself. Quality control, therefore, should concentrate not on water content, but on assuring batch-to-batch consistency in the proportioning of cementitious ingredients and aggregate. Water should be added to the mortar mix by a consistent measure of known volume such as a plastic bucket. With a water hose, it is easy to get too much water. The water proportion will vary for different conditions of temperature, humidity, unit moisture content, unit weight, and so on. The necessary water content for grout is significantly higher than that for mortar because grout must flow readily into unit cores and cavities and around reinforcement and acces-
sories. Grout consistency at the time of placement should produce a slump of 8 to 11 in. (Figure 5-14).

The amount of moisture in the sand will influence how much water is needed in a mortar mix to get the right consistency. Sand bought in bags for small projects will usually be very dry. Sand bought in bulk by the ton for larger projects will probably be damp or wet. Keeping sand piles covered with water-repellent tarps or plastic covers assures that the moisture content will not change drastically because of rain or evaporation.

To avoid excessive drying and stiffening, mortar batches should be sized according to the rate of use. With a big crew, large mortar batches will be used quickly, but with a small crew, large batches may dry out too much before they can be used. Loss of water by absorption and evaporation can be minimized on hot days by wetting the mortar boards and covering the mix in the mortar box. Within the first $1-1/2$ to $2-1/2$ hours of initial mixing, the mason may add water to replace evaporated moisture. This is called *retempering* and is accomplished by adding a little water to the mortar and thoroughly remixing. Mortars containing added color pigment should not be retempered because the increased water will lighten the color and cause variation from batch to batch.

*QUICK TIP* Masonry mortar should be the consistency of soft mud. To check for proper consistency, make a series of sharp ridges in the mortar with a hoe or trowel. If the ridges appear dry and crumbly, more water is needed. If the ridges stay sharp without slumping, the mortar is the right consistency. If you get too much water, add proportional amounts of each dry ingredient to bring it back to the proper consistency.

![Masonry grout slump compared to typical concrete slump. (from Beall, Christine, Masonry Design and Detailing, 4th edition, McGraw-Hill, New York).](image)
There are two traditional methods of mixing mortar on the job site. For small projects, *hand mixing* is most economical, using a mason’s hoe and a mortar box or wheelbarrow. First, all of the dry ingredients are measured and mixed thoroughly with the hoe. Putting in half the sand first, then the cement and lime, and then the rest of the sand, makes blending a little quicker and easier. The materials are alternately pulled and pushed back and forth until the color is even. The mix is next pushed to one end of the mortar box or wheelbarrow, or a hole is made in the middle, and one or two gallons of water added to start. With a chopping motion of the hoe, the dry ingredients are mixed into the water, and the mix alternately pushed and pulled back and forth and more water added if necessary until the consistency and workability are judged to be satisfactory.

For larger projects, *machine mixing* is used to combine mortar ingredients. The mechanical drum or paddle-blade mixers used are similar to but of lighter duty than concrete mixers because they are not required to handle large-size aggregate. Capacities range from 4 to 7 cu. ft. About three-fourths of the mixing water, half the sand, and all of the cementitious ingredients are added first and briefly mixed together. The balance of the sand is then added, together with the remaining water. After all the materials and water have been combined, grout should be mixed a minimum of five minutes, and mortar a minimum of three and a maximum of five minutes. Less mixing time may cause nonuniformity, poor workability, low water retention, and lower-than-optimum air content. Overmixing causes segregation of materials and entrapment of excessive air, which may reduce bond strength. Pigments and admixtures are charged into the mixer last.

### 5.4 Unit Masonry Construction

Unit masonry construction consists of the placement of brick or block and mortar and the installation of accessory items such as anchors, ties, reinforcement, flashing, and weeps. The mechanics of brick and block laying are not difficult to learn, but skill and speed will improve only with time and practice. Increasing skill with trowel and mortar makes the work go faster and more efficiently and increases daily production rates. A skilled mason can lay an average of 530 modular brick or 125 heavyweight concrete block or 160 lightweight block in a day.
5.4.1 Unit and Mortar Placement

One of the most important elements of masonry construction is keeping the wall straight, level, and plumb and accurately maintaining the horizontal and vertical coursing. The initial layout of a wall discussed above included a dry run of units to establish horizontal coursing and adjust head joint spacing as necessary. Vertical coursing can be established by building leading sections or *leads* at the ends or corners of walls (Figure 5-16). Vertical coursing must be carefully measured for the leads to establish the correct bed joint thickness and height of each course for the whole wall. A *story pole* measured and marked ahead of time with the height of each course and the thickness of each mortar bed joint can be used to accurately and consistently maintain vertical coursing in the leads. A simple story pole can be made by marking the coursing heights on a straight piece of lumber that is long enough to mark the coursing for the full height of the wall.

The first course of a lead should be at least four or five units long and carefully aligned so the wall will be straight and not bowed or curved. Corners must be laid at true right angles of exactly 90 degrees. The second and successive courses of the lead are *racked back* one-half unit length in each course to establish a typical running bond pattern in which one unit overlaps the unit in the course below by half its length. A four-foot-long mason’s level or straight 2 × 4 laid carefully along the “rack” of the lead should touch the corner of each brick or block (Figure 5-18). Leads are usually built four or five courses higher than the center of the wall, and as each course of the lead is laid, it should be carefully

![Image of tools]

A mason’s tools include a steel framing square, 48-in. mason’s level, folding rule, chalk line, line blocks or line pins, story pole, and string for layout; a bricklayer’s hammer and brickset for breaking brick; a saw with a masonry blade for cutting block; a hawk or mortar board for holding small quantities of mortar; a trowel and jointing tools for placing mortar and finishing joints; and brushes to clean the surface of a wall (Figure 5-15). Jointing tools include rounded or convex jointers to produce concave joints, V-jointers, raking tools, and others.

![Quick Tip]

A story pole for modular brick can be made by first marking a long 2 × 4 in 8-in. increments, then laying three bricks on edge, spacing 3/8 in. between them to allow for the mortar joints. Three modular brick and three mortar joints equals 8 in., so these three units can be used to mark the individual courses between each of the 8-in. increments (Figure 5-17). For concrete block, each 8-in. increment represents the height of one course of 7-5/8-in. modular units with one 3/8-in. bed joint.
MASON'S CHISEL
OR BRICKSET

JOINTER

TROWELS

LINE BLOCKS

LINE PIN

LEVEL

MASON'S TWINE

STORY POLE

POWER MORTAR MIXER

MORTAR HOE

BRUSHES

MORTAR BOX

FIGURE 5-15

Masonry tools.
checked to assure that it is level in both directions and plumb. A mason’s level is used as a straightedge to check horizontal alignment. Units are brought to level and made plumb by light tapping with the trowel handle. This tapping, plus the weight of the unit and those above, helps form a good bond at the bed joint. Once the units have been laid, however, they cannot be adjusted or realigned by tapping without breaking the mortar bond. If it is necessary to reposition a unit, all the mortar must be removed and replaced with fresh.

For filling in the wall between leads, a string line is stretched from end to end and the top outside edge of each unit can then simply be aligned with the string. Nylon string is wrapped securely around two wooden line blocks. One line block is hooked on the corner of one lead so that the string is level with the top of the unit in the course being laid (Figure 5-19). The string is then stretched to the opposite corner lead and the other line block is hooked at the same height. The line blocks are held in place by the tension of the string. Steel line pins can also be used to run the string line. They are driven into the head joints of the leads and the string is wrapped around and pulled tightly. The
line blocks should hold the string slightly away from the face of the wall so that the following units will not touch it or push it out of alignment. The masonry in between the leads can now be laid to the line to keep the wall straight and the brick course level. The string line should always be pulled tight enough to prevent sagging and should occasionally be checked with a line level. A mason’s level is used to make sure the face of the wall is plumb. The line blocks and string are moved up the corners of the leads as each course of the wall is filled in, and the leads are continually built up several courses above the middle of the wall.

Commercial story poles are made of steel with adjustable coursing scales attached and are designed to eliminate the need for build-
ing leads. The poles attach to the structure at the corners or ends of the wall, and the string line is pulled from pole to pole. The poles must be rigid enough not to bend when the string is pulled taut from one side, and they must be easily plumbed and maintained for the height of the wall.

Brick masonry must be laid with full head and bed joints to assure adequate strength and resistance to moisture penetration. Bed joints should not be furrowed, but slightly beveled away from the cavity to minimize mortar droppings in the cavity (Figure 5-20). Bed joint mortar should be spread only a few feet at a time so that the mortar will not dry out too much before the next course of units is placed. The ends of the bricks should be fully buttered with mortar so that when they are shoved into place, mortar is squeezed from the joint (Figure 5-21). So-called clip joints in which only a thin section of mortar is placed at the face of the joint will allow excessive moisture to penetrate the masonry. Even though the joints look full and solid after the wall is completed and much less mortar is required to complete the work, callbacks from unhappy homeowners and the liability for water damage and cracking make this a risky practice.

A masonry line block holds the string in place so units can be laid to the line.
Since concrete blocks are hollow, they are mortared differently than bricks. Concrete block walls are typically laid with what is called *face shell bedding*, in which the mortar head and bed joints are the same depth as the face shells and flanges (Figure 5-22). Because of their weight and difficulty in handling, masons often stand several blocks on end and apply mortar to the head flanges of three or four units at one time. Each block is then individually placed in its final position, tapped down into the mortar bed, and shoved against the previously laid block, thus producing well-filled vertical head joints at both faces of the masonry. When installing the
last brick or block in the middle of a course, all edges of the opening and all vertical edges of the unit should be buttered with mortar and the unit carefully lowered into place. If any of the mortar falls out, leaving a void in the joint, the closure unit should be removed and the operation repeated.

In cavity wall and veneer wall construction, it is extremely important that the cavity between the outer wythe and the backing wall be kept clean to assure proper moisture drainage. If mortar clogs the cavity, it can form bridges for moisture passage to the backing wall, or it may block weep holes. Some masons use a removable wooden strip to temporarily block the cavity as the wall is laid up and prevent mortar droppings. However, beveling the mortar bed as shown in Figure 5-20 allows little mortar to extrude toward the cavity.

To add visual interest to masonry walls, units may be laid in different positions as shown in Figure 5-5, and arranged in a variety of patterns as shown in Figure 5-7. The patterns were originally conceived in connection with masonry wall bonding techniques that are not widely used today. In older historic masonry, rowlock and header courses were used to structurally connect multiple wythes of a thick masonry wall together. Most contemporary buildings use the $\frac{1}{3}$ or $\frac{1}{2}$

Hollow masonry units are typically laid with face shell bedding. (Photo courtesy PCA).
running bond, or stack bond with very little decorative pattern work. Brick soldier and sailor courses create 8-in.-tall head joints. Because the bed surface of some brick can be relatively smooth, mortar will sometimes slump in a head joint of this height. Concrete block head joints do not have the same problem because the block surface is usually rougher and holds the mortar in place better. Brick soldier and sailor courses should be installed carefully to prevent voids in the head joints, which might be easily penetrated by moisture. Units used for sailor or shiner courses must be solid and uncored.

To achieve a consistent pattern on the wall, units with a pronounced color range from light to dark, or blends which contain more than one color of brick must be uniformly distributed. Brick manufacturers routinely attach instructions for unstacking and using each pallet of brick to assure that the colors are distributed uniformly in the wall. Working from more than one pallet at a time will also help assure good blending of slight inadvertent color differences. Narrow color ranges, however, present fewer potential problems than wider ranges or blends of more than one color (Figure 4-5).

Mortar color and joint type can be just as important in determining the appearance of a wall as the selection of a unit type or color, and variations in aesthetic effect can be achieved by using different types of mortar joints. There are several types of joints common today (Figure 5-23). Rough-cut or flush joints are used when other finish materials, such as stucco, gypsum board, or textured coatings, are to be applied over the masonry. These joints are formed by simply slicing off excess mortar with the edge of the trowel immediately after the units are laid. Weathered joints are more difficult to form since they must be struck off with the trowel point from below, but the mortar is somewhat compacted by the action, and the joint sheds water naturally. Struck joints are easily cut with a trowel point, but the small ledge created collects water, snow, and ice, which may then penetrate the wall. Raked joints are made by scraping out a portion of the mortar while it is still soft, using a square-edged tool. Even though the mortar is slightly compacted by this action, it is difficult to make the joint weather resistant, and it is not recommended where driving rain, high winds, or freezing are likely to occur. The cut of the joint does form a shadow and tends to give the wall a darker appearance. Weeping joints leave excess mortar protruding from the joint to give a rustic appearance, but again are not
weather resistant. Other, more specialized effects can be achieved with tools to bead or groove a mortar joint. The most moisture-resistant joints are tooled *concave* and *V-shaped* joints. Mortar squeezes out of the joints as the masonry units are set in place, and the excess is struck off with a trowel. After the mortar has become “thumbprint” hard (i.e., when a clear thumbprint can be impressed and the cement paste does not stick to the thumb), joints are finished with a jointing tool slightly wider than the joint itself. As the mortar hardens, it has a tendency to shrink slightly and separate from the edge of the masonry unit. Proper tooiling compresses the mortar against the unit and compacts the surface, making it more dense and more resistant to moisture penetration. Concave or V-tooled joints are recommended for use in areas subject to heavy rains and high winds. However, full head and bed joints and good mortar bond are more critical to moisture resistance than tooiling. Less moisture-resistant joint treatments may be used in mild to moderate exposures if the workmanship is good, the bond between units and mortar is complete and intimate, and the flashing and weeps are properly designed and installed.

Horizontal joints should be tooled before vertical joints, using a long jointer sometimes called a *slicker* that is upturned on one end to

![Masonry joint profiles.](image-url)
prevent gouging. Jointers for vertical tooling are small and S-shaped. Although the material most commonly used for these tools is steel, plastic jointers are used to avoid darkening or staining white or light-colored mortars. After the joints have been tooled, mortar burrs or ridges should be trimmed off flush with the face of the unit with a trowel edge, or by rubbing with a burlap bag, a brush, or a piece of carpet.

It is important that the moisture content of the mortar be consistent at the time of tooling, or color variations may create a blotchy appearance in the wall. Drier mortar tools darker than mortar that is wetter when tooled. Along with time and weather conditions, brick moisture content at the time of laying affects mortar curing time. An inconsistent unit moisture content therefore affects the color of the finished joint. If an unprotected pallet of brick, for instance, becomes partially wet during an overnight rain, the wet units will cause patches of lighter-colored joints because their higher moisture content keeps the mortar moist for a longer period of time than adjacent areas.

Even with high-quality workmanship, some routine patching or repair of damaged or defective mortar joints is to be expected. In addition, any holes left by line pins should be filled with fresh mortar before the joints are tooled. The troweling of mortar into joints after the units are laid is known as pointing. It is preferable that pointing and patching be done while the mortar is still fresh and plastic, and before final tooling of the joints is performed. If however, the repairs must be made after the mortar has hardened, the joint should be raked or chiseled out to a depth of about 1/2 in. thoroughly wetted, and pointed with fresh mortar.

5.4.2 Flashing and Weep Holes

Flashing must be installed in continuous runs with all seams and joints lapped 4 to 6 in. and sealed with a nonhardening mastic or caulking material. Unsealed lap joints will allow water to flow around the end of the flashing and penetrate the wall. At lateral terminations where the flashing abuts other construction elements, and at terminations on each side of door jambs, flashing must be turned up to form an end dam. Flexible flashing can be simply folded into place (Figure 5-24).

Flashing should never be stopped short of the face of the wall, or water can flow around the front edge and back into the wall. Flexible
flashing should be extended beyond the face of the wall and later trimmed flush with the face of the joint using a utility knife. The vertical leg of the flashing should be turned up several inches to form a back dam and be placed in a mortar joint in a concrete block backing wythe or behind the sheathing in a frame wall (Figure 5-25).

Weep holes are required in masonry construction at the base course and at all other flashing levels (such as window sills and lintels) so that water which is collected on the flashing can be drained from the wall as quickly and effectively as possible. Weep holes are formed by leaving the mortar out of the head joint between bricks at a spacing of 24 in. on center, or leaving the bottom portion of a concrete block head joint empty at a spacing of 32 in. on center. To function properly, weep holes must be unobstructed by mortar droppings or other debris. Blocked or missing weep holes can cause saturation of the masonry just above the flashing as moisture is dammed in the wall for longer periods of slow evaporation. Efflorescence, staining, corrosion of steel lintels, and freeze-thaw damage can result. To disguise the appearance of the open joints, they can be fitted with louvered metal or plastic grid weep vents (Figure 5-26).

5.4.3 Installing Accessories and Reinforcement

Metal ties, anchors, horizontal joint reinforcement, and steel reinforcing bars are all placed by the mason as the work progresses. Anchors, ties, and joint reinforcement must be properly spaced and placed in the mortar to assure complete encapsulation and good mortar bond. Since mortar is spread only a limited distance along bed joints to avoid excessive evaporation, long sections of joint reinforcement are usually
CHAPTER FIVE

Terminating back leg of masonry flashing.

**Figure 5-25**

- **House Wrap or Asphalt Felts**
- **Sheathing**
- **Tuck Flashing Behind**
- **WEEP**
- **Self-Adhered Flashing on Face of CMU**
- **Tuck Plastic Sheet Flashing into CMU Joint**
laid directly on the units and lifted slightly with the fingers after the mortar is placed so that mortar can get underneath the wires. All metal accessories which are embedded in mortar joints should be kept a minimum of $\frac{5}{8}$-in. from the exterior face of the joint so they are well protected from wetting and corrosion.

Vertical steel reinforcement in a double-wythe wall is placed in the cavity and the masonry is built up around it. Spacers are used at periodic intervals to hold the reinforcing bars up straight and keep them in the correct location. Spacers can also be used to support horizontal bars (Figure 5-27). For single-wythe CMU walls with steel reinforcement, special open-end units are made so that the block can be placed around the vertical bars rather than threaded over the top (Figure 5-28). Horizontal steel is placed in courses of special lintel or bond beam blocks.

5.4.4 Control and Expansion Joints

Allowances must be made in brick and concrete masonry construction for expansion and contraction of the units. All construction materials expand and contract with temperature changes, some to a greater or lesser degree than others. Clay brick also expands with the absorption of moisture, and concrete masonry shrinks with loss of residual moisture from the manufacturing and construction process. The exact locations of control and expansion joints will be affected by design features such as openings, offsets, and intersections. In brick walls, expansion joints should be located near corners because the opposing push of intersecting walls can cause cracking. For both brick and concrete masonry walls, joints should be located at points of weakness or high stress concentration such as abrupt changes in wall height; changes in wall thickness; columns and pilasters; and at one or both sides of windows and doors. Freestanding walls of relatively short length that are not connected to other structures may not require control or expansion joints if they are free to expand and contract without restraint.
Steel reinforcement can also be used to restrain movement and reduce the need for control and expansion joints. Steel joint reinforcement is routinely used in concrete masonry walls to reduce shrinkage and is usually placed in every second or third bed joint.

**Expansion Joints:** A masonry expansion joint is a soft joint without mortar that is designed to accommodate the natural expansion of brick. Any brick wall that is 20 ft. or more in length should have at least one expansion joint. Deciding where to put expansion joints will depend on the design. If either end of the wall is built against existing construction such as a house, garage, or another wall, an expansion joint can be placed between the two elements. If the wall is a long, straight section, an expansion joint should be located so that it divides the wall into sections that are no more than 20 ft. long. If the wall is an L or U shape, an expansion joint should be located near the corners (Figure 5-29).

Expansion joints should be $\frac{3}{8}$ in. to $\frac{1}{2}$ in. wide. To keep mortar from accidentally blocking the joint during construction, a soft foam pad can be placed in it, or a piece of temporary plywood that can be removed later. If a foam pad that will stay in place is used, its edge

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**FIGURE 5-28**
Open-ended concrete masonry A-block.

**FIGURE 5-29**
Brick masonry expansion joint locations.
should be recessed from the face of the wall about 3/4 in. so the joint can be caulked after the wall is finished.

**Control Joints:** Control joints are continuous, weakened joints designed to accommodate the natural shrinkage of concrete masonry in such a way that cracking will occur in straight lines at these joints rather than at random locations (Figure 5-30). Control joints also must incorporate a tongue-and-groove type key so that adjoining wall sections resist wind loads together, but still expand and contract independently. Control joints in concrete masonry walls that are required to keep out moisture must be sealed against leakage. To do this, the mortar is raked out before it hardens to a depth of 1/2 in. to 3/4 in., which will allow caulking for weather resistance. Concrete masonry always shrinks more than it expands, so even though control joints contain mortar, they can accommodate thermal expansion and contraction which occurs after the initial curing shrinkage.

If joint reinforcement is located in every other bed joint, space control joints at three times the wall height (e.g., for a 6-ft.-high wall, space control joints at 18 ft. on center). If joint reinforcement is located in every third bed joint, space control joints at 2-1/2 times the wall height (e.g., for a 6-ft.-high wall, space control joints at 15 ft. on center). **Joint reinforcement should stop on either side of a control joint. It should not continue through it.**
5.5 Stone Masonry Construction

Stone masonry is similar in many ways to unit masonry, but there are also some differences. Stone is a natural material, so its size and shape are not uniform, and it’s also a very heavy material. Stone is dimensionally stable and does not expand and contract with changes in temperature or moisture content, so stone masonry construction does not require expansion or control joints.

5.5.1 Cutting and Shaping Stone

When rubble stone is laid in mortar, irregular shapes are taken up to some degree in the mortar joints themselves. When stone is dry-stacked without mortar, the fit of the stones must be more precise. For

To work with stone requires very few tools besides those required for working with mortar. Cutting and shaping rubble stone will require a brick or stone mason’s hammer, a small club hammer, and a couple of chisels called a pointing chisel and a large pitching chisel or small mason’s chisel (Figure 5-31).

To work with stone requires very few tools besides those required for working with mortar. Cutting and shaping rubble stone will require a brick or stone mason’s hammer, a small club hammer, and a couple of chisels called a pointing chisel and a large pitching chisel or small mason’s chisel. For cutting and shaping rubble stone, a brick or stone mason’s hammer, a small club hammer, and a couple of chisels called a pointing chisel and a large pitching chisel or small mason’s chisel are required. For working with stone requires very few tools besides those required for working with mortar. Cutting and shaping rubble stone will require a brick or stone mason’s hammer, a small club hammer, and a couple of chisels called a pointing chisel and a large pitching chisel or small mason’s chisel. For cutting and shaping rubble stone, a brick or stone mason’s hammer, a small club hammer, and a couple of chisels called a pointing chisel and a large pitching chisel or small mason’s chisel are required.

both types of stonework, though, it will often be necessary to cut and shape individual stones to make them fit better.

Granite is the most difficult stone to cut, but limestone, sandstone, and slate are relatively easy to work with. To cut rubble, it is first laid on solid ground for firm, even support. Cutting should not be done on concrete surfaces because the hard concrete and uneven support may cause the stone to break in the wrong place. The cut is marked with chalk, crayon, or pencil, and scored with a chisel. Often, the stone will break along the line before it is scored all the way around. Small lumps or protrusions are removed with the pointing chisel. Flagstones can be cut by laying them over a small pipe and striking with the chisel. Small pieces can also be trimmed off of flagstone with a mason’s hammer.

5.5.2 Mortar for Stone Masonry

The same types of mortar used for brick and block construction are suitable for stone masonry work as well. Sometimes the proportion of lime is reduced, and one popular mix uses 1 part lime, 2 parts portland cement, and 9 parts sand or 1 part masonry cement to 3 parts sand. Because stone is so heavy, the mortar should be mixed to a slightly stiffer consistency than that used with unit masonry, even though a stiffer mix is a little more difficult to work with. For light-colored stone, a light-colored mortar can be made using white portland cement instead of ordinary gray cement, or pigments can be added to create other colors.

5.5.3 Setting Stone

Ashlar stone that is laid in straight horizontal courses can be installed using string lines and line blocks just like unit masonry. For rubble stone that is less precise, pattern bonds are more like putting together a puzzle in which no two pieces are the same size or shape. There is an art to creating uniformity in pattern so that the front of the house looks the same as the sides and back. Colors must be blended and some regularity of coursing and placement is required. The necessary skills can be acquired only with hands-on experience and a good eye for the esthetics.

5.5.4 Flashing and Weep Holes

Even though stone is not as absorptive as brick or block, stone masonry walls still require flashing and weeps to drain moisture from the wall. Water entry in stone walls, like in brick and block walls, is most often
through the mortar joints, and when the joints are irregular and difficult to tool, water penetration can be significant.

5.5.5 Accessories

Residential stone masonry usually is limited to veneer applications, garden walls, and retaining walls. Steel reinforcement is seldom necessary for these applications, so the accessories necessary for stone masonry construction are usually limited to wall ties and anchors. These need flexibility to accommodate the irregularities of the stone, and either wire or corrugated metal are most frequently used.

5.6 Grouting Masonry

Concrete block basement walls often require steel reinforcing for added strength. In reinforced concrete block construction, the cores of the hollow units are pumped with grout to secure the reinforcing steel and bond it to the masonry. All of the cores of a concrete block wall may be grouted with reinforcement spaced every few cores, or the grout may be limited only to the cores which contain reinforcement.

If only isolated cores of a concrete block wall will be grouted, the cores that will be grouted must be fully bedded in mortar, including the webs and face shell flanges. This will prevent the grout from flowing beyond its intended location. If the whole wall is to be grouted, the face shells are mortared as usual, but the webs are not. This allows the grout to flow laterally inside the wall for better bond. Spacers are used to maintain alignment of the vertical reinforcement to assure that grout completely surrounds the steel for full embedment and proper structural performance. Protrusions or fins of mortar which project into the cores will interfere with proper flow and distribution of the grout and could prevent complete bonding.

The low-lift method of grouting a wall is done in 8-in. lifts as the wall is laid up. Grout should be well mixed to avoid segregation of materials, and carefully poured to avoid splashing on the top of the units, since dried grout will prevent proper mortar bond at the succeeding bed joint. At least 15 minutes should elapse between pours to allow the grout to achieve some degree of stiffness before the next layer is added. If grout is poured too quickly, and the mortar joints are fresh, hydrostatic pressure can cause the wall to bulge out of plumb. A
displacement of as little as $\frac{1}{8}$ in. will destroy the bed joint bond, and the work must be torn down and rebuilt. The joint rupture will cause a permanent plane of weakness and cannot be repaired by simply realigning the wall. Grout that is in contact with the masonry hardens more rapidly than that in the center of the grout space so it is important that consolidation or puddling of the grout take place immediately after the pour and before this hardening begins. Vibrators used in masonry grouting are usually smaller than those used in concrete work because the space they must fit into is smaller. In single-wythe, hollow-unit construction, walls may be built to a maximum 4-ft. height before grout is pumped or poured into the cores. Grout is placed in the cores and then consolidated by vibration to ensure complete filling and solid embedment of steel.

*High-lift grouting* operations are not performed until the wall is laid up to full story height. The cross webs of hollow units are fully embedded in mortar about every 25 ft. to form grout barriers. This limits the size of the pour to a manageable area and contains the grout within the designated area. Cleanouts must be provided at the base of the wall by leaving out every other unit in the bottom course of the section being poured. In single-wythe, hollow-unit walls, cleanout openings at least $3 \times 4$ in. are located at the bottom of every core containing dowels or vertical reinforcement, and in at least every second core that will be grouted, but has no steel. In solidly grouted, unreinforced single-wythe walls, every other unit in the bottom course should be left out. A high-pressure air blower is used to remove any debris which may have fallen into the cores. Cleanout plugs are filled in after cleaning the cavity, but before the grouting begins. The mortar joints in a wall should be allowed to cure for at least three days to gain strength before grouting by the high-lift method. In cold, damp weather, or during periods of heavy rain, curing should be extended to five days. Grout should be placed in a continuous operation with no intermediate horizontal construction joints within a story height. Four-foot maximum lifts are recommended, with 30 to 60 minutes between pours to allow for settlement, shrinkage, and absorption of excess water by the units. In each lift, the top 12 to 18 in. should be reconsolidated before or during placement of the next lift.

It is critical that the grout consistency be fluid, and that it be mechanically vibrated into place. When the grout is stiff, it hangs up
on the side walls of the cores and the reinforcing bars, leaving voids in which the steel is not properly bonded or embedded and is much more susceptible to corrosion from moisture within the wall.

### 5.7 Protections

During construction, partially completed masonry work requires some protection from damage caused by weather or by other construction operations.

#### 5.7.1 Bracing

High-lift grouting requires that walls be temporarily braced until the mortar and grout has fully set. Partially completed walls should also be braced during construction against lateral loads from wind or other forces applied before full design strength is attained or before permanent supporting construction is completed (Figure 5-32). Partially completed structures may be subject to loads which exceed their structural capabilities. Wind pressure, for instance, can create four times as much bending stress in a new, freestanding wall as in the wall of a completed building. Fresh masonry with uncured mortar has no tensile strength to resist such lateral forces. Most codes require that new, uncured, unanchored walls be braced against wind pressure. Bracing should be provided until the mortar has cured and the wall has been integrally tied to the structural frame of the building. Bracing should be designed on the basis of wall height and expected wind pressures.

#### 5.7.2 Coverings

Masonry walls should be covered at the end of each day and when work is not in progress. Excess moisture entering the wall during construction can cause saturation of units, which may take weeks or months to dry out. Such prolonged wetting may result in efflorescence,
particularly if the cooler winter months lengthen the drying process. Extended wetting will also prolong cement hydration, producing large amounts of calcium hydroxide, which may also be taken into solution and leached to the surface to cause calcium carbonate stains.

Covers such as water-repellent tarps or heavy plastic sheets should extend a minimum of two feet down each side of uncompleted walls and be held securely in place. During construction, scaffold planks should also be turned on edge at the end of each day so that rain will not splash mortar droppings or dirt onto the face of the masonry.

5.7.3 Cold Weather

Cold weather causes special problems in masonry construction. Even with sufficient mixing water, cement hydration and strength development in mortar and grout will stop at temperatures below 40°F. Construction may continue during cold weather if the masonry mortar and materials are kept warm during placement, preventing the masonry from freezing during the initial hours after placement before cement hydration and mortar cure are complete. Frozen mortar looks like it is hardened, but it is not actually cured and will not develop full design strength or complete bond until it is thawed and liquid water is again available for hydration. Frozen mortar is easily scratched from joints, has a “crows feet” pattern on the surface of tooled joints, and may flake at the surface. Cement hydration will resume if the temperature of the masonry is raised above 40°F and its liquid moisture content exceeds 75%. When these conditions are maintained throughout the curing period, ultimate strength development and bond will be the same as those attained under moderate conditions.

The rate at which masonry freezes is influenced by the severity of temperature and wind conditions, the temperature and absorption characteristics of the units, the temperature of reinforcing steel and metal accessories, and the temperature of the mortar at the time of placement. Wet mortar mixes expand more when frozen than drier ones, and expansion increases as the water content increases. During freezing weather, low-moisture-content mixes and high-suction units are desirable, but regardless of the conditions, mortar and grout consistency must provide good workability and flow so that bond is maximized. During cold-weather construction, it may be desirable to use a
Type III, high-early-strength portland cement because of the greater protection it will provide the mortar.

In addition to normal storage and protection, consideration should be given to the method of stockpiling sand to permit heating the materials if required. As the temperature falls, the number of different materials requiring heat will increase. Mixing water is easily heated. If none of the other materials are frozen, mixing water may be the only ingredient requiring artificial heat. It should be warmed enough to produce mortar and grout temperatures between 40 and 70°F at the time of placement. Water temperatures above 180°F can cause cement to flash set, so sand and water should be mixed first to moderate high temperatures before the cement is added. Masonry sand, which contains a certain amount of moisture, should be thawed if frozen to remove ice. Sand should be warmed slowly to avoid scorching, and care should be taken to avoid contamination of the material from the fuel source. Dry masonry units should be heated if necessary to a temperature above 20°F at the time of use. Wet, frozen masonry units must be thawed without overheating.

The degree of protection against cold weather which is provided for the work area is an economic balance between the cost of the protection and the cost of not being able to work. Protective apparatus may range from a simple windbreak to a heated enclosure. Each job must be evaluated individually to determine needs and cost benefits, but some general rules do apply. Characteristics such as strength, durability, flexibility, transparency, fire resistance, and ease of installation should be considered when selecting protective materials. Canvas, vinyl, and polyethylene coverings are often used. In most instances, a windbreak or unheated enclosure will reduce the chill factor sufficiently to provide the degree of protection required. Precautions must also be taken to safeguard workers against injury, and enclosures must be adequate to resist wind, snow, and uplift loads. Cold-weather protection measures may be necessary when the ambient temperature or the temperature of the units is below 40°F. Figure 5-33 summarizes heating and protection requirements for various work temperatures.

### 5.7.4 Hot Weather

Although not as widely discussed as cold-weather problems, hot-weather conditions also pose special concerns for masonry construction.
High temperatures, low humidity, and wind can adversely affect performance of the masonry.

Rapid evaporation and the high suction of hot, dry units can quickly reduce the water content of mortar and grout mixes so that cement hydration actually stops. Mortar workability and grout flow are inhibited and set occurs faster. High-temperature mortars have lower air contents, and air-entraining agents are less effective. Board life of mortars is shorter, and joints must be tooled sooner than normal. Evaporation at the exterior face of joints decreases durability and strength at the surface. When ambient temperatures are above 100°F, or above 90°F with wind velocities greater than 8 mph, protective

<table>
<thead>
<tr>
<th>Workday Temperature</th>
<th>Construction Requirement</th>
<th>Protection Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 40°F</td>
<td>Normal masonry procedures</td>
<td>Cover walls with plastic or canvas at end of workday to prevent water entering masonry</td>
</tr>
<tr>
<td>40–32°F</td>
<td>Heat mixing water to produce mortar temperatures between 40–100°F</td>
<td>Cover walls and materials with plastic or canvas to prevent wetting and freezing</td>
</tr>
<tr>
<td>32–25°F</td>
<td>Heat mixing water and sand to produce mortar temperatures between 40–100°F</td>
<td>With wind velocities over 15 mph provide windbreaks during workday and cover walls and materials at end of workday to prevent wetting and freezing; maintain masonry above 32°F for 16 hours using auxiliary heat or insulated blankets</td>
</tr>
<tr>
<td>25–20°F</td>
<td>Mortar on boards should be maintained above 40°F</td>
<td>Provide enclosures and supply sufficient heat to maintain masonry enclosure above 32°F for 24 hours</td>
</tr>
<tr>
<td>20–0°F and below</td>
<td>Heat mixing water and sand to produce mortar temperatures between 40–120°F</td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 5-33

Cold weather construction requirements.
measures should be taken to assure continued hydration, strength development, and maximum bond. Whenever possible, materials should be stored in a shaded location, and aggregate stockpiles covered with plastic sheets to retard moisture evaporation. High-suction brick can be wetted to reduce initial absorption, and metal accessories such as reinforcing steel, anchors and ties, mixers, mortar boards, and wheelbarrows can be kept cool by spraying with water.

Additional mixing water may be needed in mortar and grout, and additional lime will increase the ability of the mortar to retain water longer. Increasing the cement content in the mix accelerates early strength gain and maximizes hydration before evaporative water loss. Adding ice to the mixing water can also lower the temperature of the mortar and grout and slow evaporation. Water that is too hot can cause the cement to flash set. Set-retarding or water-reducing admixtures may also be used. Retempering should be limited to the first 1-1/2 hours after mixing. Mortar beds should not be spread more than 4 ft. ahead of the masonry, and units should be set within one minute of spreading the mortar. Sun shades and windscreens can modify the effects of hot, dry weather, but consideration should also be given to scheduling work during the cooler parts of the day.

5.7.5 Moist Curing

Cement hydration cannot occur if the temperature of the mortar or grout is below 40°F or if the moisture content of the mix is less than 75%. Both hot and cold weather can produce conditions which cause hydration to stop before curing is complete. These dry outs occur most frequently in concrete masonry construction and under winter conditions, but may also occur in brick construction and in hot, dry weather. Dry outs are naturally reactivated when temperatures rise above freezing and rainwater restores moisture to the wall, but until this occurs, the masonry is temporarily limited in compressive strength, bond, and weather resistance.

Moist curing methods similar to those used in concrete construction can help prevent masonry dry outs. Periodically wetting the finished masonry for several days with a fine water spray will usually assure that adequate moisture is available for curing, strength development, and good bond. Covering the walls with polyethylene sheets will also retard evaporation and create a greenhouse effect that aids in
moist curing. Extreme winter conditions may also require the application of heat inside these enclosures to maintain temperatures above 40°F. Even though concrete masonry units cannot be wetted on site before they are installed, completed concrete masonry walls can be moist-cured because the restraining conditions of the joint reinforcement and surrounding construction minimize the effects of moisture shrinkage in the units.

5.8 Cleaning Masonry

Cleaning new brick and concrete masonry is easiest if some simple protective measures are taken during construction. The finished appearance of masonry walls depends to a great extent on the attention given to the surfaces during construction and during the cleaning process. Care should always be taken to prevent mortar smears or splatters on the face of the wall, but if such stains do occur, proper cleaning can help prevent permanent discoloration.

5.8.1 Construction Precautions

Precautions which should be taken during construction include the following:

- protecting the base of the wall from rain-splashed mud or mortar droppings by using straw, sand, sawdust, or plastic sheeting spread out on the ground and up the wall surface;
- turning scaffold boards on edge at the end of the day to prevent rain from splashing mortar or dirt directly onto the wall;
- covering the tops of unfinished walls at the end of the day to prevent saturation or contamination from rain; and
- protecting masonry units and packaged mortar ingredients from groundwater or rainwater contamination by storing off the ground, protected with waterproof coverings.

5.8.2 Methods of Cleaning

The cleaning process itself can be a source of staining if chemical or detergent cleansing solutions are improperly used, or if windows, doors, and trim are not properly protected from possible corrosive
effects. New masonry may be cleaned by scrubbing with water, detergent, a muriatic acid solution, or proprietary cleaning compounds.

Detergent solutions will remove mud, dirt, and soil accumulations. One-half cup dry measure of trisodium phosphate and 1/2 cup dry measure of laundry detergent dissolved in 1 gal. of water is recommended. Acid cleaners must be carefully selected and controlled to avoid both injury and damage. Hydrochloric acid (commonly called muriatic acid) dissolves mortar particles and should be used carefully in a diluted state. Muriatic acid should be mixed with at least nine parts clean water in a nonmetallic container, and metal tools or brushes should not be used. Acid solutions can cause green vanadium or brown manganese stains on some clay masonry and should not be used on light colored tan, buff, brown, black, pink, or gray brick which contains manganese coloring agents. Proprietary cleaning compounds should be carefully selected for compatibility with the masonry material, and the manufacturer’s recommended procedures and dilution instructions should be followed.

Some contractors use pressurized water or steam cleaning combined with detergents or cleaning compounds. If the wall is not thoroughly saturated before beginning, high-pressure application can drive the cleaning solutions into the masonry, where they may become the source of future staining problems. High-pressure washing can also damage soft brick and mortar and accelerate deterioration. Abrasive sandblasting should not be used to clean masonry.

All cleaning solutions, even detergent, should be tested for adverse effects on a small, inconspicuous area of the wall. Some detergents contain soluble salts that can contribute to efflorescence. Muriatic acid can leave a white scum on the wall if the residue of dissolved cement is not thoroughly rinsed after a brief dwell time and light scrubbing. This white scum can only be removed with special proprietary compounds, or it may have to simply wear off. Detergent and acid solutions usually are applied by bucket and brush, but large jobs may require low-pressure spray application. The masonry should be thoroughly saturated from the top down before cleaning to prevent absorption of the acid or the dissolved mortar particles. Failure to adequately prewet a wall, or using an acid solution that is too strong will cause acid burn—a chemical reaction that changes the color of the masonry. Nonmetallic buckets, brushes, and tools must always be used with
acid cleaners because metals react with acid, leaving marks on the wall that can oxidize and leave stains. Muriatic acid can also discolor pigmented mortars, so it should be pretested and used with caution on this type of work. Cleaning should be scheduled as late as possible in the construction.

Walls should be cleaned when they are in the shade rather than in the sun so that the cleaning solutions do not dry out too quickly. Confine cleaning to small areas that can be rinsed before they dry. For cleaning new masonry, the Brick Industry Association (BIA) has established guidelines for the selection of methods depending on the type of brick used (Figure 5-34).

### 5.8.3 Cleaning Fresh Mortar Smears

On brick and other clay masonry units, the mortar must be thoroughly set and cured before it can be properly removed. Trying to clean wet mortar from the surface presses the cement paste into the unit pores, making it harder to clean. Wooden paddles or nonmetallic scrapers should be used to remove large mortar droppings. For small splatters, stains, or the residue from larger pieces, a medium-soft fiber-bristle brush is usually adequate. Any motions that rub or press mortar particles into the unit face should be avoided. Mortar that cures too long is harder and more difficult to remove than fresh splatters, and may require acid cleaning. Mild acid solutions easily dissolve thin layers of mortar. Large splatters should be scraped off first and, if necessary, the residue removed with acid. Muriatic acid is suitable for cleaning clay masonry if it is diluted in a ratio of one part acid to nine parts water. Muriatic acid should never be used on light-colored tan, buff, gray, or pink brick because it can react with minerals in the clay and cause green vanadium or brown manganese stains.

Mud, dirt, and soil can usually be washed away with a mild detergent solution consisting of 1/2 cup dry measure of trisodium phosphate (TSP) and 1/2 cup dry measure of laundry detergent to one gallon of clean water. Dried mud may require the use of pressurized water or a proprietary “restoration” type cleaner containing hydrofluoric acid and phosphoric acid. Hydrofluoric acid, however, etches polished surfaces such as glass, so adjacent windows must be protected from accidental contact. Hydrofluoric acid is not suitable for cleaning mortar stains and splatters because it cannot dissolve portland cement products.
<table>
<thead>
<tr>
<th>Brick Category</th>
<th>Cleaning Method</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red and red flashed</td>
<td>Bucket and brush hand cleaning</td>
<td>Hydrochloric acid solutions, proprietary compounds, and emulsifying agents may be used.</td>
</tr>
<tr>
<td></td>
<td>High pressure water</td>
<td>Smooth texture: Mortar stains and smears are generally easier to remove; less surface area exposed; easier to presoak and rinse; unbroken surface, thus more likely to display poor rinsing, acid staining, poor removal of mortar smears</td>
</tr>
<tr>
<td></td>
<td>Sandblasting</td>
<td>Rough texture: Mortar and dirt tend to penetrate deep into textures; additional area for water and acid absorption; essential to use pressurized water during rinsing</td>
</tr>
<tr>
<td>Red, heavy sanded finish</td>
<td>Bucket and brush hand cleaning</td>
<td>Clean with plain water and scrub brush or lightly applied high pressure and plain water. Excessive mortar stains may require use of cleaning solutions. Sandblasting is not recommended.</td>
</tr>
<tr>
<td>White, tan, buff, gray, specks, pink, brown and black</td>
<td>High-pressure water</td>
<td>Do not use hydrochloric (muriatic) acid. Clean with plain water, detergents, emulsifying agents or suitable proprietary compounds. Manganese-colored brick units tend to react with muriatic acid solutions and stain. Light colored brick are more susceptible than darker unit to acid burn and stains.</td>
</tr>
<tr>
<td>White, tan, buff, gray, specks, pink, brown and black with sand finish</td>
<td>High pressure water</td>
<td>Do not use hydrochloric (muriatic) acid. Clean with plain water, or lightly applied detergents, emulsifying agents, or suitable proprietary compounds. Manganese-colored brick units tend to react with muriatic acid solutions and stain. Light colored brick are more susceptible than darker unit to acid burn and stains. Sandblasting is not recommended.</td>
</tr>
<tr>
<td>Glazed brick</td>
<td>Bucket and brush hand cleaning</td>
<td>Wipe glazed surface with soft cloth within a few minutes of laying units. Use soft sponge or brush plus ample water supply for final washing. Use detergents where necessary and acid solutions only for very difficult mortar stains. Do not use acid on salt glazed or metallic glazed brick. Do not use abrasive powders.</td>
</tr>
<tr>
<td>Colored mortars</td>
<td>Method is generally controlled by the brick unit</td>
<td>Many manufacturers of colored mortars do not recommend chemical cleaning solutions. Most acids tend to bleach colored mortars. Mild detergent solutions are generally recommended.</td>
</tr>
</tbody>
</table>
Although hydrochloric acid solutions are highly effective in removing mortar stains, they are not recommended for concrete masonry. Acid solutions remove the stain by dissolving the cement, but they also dissolve the cement matrix in the unit and etch the surface, leaving it porous and highly absorptive. As the cement is dissolved, more aggregate is exposed, changing both the color and the texture of the block.

Dry rubbing is usually sufficient for removing mortar stains from concrete masonry. To prevent smearing, mortar droppings and splatters should be almost dry before being removed. Large droppings can be pried off with a trowel point, putty knife, or chisel. The block surface can then be rubbed with another small piece of block, and finally with a stiff fiber-bristle or stainless steel brush.

Remove dried mortar splatters from stone with a trowel or by scrubbing with stone dust and fiber brushes wetted with white vinegar. Acids or chemical cleaners are not usually required to clean new stone. If stubborn dirt or other foreign substances are embedded in the stone surface, mild abrasive cleaners will usually remove them. If more aggressive methods are required, consult the stone supplier about the most appropriate cleaning chemicals and procedures.

5.8.4 Efflorescence and Calcium Carbonate Stains

Efflorescence and calcium carbonate stains are the two most common forms of surface stains on masonry. Both are white and both are activated by excessive moisture in the wall, but beyond that, there are no similarities. Efflorescence is a powdery salt residue, while calcium carbonate stains are hard, crusty, and much more difficult to remove.

Efflorescence is the white powdery deposit on exposed masonry surfaces caused by the leaching of soluble salts. Efflorescence occurs when soluble salts in the units or mortar are taken into solution by prolonged wetting. As the wall begins to dry, the salt solution migrates toward the surface through capillary pores. When the water evaporates, the salts are deposited on the face of the wall (Figure 5-35). If the units and the mortar ingredients contain no soluble salts such as sodium or potassium sulfate, and if insufficient moisture is present to effect leaching, efflorescence cannot occur. The source of moisture necessary to produce efflorescence may be either rainwater or the condensation of water vapor within the assembly. Water may also be present because unfinished walls were not properly protected from rain and snow during con-
struction. “New building bloom” (efflorescence which occurs within the first year of the building’s completion) is often traced to slow evaporation of such moisture. Hot summer months are not as conducive to efflorescence because the wetting and drying of the wall is generally quite rapid. In late fall, winter, and early spring, particularly after rainy periods, when evaporation is slower and temperatures cooler, efflorescence is more likely to appear. To minimize the possible contribution of mortar ingredients to efflorescence, use portland cements with low alkali content, clean washed sand, and clean mixing water.

Efflorescence will often disappear with normal weathering if the source of moisture is located and stopped. Efflorescence can also be dry brushed, washed away by a thorough flushing with clean water, or scrubbed away with a brush.

Calcium carbonate stains are hard encrustations which can be removed only with acid cleaners. Calcium hydroxide is present in masonry mortar as part of the hydrated lime in cement-lime mortars, and as a by-product of the portland cement hydration process itself. Portland cement will produce about 12—20% of its weight in calcium hydroxide at complete hydration. Calcium hydroxide is only slightly soluble in water, but extended saturation of the mortar prolongs the hydration process producing a maximum amount of calcium hydroxide and provides enough moisture to leach the calcium hydroxide to the surface. When it reacts with carbon dioxide in the air, the calcium hydroxide forms a concentrated calcium carbonate buildup, usually appearing as white streaks from the mortar joints and sometimes referred to as “lime deposits” or “lime run” (Figure 5-36). The existence of calcium hydroxide in cement-based mortar systems cannot be avoided. Preventing saturation of the wall both during and after construction, how-
ever, will eliminate the mechanism needed to form the liquid solution and carry it to the masonry surface.

Before calcium carbonate stains can be removed, the source of moisture must be located and stopped. Once that is done, the stain and surrounding area should be saturated with water, and a dilute solution of one part muriatic acid to nine parts water applied. Using a stiff fiber-bristle brush, the stain can be scrubbed away and the wall thoroughly rinsed with water to remove the acid and residue.

### 5.9 **Clear Water Repellents**

Water-repellent coatings are often applied on architectural concrete block and on some light-colored stone, but their effectiveness is usually limited to a period of three to seven years, depending on the product selected. Water-repellent coatings can be applied in one of three ways, depending on the size of the surface being treated:

- With a synthetic bristle paint brush
- With a synthetic roller and plastic paint roller pan
- With low-pressure (20-psi) spray equipment with a stainless steel fan tip nozzle.
When water repellents are applied by sprayer, sheets of plastic should be used to protect adjacent surfaces and landscaping. The application of water-repellent coatings does not require any special skills or equipment, but manufacturer’s label instructions should be followed for handling, application rates, cleanup, and disposal. Some products contain VOCs (volatile organic compounds), the use of which may be restricted in some areas, and the disposal of which is regulated in almost all areas.

The surface to which the coating will be applied must be clean and free of dirt or oils that would prohibit absorption of the coating into the surface. If general or spot cleaning is necessary, the surface should be allowed to dry thoroughly before proceeding. The mortar in new masonry walls (or freshly placed concrete) should fully cure for at least 28 days before applying a water repellent. Water-based coatings will have less odor than solvent-based products.

Spray applications should be made only when there is little or no wind to avoid damage from the spray drifting onto other surfaces. Regardless of whether the application is by brush, roller, or spray, the water repellent should be put on the wall from the bottom up with enough material applied to create a 6-in. to 8-in. rundown below the contact point. The coating should be allowed to penetrate the surface for two or three minutes and then reapplied in the same saturating manner. When the first coat is dry to the touch, or within two hours of the first application, a second saturating coat can be applied in the same way as described above.