14

Masonry Construction

14–1 BRICK MASONRY

Masonry Terms

A number of specialized terms are commonly used in brick masonry construction. The reader should be familiar with these terms in order to understand the construction practices described in this section and observed in the field. Many of these terms and procedures described in this section are also applicable to concrete masonry construction, which is presented in Section 14–2. Figure 14–1 illustrates the terms applied to the six possible positions in which an individual brick may be placed. The six surfaces of a brick are identified as the face, the end, the side, the cull, and the beds, as shown in Figure 14–2. Brick frequently must be cut to fit into corners and other places where a whole brick cannot be used. Several common shapes are shown in Figure 14–3.

Figure 14–4 illustrates the terms applied to the components of a brick wall. A *course* is a horizontal layer of brick in the plane of the wall. In this illustration the individual bricks in each course, except the top course, are in the *stretcher* position. A *wythe* is a vertical section one brick thick. A *header* is a brick placed with its long axis perpendicular to the direction of the wall. Headers are used to bond two wythes together. The bricks in the top course of Figure 14–4 are in the header position. A *bed joint* is a horizontal layer of mortar (or bed) on which bricks are laid. *Headjoints* are vertical mortar joints between brick ends. A *collar joint* is a vertical joint between brick wythes. The usual thickness of mortar joints is ¼ in. (6 mm) for glazed brick and tile and either ⅜ in. (10 mm) or ½ in. (13 mm) for unglazed brick and tile. The exposed surfaces of mortar joints may be finished by troweling, tooling, or raking, as shown in Figure 14–5. A *troweled joint* is formed by cutting off excess mortar with the trowel and then compacting the joint with the tip of the trowel. Troweled joints include the flush joint, the struck joint, and the weather joint. A *tooled joint* is formed by using a special tool to compact and shape the mortar in the joint. The two most common tooled joints are the concave joint and the V-joint. Tooled joints form the most watertight joints. Raked joints are formed by removing a layer of mortar from the joint with a special tool. *Raked joints* are often used for appearance but are difficult to make completely watertight.

Figure 14–1 Terms applied to brick positions. (Courtesy of The Brick Industry Association)

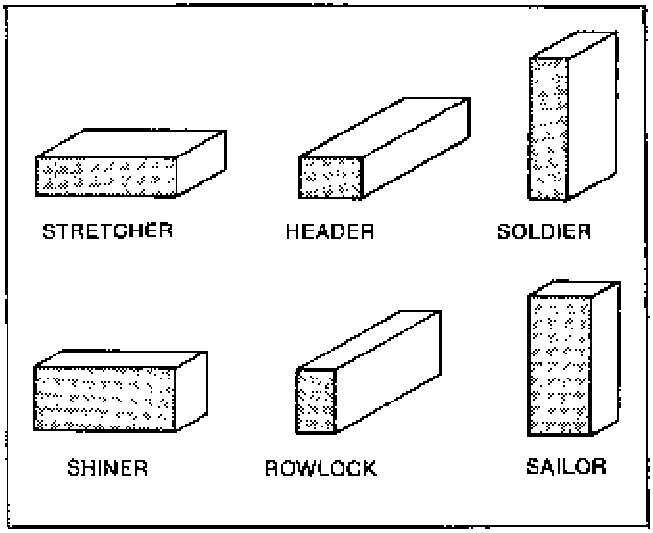


Figure 14–2 Identification of brick surfaces.

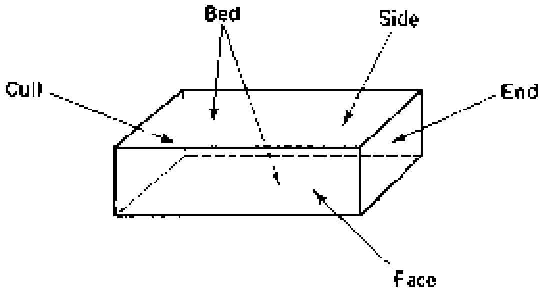
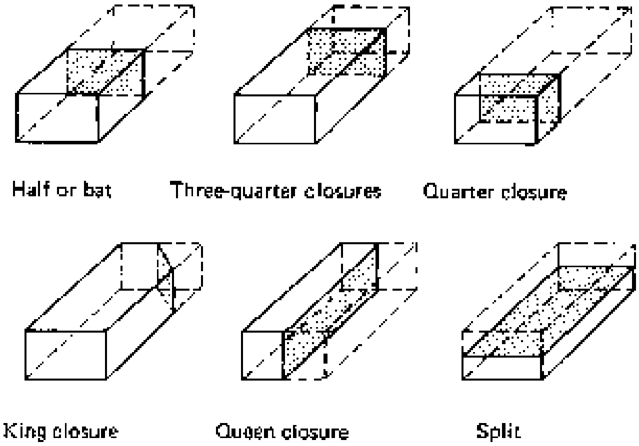


Figure 14–3 Names of cut brick.



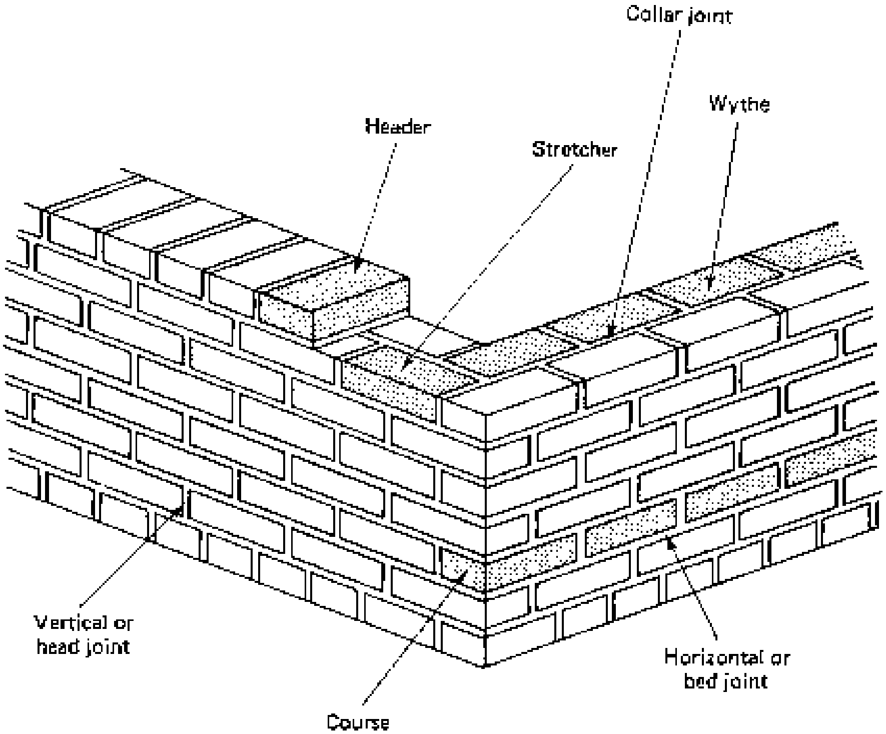


Figure 14–4 Elements of a brick wall.

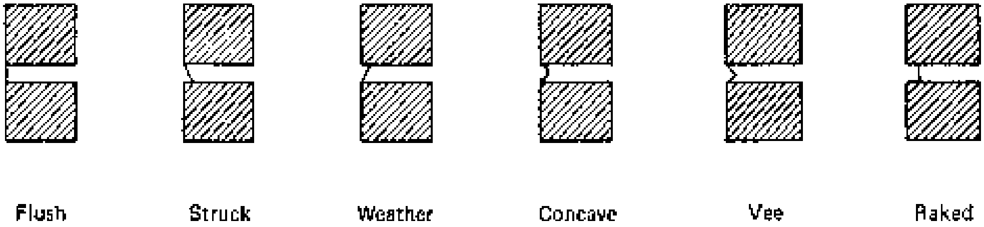


Figure 14–5 Mortar joint finishes.

Materials

Brick is manufactured in a number of sizes and shapes. Typical brick shapes are illustrated in Figure 14–6. The actual size ($W \times H \times L$) of standard nonmodular brick is 3¾ × 2¼ × 8 in. (95 × 57 × 203 mm). Oversized nonmodular brick is 3¾ × 2¾ × 8 in. (95 × 70 × 203 mm). The other bricks shown are a few of the modular shapes available. The actual sizes of these bricks are: Standard Modular, 3⅝ × 2¼ × 7⅝ in. (92 × 57 × 194 mm); Economy,

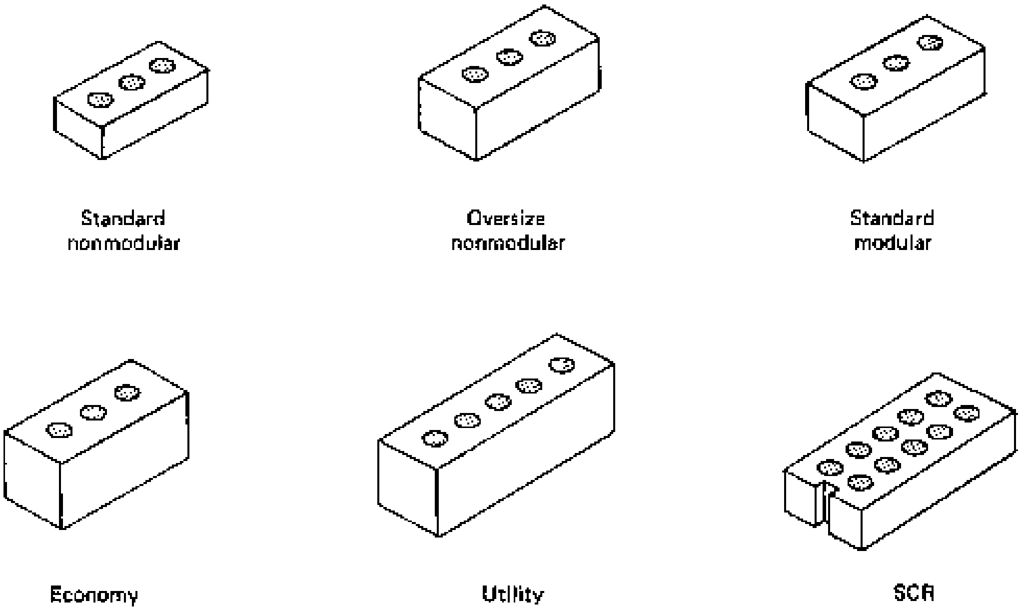


Figure 14–6 Typical brick shapes.

3⅝ × 3⅝ × 7⅝ in. (92 × 92 × 194 mm); Utility, 3⅝ × 3⅝ × 11⅝ in. (92 × 92 × 295 mm); and SCR, 5⅝ × 2¼ × 11⅝ in. (143 × 57 × 295 mm).

The compressive strength of individual bricks produced in the United States ranges from about 2500 lb/sq in. (17.2 MPa) to over 22,000 lb/sq in. (151.7 MPa). The overall compressive strength of brick assemblies is a function of both the compressive strength of the individual brick and the type of mortar used. Reference 5 describes procedures for determining the design strength of brick structural units by either performing tests on masonry assemblies or by using assumed strength values based on brick strength and mortar type. Assumed 28-d compressive strength values for masonry range from 530 lb/sq in. (3.7 MPa) for 2000 lb/sq in. (13.8 MPa) brick with Type N mortar and no inspection to 4600 lb/sq in. (31.7 MPa) for 14,000 lb/sq in. (96.5 MPa) brick with Type M mortar and construction inspection by an architect or engineer.

Mortars for unit masonry are covered by ASTM Standard C270 (Standard Specification for Mortar for Unit Masonry) and ASTM Standard C476 (Standard Specification for Mortar and Grout for Reinforced Masonry). The principal mortar types include types M, S, N, O, PM, and PL. Type M mortar is a high-strength mortar for use whenever high compressive strength and durability are required. Type S mortar is a medium-high-strength mortar for general-purpose use. Type N mortar is a medium-strength mortar for general use except that it should not be used below grade in contact with the earth. Type O is a low-strength mortar principally used for non-load-bearing partitions and for fireproofing. Types PM and PL are used for reinforced masonry. Mortar properties may be specified by strength or by proportions, but not both, as shown in Table 14–1.

Table 14–1 Mortar specifications

	By Strength	By Proportion*		
Mortar Type	***28-d Compressive Strength-lb/sq in. (MPa)***	***Portland Cement***	***Masonry Cement***	***Hydrated Lime***
M	2500 (17.2)	1	None	¼
		1	1	None
S	1800 (12.4)	1	None	¼ to ½
		½	1	None
N	750 (5.2)	1	None	½ to 1
		None	1	None
O	350 (2.4)	None	1	1 to 2
PM	2500 (17.2)	1	1	None
PL	2500 (17.2)	1	None	¼ to ½

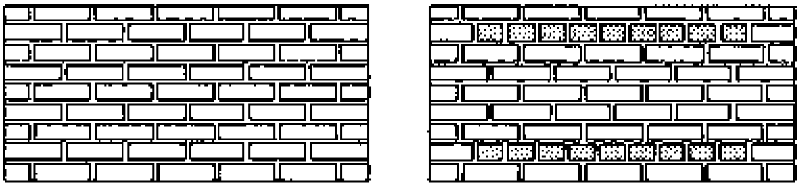
*Aggregate volume should be 2¼ to 3 times the sum of the volumes of cement and lime used.

Pattern Bonds

Structural bonding of masonry units is accomplished by the adhesion of mortar to masonry and by interlocking the masonry units or by embedding ties in the mortar joints. The manner in which the masonry units are assembled produces a distinctive pattern referred to as *pattern bond.* The five most common pattern bonds are the running bond, common bond, Flemish bond, English bond, and stack bond, shown in Figure 14–7. *Running bond* uses only stretcher courses with head joints centered over stretchers in the course below. *Common bond* uses a header course repeated at regular intervals; usually every fifth, sixth, or seventh course. Headers provide structural bonding between wythes. *Flemish bond* alternates stretchers and headers in each course with headers centered over stretchers in the course below. *English bond* is made up of alternate courses of headers and stretchers, with headers centered on stretchers. *Stack bond* provides no interlocking between adjacent masonry units and is used for its architectural effect. Horizontal reinforcement should be used with stack bond to provide lateral bonding.

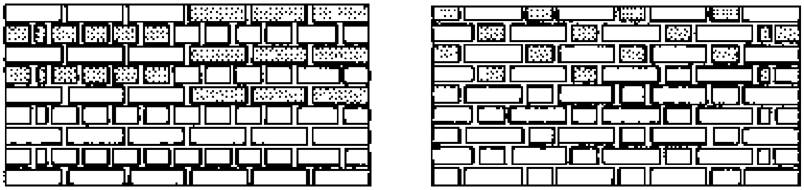
Hollow Masonry Walls

Masonry *cavity walls* are made up of two masonry wythes separated by an air space 2 in. (50 mm) or more in width and tied together by metal ties. Brick cavity walls combine an exterior wythe of brick with an interior wythe of brick, structural clay tile, or concrete masonry. Cavity walls have a number of advantages over a single solid masonry wall. These advantages include greater resistance to moisture penetration, better thermal and acoustical insulation, and excellent fire resistance. A hollow masonry bonded wall constructed of utility brick, called a *utility wall,* is shown in Figure 14–8. While masonry bonded walls are not as water resistant as cavity walls, they can resist water penetration when properly



Running bond

Common bond

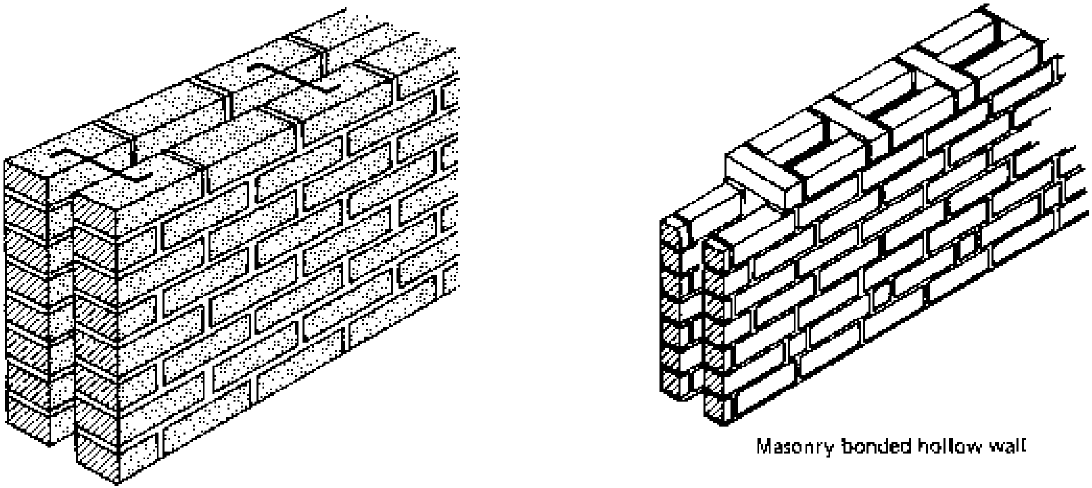


English bond

Flemish bond

Stack bond

Figure 14–7 Principal brick pattern bonds.

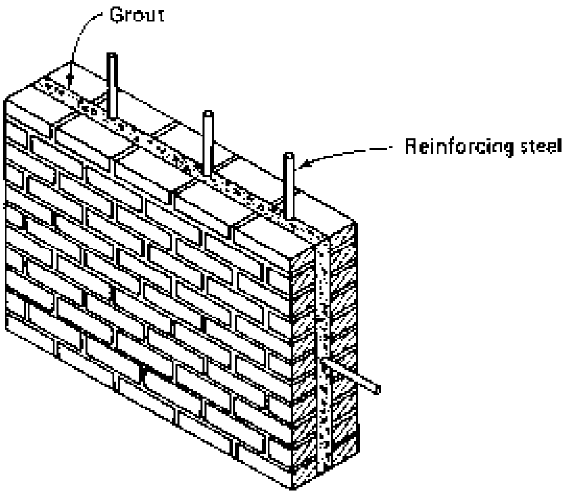


Brick cavity wall

Masonry bonded hollow wall

Figure 14–8 Brick cavity and masonry bonded hollow walls.

Figure 14–9 Reinforced brick masonry wall.



constructed. Recommended practice for construction of the utility wall includes bonding every sixth course (with alternating headers and stretchers), installing flashing at the bottom of the wall, providing weep holes along the bottom exterior brick course on 24-in. (610-mm) centers, using type S mortar, and providing concave tooled joints on the exterior surface. The cavity between wythes may be filled with insulation if desired.

Reinforced Brick Masonry

The term *reinforced brick masonry* (or RBM) is applied to brick masonry in which reinforcing steel has been embedded to provide additional strength. Typical reinforced brick masonry wall construction is illustrated in Figure 14–9. Notice the construction is basically the same as that of a cavity wall except that reinforcing steel has been placed in the cavity and the cavity was then filled with portland cement grout. Design requirements for reinforced brick masonry are presented in reference 1. A 17-story apartment building constructed with 11-in.-thick (280-mm) reinforced brick masonry bearing walls is shown in Figure 14–10. Prefabricated reinforced brick panels are now being used to provide special shapes in wall construction. Such panels may be rapidly erected in the field, even during inclement weather. The minimum suggested amount of mortar protection for masonry reinforcement is shown in Table 14–2.

Bond Beams and Lintels

A *bond beam* is a continuously reinforced horizontal beam of concrete or masonry designed to provide additional strength and to prevent cracking in a masonry wall. Bond beams are frequently placed at foundations and roof levels but may be used at any vertical interval specified by the designer. Support over openings in masonry walls may be provided by lintels or by masonry arches, as shown in Figure 14–11. *Lintels* are short beams of wood, steel, stone, or reinforced brick masonry used to span openings in masonry walls.

Figure 14–10 Seventeen-story building constructed with reinforced brick masonry bearing walls. (Courtesy of The Brick Industry Association)

Table 14–2 Protection for masonry reinforcement

Application	Minimum Cover (Exposed Face)
Bottom of footings	3 in. (76 mm)
Columns, beams, or girders not exposed to weather or soil	1½ in. (38 mm)
Horizontal joint reinforcement bars ¼ in. (6 mm) or less in diameter	⅝ in. (16 mm)
All other	
Not exposed to weather or soil	1 bar diameter but at least ¾ in. (19 mm)
Exposed to weather or soil	2 in. (51 mm)

Jack arch

Segmental arch

Precast concrete lintel

Reinforced brick masonry lintel

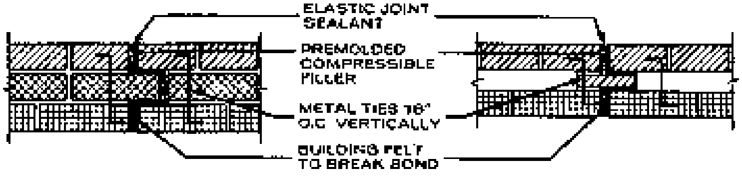
Figure 14–11 Support over openings in brick walls.

Control Joints and Flashings

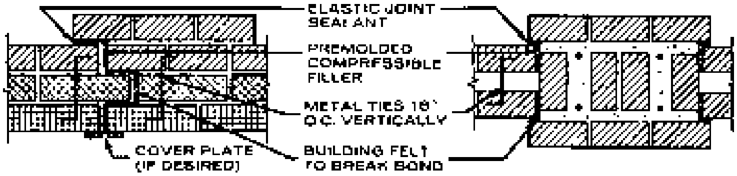
Expansion or *control joints* in masonry walls are used to permit differential movement of wall sections caused by shrinkage of concrete foundations and floor slabs, temperature and moisture changes, and foundation settlement. Control joints are grooves placed in masonry to control shrinkage cracking. The usual procedure is to separate walls into sections with vertical expansion joints where differential movement may occur. Long, straight walls should be divided into sections. Other expansion joints are placed at window and door openings, at columns and pilasters, at wall offsets, at cross walls, and under shelf angles in multistory buildings. Structural bonding across the expansion joint may be provided by interlocking construction or by flexible ties extending across the joint. Some typical expansion joints used for brick walls are shown in Figure 14–12. The exterior of expansion joints must be sealed with a flexible sealant to prevent moisture penetration.

Flashing consists of layers of impervious material used to seal out moisture or to direct any moisture that does penetrate back to the outside. Flashing is used above vertical joints in parapet walls, at the junction of roofs and walls, at window sills and other projections, around chimney openings, and at the base of exterior walls. Typical flashings used with brick masonry are illustrated in Figure 14–13. Flashings used where roofs intersect walls or chimneys are frequently composed of two parts, a base flashing and a counterflashing. The base flashing covers the joint between intersecting surfaces while the counterflashing seals the joint between the base flashing and the vertical surface, as shown in the chimney of Figure 14–13.

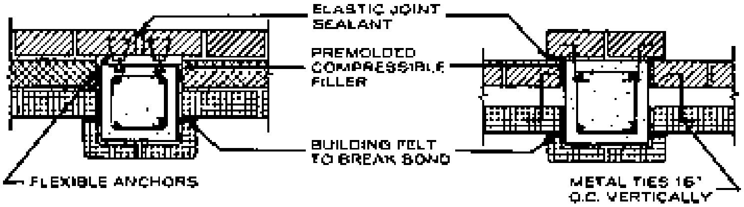
Figure 14–12 Expansion joints in brick masonry. (Courtesy of The Brick Industry Association)



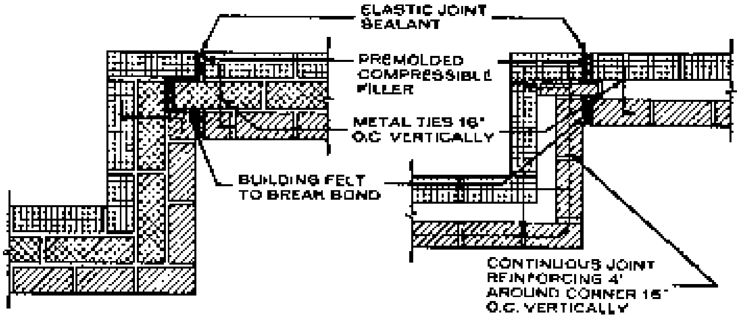
EXPANSION JOINTS IN STRAIGHT WALLS



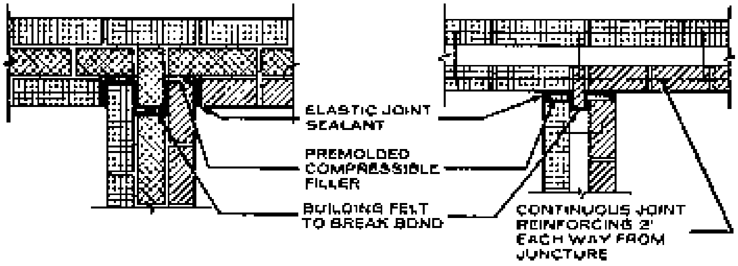
EXPANSION JOINTS AT PILASTERS



EXPANSION JOINTS AT CONCEALED COLUMN



EXPANSION JOINTS AT OFFSETS



EXPANSION JOINTS AT JUNCTURES

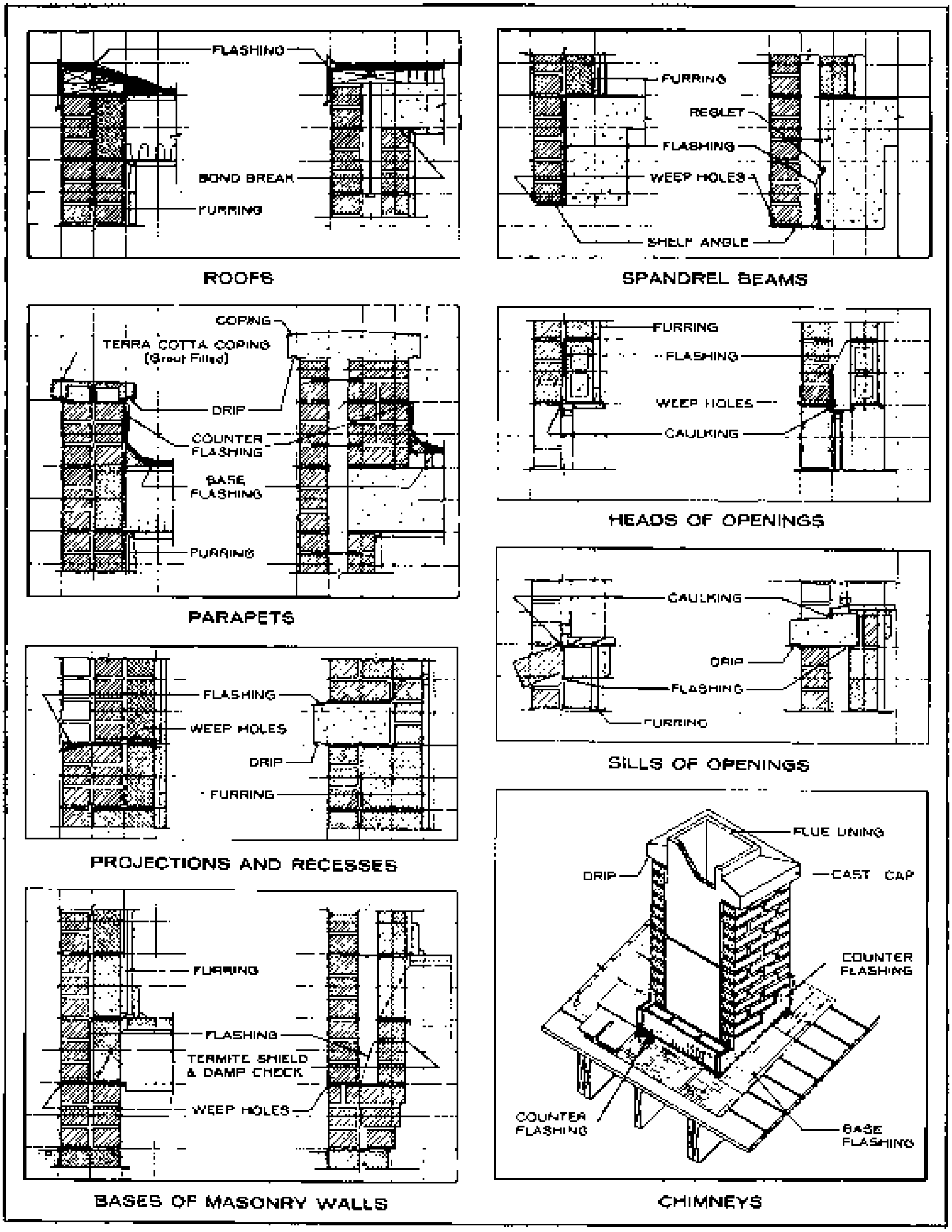


Figure 14–13 Flashing used in brick masonry construction. (Courtesy of The Brick Industry Association)

14–2 CONCRETE MASONRY

Materials

Concrete masonry units are classified as concrete brick, concrete tile, solid load-bearing concrete block, hollow load-bearing concrete block, and hollow non-load-bearing concrete block. Concrete block that is glazed on one or more surfaces is available. Such units are used for their appearance, ease of cleaning, and low cost. *Solid concrete block* must have at least 75% of its cross section made up of concrete. Block having over 25% of its cross-sectional area empty is classified as *hollow block.* The usual hollow concrete block has a core area making up 40 to 50% of its cross section. Typical shapes and sizes of concrete masonry units are shown in Figure 14–14. The most common nominal size of standard block is 8 × 8 × 16 in. (203 × 203 × 406 mm) [actual size 7⅝ × 7⅝ × 15⅝ in. (194 × 194 × 397 mm)]. Half-thick (4-in. or 100-mm) and half-length (8-in. or 203-mm) block are also available. Concrete block is available as either heavyweight or lightweight block, depending on the type of aggregate used. Heavyweight load-bearing block typically weighs 40 to 50 lb (18.1 to 22.7 kg) per unit, while a similar lightweight unit might weigh 25 to 35 lb (11.3 to 15.9 kg). Mortars used for concrete masonry units are the same as those used for brick masonry (Section 14–1). Mortar joints are usually ⅜ in. (9.5 mm) thick. Joints in exterior walls should be tooled for maximum watertightness.

Concrete block may also be laid without mortar joints. Either standard or ground block may be stacked without mortar and then bonded by the application of a special bonding material to the outside surfaces. In this case, the bonding agent provides structural bonding as well as waterproofing for the wall. The time required to construct a concrete block wall using this method may be as low as one-half the time required for conventional methods. In addition, the flexural and compressive strength of a surface bonded wall may be greater than that of a conventional block wall. There are also special types of concrete block made with interlocking edges to provide structural bonding as the units are stacked without mortar.

Lintels spanning openings in concrete block usually consist of precast concrete shapes, cast-in-place concrete beams, or reinforced concrete masonry.

Reinforced Concrete Masonry

Reinforced concrete masonry construction is used to provide additional structural strength and to prevent cracking. Figure 14–15 illustrates several methods of reinforcing a one-story concrete block wall. At the top of the wall a concrete bond beam (A) is created by filling U-shaped block (called lintel block or beam block) with reinforced concrete. Vertical reinforcement is provided by placing reinforcing steel in some of the block cores and filling these cores with concrete (B). Additional horizontal reinforcement is obtained from reinforcing steel placed in the mortar joints (D). This type of construction is appropriate for areas of high design loads, such as earthquake and hurricane zones.

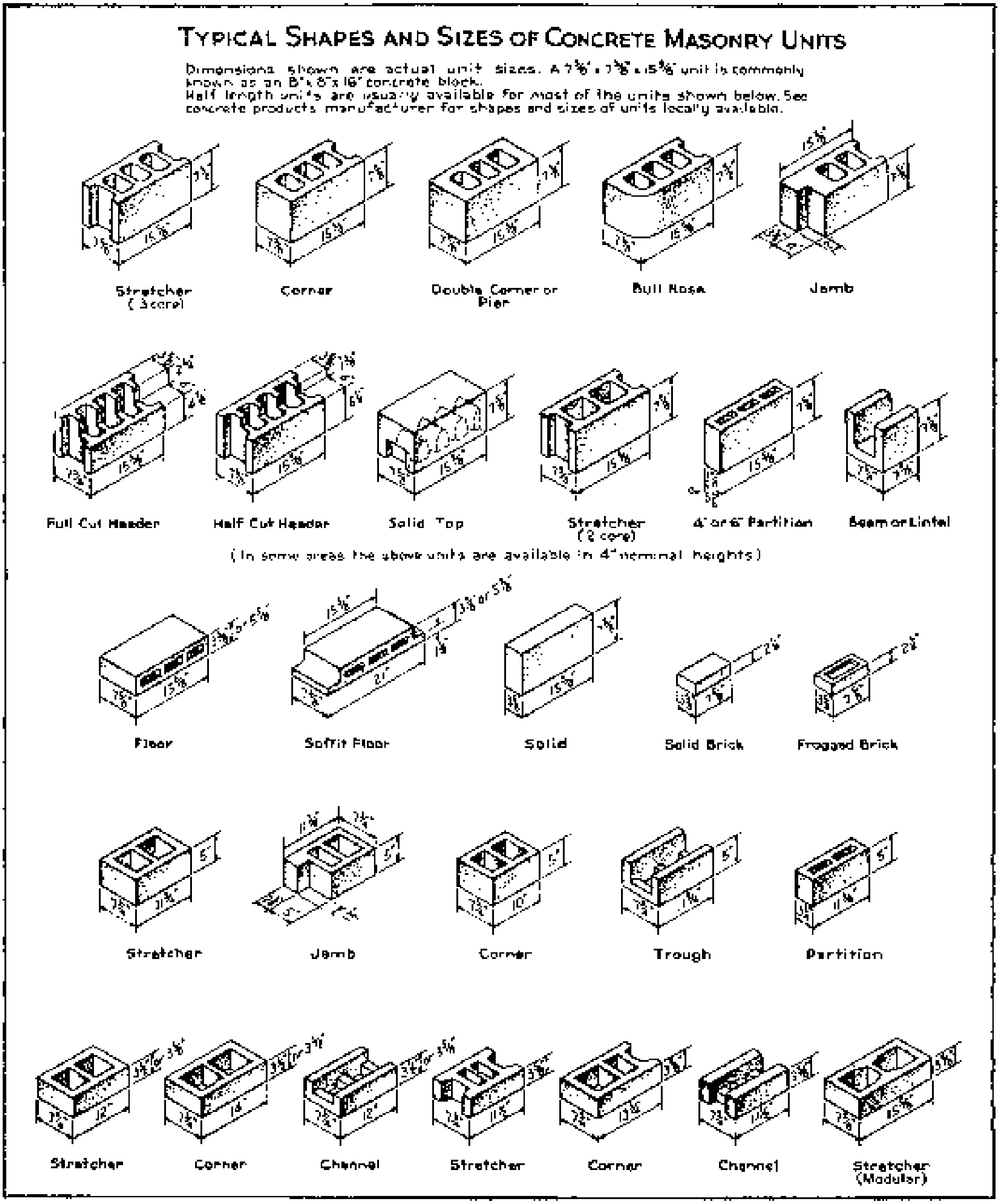


Figure 14–14 Typical concrete masonry units. (Courtesy of Portland Cement Association)

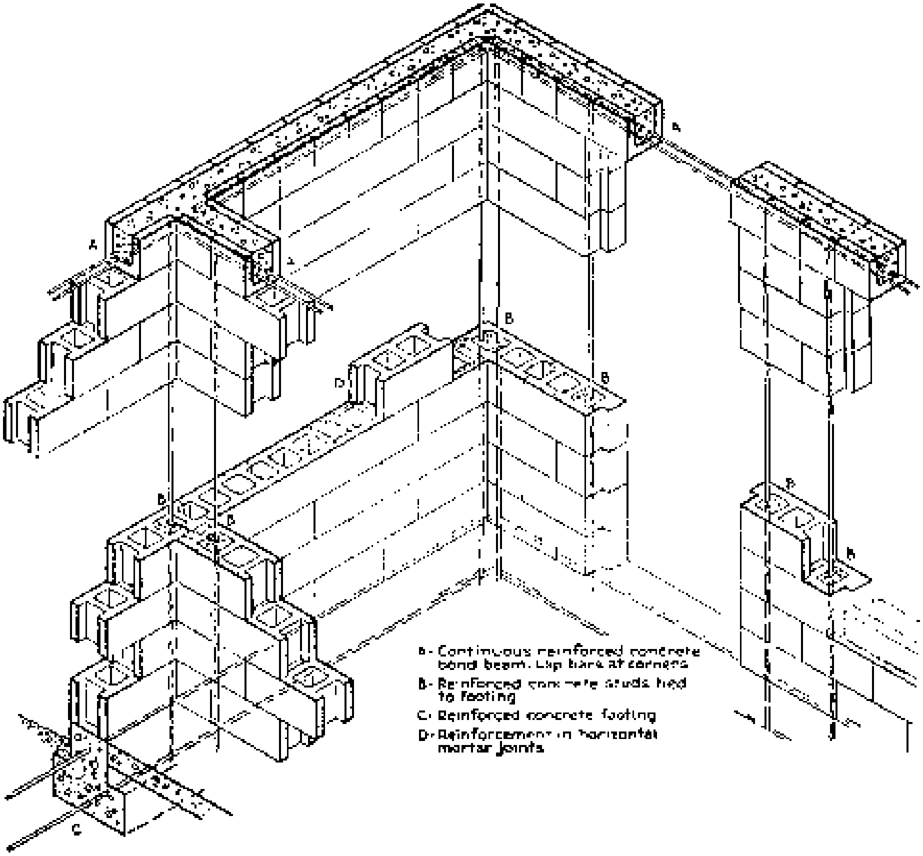
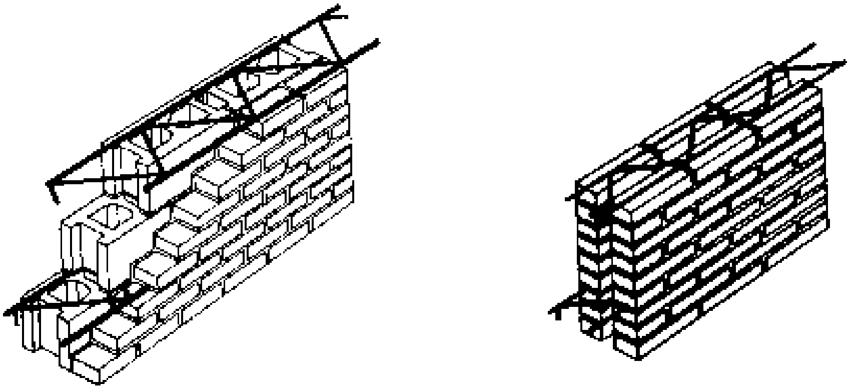


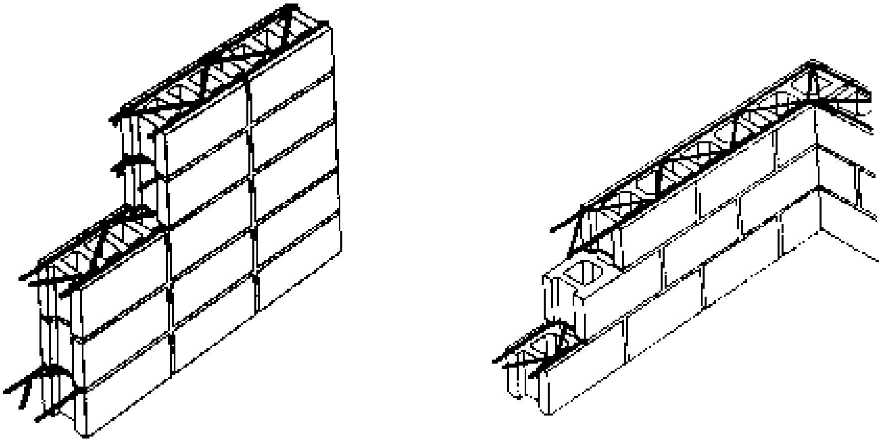
Figure 14–15 Some methods for reinforcing concrete masonry walls. (Courtesy of Portland Cement Association)

Additional applications of horizontal joint reinforcement illustrated in Figure 14–16 include tying face units to backup units, bonding the two wythes of cavity walls, and reinforcing single wythe walls. Reinforced concrete masonry construction is also used in high-rise building construction. Depending on wall height and design load, some or all of the concrete block cores may be filled with reinforced concrete. A high-rise motel using reinforced concrete masonry walls is shown under construction in Figure 14–17. Details of the placement of reinforcement in a reinforced concrete masonry wall are shown in Figure 14–18. Figure 14–19 shows grout being pumped into the block cores of a reinforced concrete masonry wall. The minimum suggested amount of mortar protection for masonry reinforcement is shown in Table 14–2.



Tied wall

Cavity wall



Stack bond wall

Running bond wall

Figure 14–16 Horizontal joint reinforcement. (Courtesy of Dur-O-waL, Inc.)

Pattern Bonds

The running bond is probably the most common pattern bond used in concrete masonry as it is in brick masonry. However, a number of other pattern bonds have been developed to provide architectural effect. Several of these patterns are illustrated in Figure 14–20. The term *ashlar masonry* is carried over from stone masonry and is now commonly used to identify masonry of any material which uses rectangular units larger than brick laid in a pattern resembling stone.

Figure 14–17 Construction of a high-rise motel using reinforced concrete masonry walls. (Courtesy of Portland Cement Association)

Figure 14–18 Placement of reinforcing steel in reinforced concrete masonry wall. (Courtesy of Portland Cement Association)

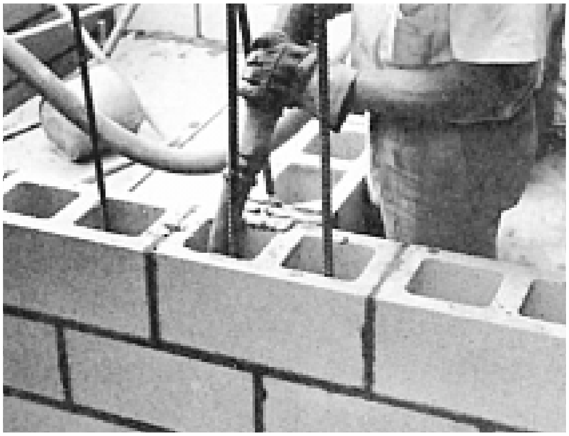


Figure 14–19 Pumping grout into reinforced concrete masonry wall. (Courtesy of Portland Cement Association)

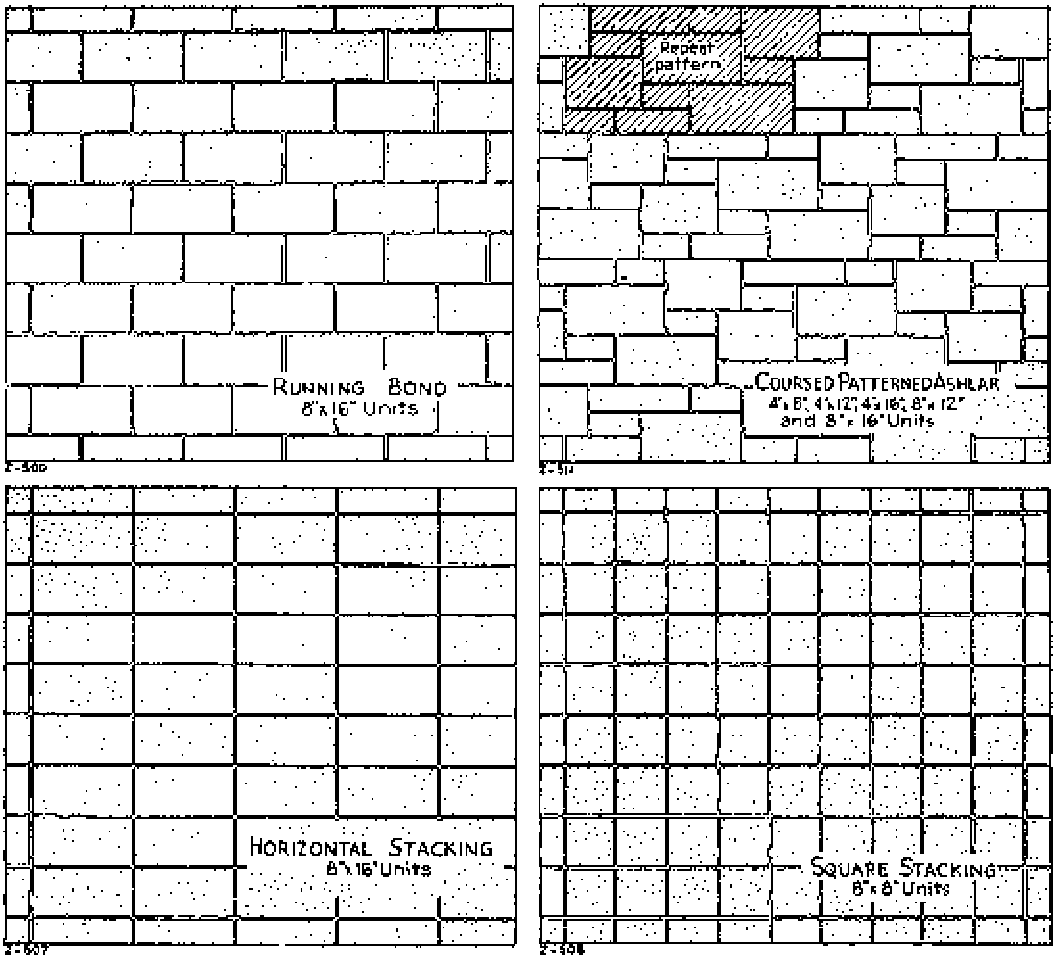
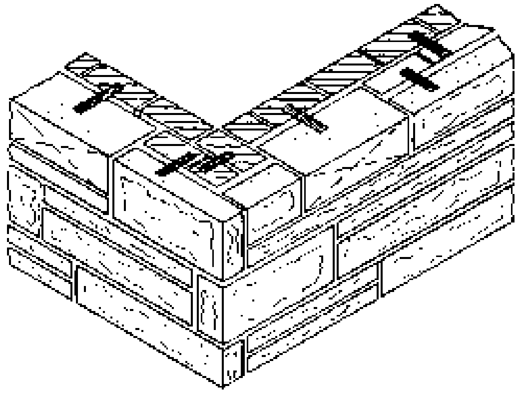


Figure 14–20 Concrete masonry pattern bonds. (Courtesy of Portland Cement Association)

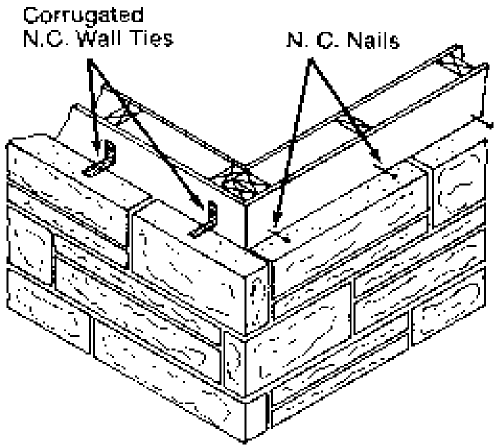
14–3 OTHER MASONRY MATERIALS

In addition to brick and concrete, masonry units of stone and clay tile are also available. Load-bearing structural clay tile is used in a manner similar to concrete block. However, structural clay tile is seldom used in the United States today, and only a small quantity of glazed structural clay tile is currently being manufactured in this country. Stone and architectural terra-cotta are used primarily as wall veneers. Stone veneer is held in place by ties embedded in the mortar joints or by mechanical anchors fastened to the supporting structure, as shown in Figure 14–21. Shaped stone is also used for window sills, lintels, parapet coping (caps), and wall panels. Construction details for use of large architectural stone panels on a multistory building are shown in Figure 14–22.

Figure 14–21 Stone veneer. (Courtesy of Indiana Limestone Institute of America, Inc.)

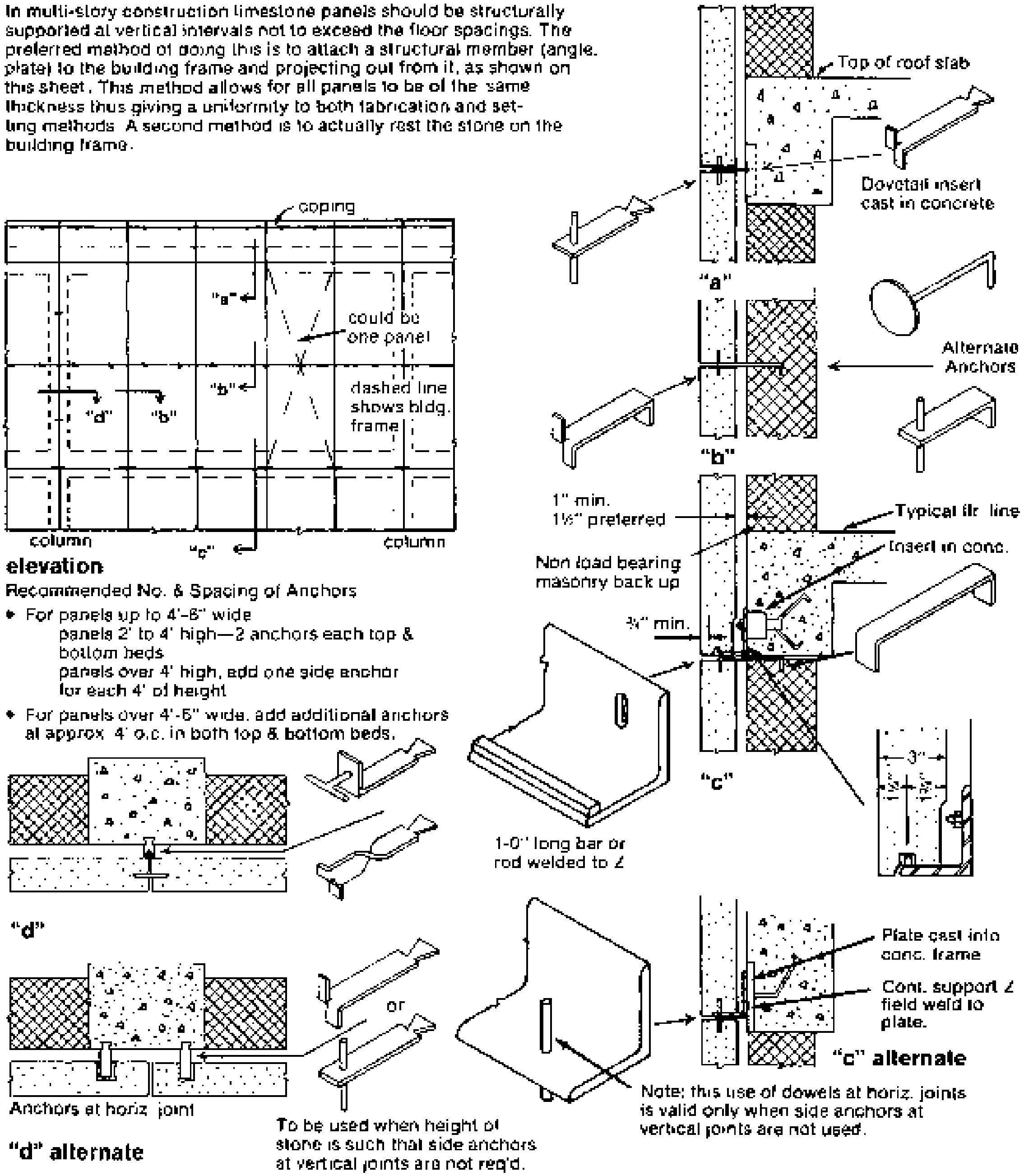


Stone Veneer with Bond Stone Anchored to Brick Backing



Stone Veneer Anchored to Wood Frame Backing

N.C. = noncorrosive



In multi-story construction limestone panels should be structurally supported at vertical intervals not to exceed the floor spacings. The preferred method of doing this is to attach a structural member (angle, plate) to the building frame and projecting out from it, as shown on this sheet. This method allows for all panels to be of the same thickness thus giving a uniformity to both fabrication and setting methods. A second method is to actually rest the stone on the building frame.

elevation

Recommended No. & Spacing of Anchors

- For panels up to 4'-6" wide
  panels 2' to 4' high—2 anchors each top & bottom beds
  panels over 4' high, add one side anchor for each 4' of height
- For panels over 4'-6" wide, add additional anchors at approx. 4' o.c. in both top & bottom beds.

To be used when height of stone is such that side anchors at vertical joints are not req'd.

Note: this use of dowels at horiz. joints is valid only when side anchors at vertical joints are not used.

Figure 14–22 Anchorage of stone panels to multistory building. (Courtesy of Indiana Limestone Institute of America, Inc.)

14–4 ESTIMATING QUANTITY OF MASONRY

Number of Bricks Required

Although tables are available for estimating the quantity of brick required for standard walls, the estimating procedure is not difficult. Estimating the number of bricks required for a masonry wall involves five steps: (1) calculating the net surface area of the wall, (2) calculating the surface area of one brick as positioned (including the mortar joint), (3) dividing the wall area by the surface area of one brick, (4) multiplying this number by the number of wythes of wall thickness, and (5) adding an amount for waste.

First, the gross surface area of the wall is calculated in square feet (m^2) and the area of openings is subtracted to give the net surface area of the wall. Do not double count the area of corners where two walls intersect. Next, the surface area of the brick as positioned (including the mortar joint) is calculated. Dividing the wall net surface area by the surface area of one brick (including the mortar joint) yields the number of bricks per wythe for the wall. The number of bricks per wythe is then multiplied by the wall thickness (number of wythes). Finally, a factor (usually 2–10%) must be added for waste. The method is illustrated in Example 14–1.

EXAMPLE 14–1

Calculate the number of bricks 3¾ × 2¼ × 8 in. (95 × 57 × 203 mm) laid in running bond required for a double wythe wall 8 ft high by 14 ft wide (2.44 × 4.27 m) having one opening 48 × 72 in. (1.22 × 1.83 m) and one opening 32 × 48 in. (0.81 × 1.22 m). Mortar joints are ½ in. (13 mm). Allow 3% for brick waste.

SOLUTION

$$\text{Net wall area} = (8 \times 14) - \frac{(48 \times 72)}{144} - \frac{(32 \times 48)}{144} = 77.33 \text{ sq ft}$$

$$[= (2.44 \times 4.27) - (1.22 \times 1.83) - (0.81 \times 1.22) = 7.2 \text{ m}^2]$$

$$\text{Area of 1 brick} = \frac{(2.25 + 0.5)(8.0 + 0.5)}{144} = 0.1623 \text{ sq ft}$$

$$[= (0.057 + 0.013)(0.203 + 0.013) = 0.01512 \text{ m}^2]$$

$$\text{Number of bricks required} = \frac{77.33}{0.1623} \times 2 \times 1.03 = 982$$

$$\left[= \frac{7.2}{0.01512} \times 2 \times 1.03 = 981\right]$$

Quantity of Mortar Required

A similar procedure can be used to calculate the quantity of mortar required for a particular wall. First, the volume of mortar required for a single brick is calculated. Equation 14–1 may be used for this purpose.

$$\text{Volume per brick (cu in. or m}^3\text{)} = (t)\,(W)\,(L + H + t) \qquad \textbf{(14–1)}$$

where t = joint thickness (in. or m)
W = brick width/depth (in. or m)
L = brick length (in. or m)
H = brick height (in. or m)

Multiplying the mortar required per brick by the number of bricks and adding a waste factor (usually about 25%) yields the mortar required per wythe. When the wall is more than one wythe thick, we must multiply by the number of wythes and add the volume of mortar needed to fill the gap between wythes. The volume of mortar between wythes is simply the product of the joint thickness times the net area of the wall. Again a waste factor must be added. A sample calculation is given in Example 14–2.

EXAMPLE 14–2

Estimate the quantity of mortar required for the problem of Example 14–1. The joint thickness between wythes is ½ in. (13 mm). Assume a 25% waste factor.

SOLUTION

$$\text{Volume per brick} = \frac{(0.5)(3.75)(8.0 + 2.25 + 0.5)}{1728} = 0.01166 \text{ cu ft}$$

$$[=(0.013)(0.095)(0.203 + 0.057 + 0.013) = 0.00033716 \text{ m}^3$$

$$\text{Volume per wythe} = 0.01166 \times \frac{982}{2} = 5.7 \text{ cu ft}$$

$$\left[=0.00033716 \times \frac{981}{2} = 0.165 \text{ m}^3\right]$$

$$\text{Volume between wythes} = \frac{(0.5)}{12}(77.33) = 3.2 \text{ cu ft}$$

$$[=(0.013)(7.2) = 0.094 \text{ m}^3]$$

$$\text{Mortar required} = 1.25\,(2 \times 5.7 + 3.2) = 18.3 \text{ cu ft}$$

$$[=1.25\,(2 \times 0.165 + 0.094) = 0.53 \text{ m}^3]$$

14–5 CONSTRUCTION PRACTICE

Wind Load on Fresh Masonry

Masonry walls must be designed to safely resist all expected loads, including dead loads, live loads, and wind loads. While the designer must provide a safe structural design, the builder must erect the structure as designed and must also be able to determine the support requirements during construction. Many failures of masonry walls under construction have occurred as the result of inadequate bracing against wind load.

The maximum safe height of an unbraced masonry wall under construction may be calculated by setting the overturning moment produced by wind force equal to the resisting moment produced by the weight of the wall. Referring to Figure 14–23, we will analyze moments about the toe of the wall (A) for a unit length of wall. The design wind load in lb/sq ft (kPa) obtained from the local building code may be used to compute bracing requirements. Alternatively, the maximum anticipated wind velocity can be estimated from local weather records and converted to wind load using Table 14–3. The method of analysis is as follows:

$$\text{Overturning moment } (M_o) = P \cdot \frac{h}{2} = qh \cdot \frac{h}{2} = \frac{qh^2}{2}$$

$$\text{Resisting moment } (M_r) = W \cdot \frac{t}{2} = d \cdot h \cdot \frac{t}{2} = \frac{dht}{2}$$

Free equilibrium, $\Sigma M_A = 0$

Hence $M_o - M_r = 0$

and $M_o = M_r$

Substitution yields $\frac{qh^2}{2} = \frac{dht}{2}$

$$h_s = \frac{dt}{q} \tag{14–2}$$

where q = wind force (lb/sq ft or kPa)
H = wall height (ft or m)
h_s = safe unbraced height (ft or m)
t = wall thickness (ft or m)
d = weight of wall per unit of surface (lb/sq ft or kN/m^2)
P = resultant wind force (lb or kPa)
W = resultant weight force (lb or kN)

Typical values for the weight of masonry walls per unit of height are given in Table 14–4. Notice that this analysis does not include any specific factor of safety. However, it does neglect all bonding provided by the partially set mortar. In practice, this should provide an adequate factor of safety except in unusual cases.

The proper bracing of a concrete masonry wall under construction is illustrated in Figure 14–24. Shores, forms, and braces must not be removed until the mortar has

Figure 14-23
Analysis of loads on fresh masonry wall.

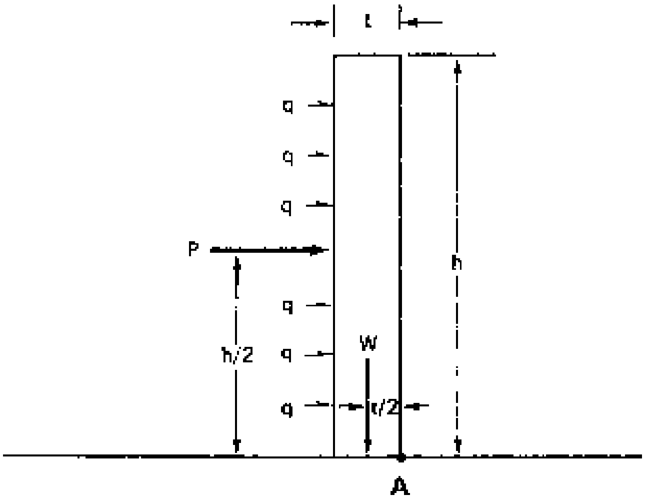


Table 14-3 Design wind load pressure

Wind Velocity		Design Wind Load*	
mi/h	*km/h*	*lb/sq ft*	*kPa*
50	80	6	0.29
60	96	7	0.34
70	112	11	0.53
80	128	15	0.72
90	144	20	0.96
100	161	26	1.24
110	177	32	1.53
120	193	39	1.87
130	209	45	2.15

*Effective wind pressure on ordinary structures less than 30 ft (9.1 m) high in flat, open country (ANSI A58.1-1972).

developed sufficient strength to carry all construction loads. Concentrated loads should not be applied to a masonry wall or column until 3 d after construction.

EXAMPLE 14-3

Find the maximum safe unsupported height in feet and meters for an 8-in. (20-cm) heavyweight concrete block wall if the maximum expected wind velocity is 50 mi/h (80 km/h).

Table 14–4 Typical unit weight for masonry walls

Type of Wall	Weight per Unit of Wall Surface lb/ft^2	Weight per Unit of Wall Surface kN/m^2
Heavyweight concrete block		
4-in. (10-cm)	29	1.39
6-in. (15-cm)	44	2.11
8-in. (20-cm)	56	2.68
12-in. (30-cm)	80	3.83
Lightweight concrete block		
4-in. (10-cm)	21	1.01
6-in. (15-cm)	30	1.44
8-in. (20-cm)	36	1.72
12-in. (30-cm)	49	2.35
Brick (solid)		
4-in. (10-cm)	40	1.92
6-in. (15-cm)	60	2.87
8-in. (20-cm)	80	3.83
12-in. (30-cm)	120	5.75

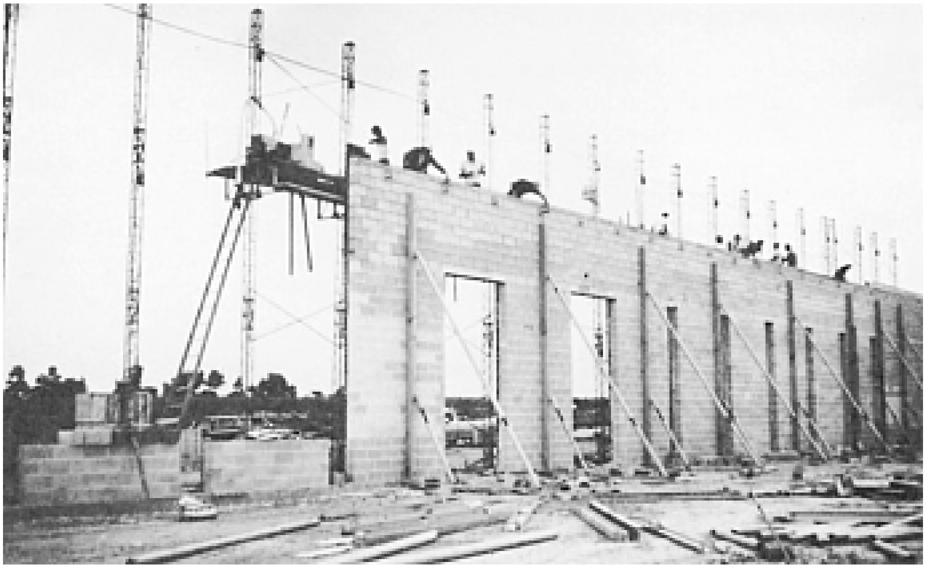


Figure 14–24 Bracing of a concrete masonry wall under construction. (Courtesy of Portland Cement Association)

SOLUTION

$$h_s = \frac{d \times t}{q} \qquad \text{(Eq 14–2)}$$

$$\text{d} = 56 \text{ lb/ft}^2 (2.68 \text{ kN/m}^2) \qquad \text{(Table 14–4)}$$

$$\text{t} = 8/12 \text{ ft } (0.20 \text{ m})$$

$$q = 6 \text{ lb/sq ft } (0.29 \text{ kPa}) \qquad \text{(Table 14–3)}$$

$$h_s = \frac{(56)(8/12)}{6} = 6.2 \text{ ft}$$

$$\left[= \frac{(2.68)(0.20)}{0.29} = 1.9 \text{ m} \right]$$

Masonry Materials

Masonry mortar must meet the requirements of ASTM C270. Sand should be clean and well graded in accordance with ASTM C144. The best mortar workability is obtained when the sand contains particles of all sizes from very fine to coarse. Harsh mortars are produced by sand having insufficient fines while excess fines will result in mortar having good workability but lower strength and high porosity. Machine mixing is recommended but in any case, mixing should continue for at least 3 min. Mortar that has stiffened from evaporation may be retempered by adding additional water and remixing. However, to avoid the possibility of using mortar that has stiffened due to hydration, mortar should be discarded 2½ h after initial mixing.

Placing Masonry and Reinforcement

Concrete masonry units should be stored and laid in a dry condition. Brick having adsorption rates greater than 20 g of water per minute should be wetted before being placed to reduce its absorption rate. However, such brick should be allowed to dry after wetting so that it is in a saturated, surface-dry condition when laid.

Masonry units should be placed with joints of the specified width. Brick should be laid with full bed and head joints. In general, concrete block may be laid with either full mortar bedding or face-shell bedding (illustrated in Figure 14–25). However, full mortar bedding should be used for the bottom or starting course of block and for high-load-bearing units. Tooled mortar joints should be carefully compacted with a finishing tool after the mortar has partially stiffened to provide maximum watertightness. Maximum construction tolerances for brick masonry specified by the Brick Institute of America include vertical or plumb variations of ¼ in. (6 mm) in 10 ft (3 m) and ½ in. (13 mm) in 40 ft (12 m); horizontal or grade variation of ¼ in. (6 mm) in 20 ft (6 m) and ½ in. (13 mm) in 40 ft (12 m) or more; variation from the plan position of ½ in. (13 mm) in 20 ft (6 m) and ¾ in. (19 mm) in 40 ft

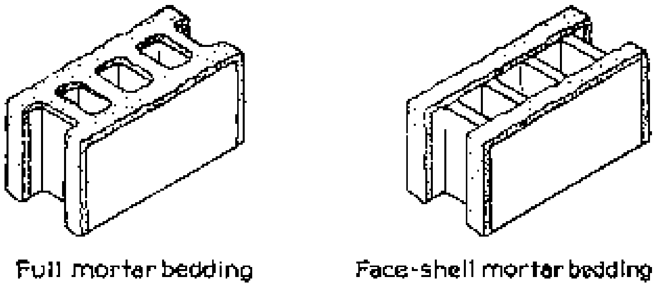


Figure 14–25 Mortar bedding of concrete block. (Courtesy of Portland Cement Association)

(12 m) or more; and variation in section thickness of –¼ in. (6 mm) to +½ in. (13 mm). Reinforcing steel must be protected by the minimum thickness of cover described in Table 14–2. Masonry reinforcement not exceeding ¼ in. (6 mm) in diameter should have a minimum mortar cover of ⅝ in. (16 mm) on exterior faces and ½ in. (13 mm) on interior faces. This type of reinforcement should be lapped at least 6 in. (152 mm) at splices to provide adequate bonding at the splice.

Bonding Masonry

Adequate bonding must be provided where masonry walls intersect, between the wythes of cavity walls or multiple-wythe walls, and between units in stack bond construction. Bonding may be provided by masonry bonding units, by corrosion-resistant metal ties, or by truss or ladder-type masonry reinforcement. The size and spacing of bonding specified by the designer must be used. Care must also be exercised to ensure that expansion joints are properly filled with elastic material and kept clean of mortar and other rigid materials.

Masonry grout is a fluid mixture of cement, sand, and water or cement and water. It may also contain various admixtures. Grout may be used to fill reinforced bond beams, bond together adjacent masonry wythes and their reinforcement, and bond together masonry units and steel reinforcement placed in the hollow cores of masonry units. *Self-consolidating grouts* use a superplasticizing admixture to produce an extremely fluid grout capable of easily filling small spaces within masonry units. The procedures for protecting grout in hot or cold weather conditions are similar to those described next for masonry construction. However, for air temperatures of 25° F (–4° C) or below, grout should be protected by insulating blankets or heated enclosures for 48 h after it is placed unless only Type III cement is used in the grout.

Weather Protection

Concrete masonry units must be dried to the specified moisture content before use. After drying, they should be stored off the ground and protected from rain. The top of exposed concrete and brick masonry under construction should be protected from rain by covering with a waterproof material whenever work is stopped. Masonry walls that are saturated by rain during construction may require months to completely dry out and will undergo increased shrinkage during drying. Efflorescence, or staining of brick surfaces by dissolved salts, often results when brick walls are saturated during construction.

During hot weather, the workability of mortar and the length of time that it remains workable may be considerably reduced. The following recommendations have been made for reducing the effects of hot weather on masonry construction.

Insure that sand is moist; sprinkle sand piles if necessary to maintain moisture.

Store masonry units, mixing equipment, and materials in shaded areas.

Cover mortar boxes and dampen mortar boards.

Use wind breaks to protect construction areas.

Cover masonry walls with plastic at the end of work and/or fog mortar joints after they have obtained initial set.

The precautions for placing masonry units during cold weather are similar to those described in Chapter 12 for placing concrete. When masonry units are to be placed in air temperatures below 40° F (4° C), the requirements of references 2 and 6 should be observed. Some recommended cold-weather construction procedures are described next.

Placing Masonry Units

- Do not lay glass masonry units. Since the units absorb little water, the mortar may be damaged by freezing.
- Heat sand and/or water to obtain a mortar temperature of 40°–120° F (4°–49° C) at time of mixing. However, do not heat sand or water above 140° F (60° C).
- The use of an admixture to lower the mortar freezing point is not recommended. However, a nonchloride-based accelerator may be used to shorten the time required for the mortar to develop sufficient strength to resist freezing. The use of an accelerator does not eliminate the requirement of protecting masonry from freezing but does reduce the time required for protection.
- Do not place masonry on a frozen base or bed, since proper bond will not be developed between the bed mortar and the frozen surface. If necessary, thaw the supporting surface by careful use of heat. Do not lay wet or frozen masonry units.
- For air temperatures below 20° F (–7° C), use a heated enclosure and maintain a temperature above freezing within the enclosure.

Protecting New Construction

- Protect newly laid masonry by covering it with a weather-resistant membrane or insulating blanket for 24 h after placing.
- For air temperatures of 20° F (–7° C) or below, keep newly laid masonry above freezing using heated enclosures or other heating methods for at least 24 h.

The durability of completed masonry panels during freeze-thaw cycles has been evaluated in laboratory tests sponsored by the Portland Cement Association. It was found that masonry panels constructed from durable brick and air-entrained ASTM C270 Type S mortar and air-entrained Type S masonry cement could withstand prolonged exposure to severe freeze-thaw conditions without damage. However, masonry panels constructed with the same brick and Type S mortar with low air content suffered frost damage ranging from slight to severe.

PROBLEMS

1. Estimate the number of 3¾ × 2¼ × 8-in. (95 × 57 × 203-mm) bricks required for a double-wythe wall 8 ft high × 30 ft wide (2.44 × 9.14 m) having one opening 48 × 72 in. (1220 × 1830 mm) and three openings 26 × 48 in. (660 × 1219 mm). Mortar joints are ½ in. (13 mm). Assume 3% brick waste.
2. If the cost of brick construction in place is $880 per 1000 bricks, estimate the cost of the brick exterior wall for the following building. The building is rectangular with a perimeter of 100 ft (30.5 m). The wall is 8 ft (2.44 m) high with one opening 36 × 80 in. (914 × 2032 mm) and 10 openings 30 × 48 in. (762 × 1220 mm). The brick is 3¾ × 2¼ × 8 in. (95 × 57 × 203 mm) laid in running bond, double wythe.
3. Explain the meaning of the terms *course* and *wythe* as used in masonry construction.
4. a. Describe how masonry units should be stored at a construction site.
   b. Why and how should masonry walls be protected before the building roof is put in place?
5. What is the minimum mortar cover required for a No. 3 rebar located near the exterior face of a reinforced concrete masonry wall exposed to weather?
6. Estimate the amount of mortar required for the brick wall of Problem 3 if the joint between wythes is ⅝ in. (16 mm). Assume 25% mortar waste.
7. Find the maximum safe unsupported height of a 6-in. (150-mm) solid brick wall if the design wind load is 15 lb/sq ft (0.72 kPa).
8. In what situations might the methods for reinforcing concrete block walls illustrated in Figure 14–15 be needed?
9. How long after initial mixing may mortar be used before discarding?
10. Develop a computer program to calculate the maximum safe height of an unbraced masonry wall under construction using Equation 14–2. Solve Problem 7 using your program.

REFERENCES

1. *Building Code Requirements for Masonry Structures and Specifications for Masonry Structures and Commentaries (ACI 530-05/ASCE 5-05/TMS 402-05 and ACI 530.1-05/ASCE 6-05/TMS 602-05).* Reston, VA: ASCE, 2005.

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3. *Masonry Structures: Behavior and Design*. Brick Institute of America, Reston, VA.
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5. *Recommended Practice for Engineered Brick Masonry*. Brick Industry Association, Reston, VA.
6. *Recommended Practices and Guide Specifications for Cold Weather Masonry Construction.* International Masonry Industry All-Weather Council, International Masonry Institute, Washington, DC, 1992.
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