A veneer is a nonstructural facing used as a decorative or protective covering. Masonry veneers are among the most popular applications of masonry in the United States and Canada. Most of the masonry used in residential construction is used as a veneer attached to wood or sometimes to metal stud backing walls. Brick, concrete block, and stone are all used as masonry veneers, but brick veneer is by far the most common. Unlike masonry foundation and basement walls, masonry veneers are not designed to support the weight of the structure itself, but must resist lateral wind and earthquake loads and, in most cases, support their own weight. Masonry veneers must be carefully designed and constructed to accommodate moisture penetration through the facing without causing damage to the structure or leakage to the interior.

7.1 Veneer Anchorage

There are two basic methods of attaching masonry veneer. Adhered veneer is secured by adhering the veneer with mortar to a solid backing wall. This method of attachment is usually reserved for thin veneers that are not capable of supporting their own weight. In residential construction, adhered veneer is not common but might be used to attach thin stones to an exposed concrete or masonry foundation.
Anchored veneer is secured by metal anchors attached to either a solid backing wall or a stud wall. An anchored masonry veneer supports its own weight, resting directly on the slab or foundation wall. Building codes regulate the design of masonry veneers by prescriptive requirements based on empirical data. The CABO One and Two Family Dwelling Code requires that masonry veneers be supported on non-combustible construction, and limits the height of masonry veneers over wood frame backing walls to 30 feet above the foundation with an additional 8 feet at gable ends.

Anchored masonry veneers transfer lateral loads to the backing wall through metal anchors and their fasteners. Flexible veneer anchors permit slight horizontal and vertical movement parallel to the plane of the wall but resist tension and compression forces perpendicular to it. Corrugated sheet metal anchors are typically used in residential construction. These should be 22-gauge galvanized steel, 7/8 in. wide × 6 in. long. Corrosion-resistant nails should penetrate wood studs a minimum of 1-1/2 in., exclusive of sheathing thickness. Galvanized or stainless steel screws should be used to attach corrugated anchors to metal studs. Corrugated anchors are relatively weak in compression compared to commercial veneer anchors, and they provide load transfer only if the horizontal leg is properly aligned in plane with the mortar bed joint and one of the two fasteners is positioned at the 90° bend (Figure 7-1). Anchors randomly attached to the backing wall and bent at odd angles to fit into the mortar joints are ineffective. Masonry veneer anchors must be embedded in the mortar joint a minimum of 1-1/2 in. for lateral load transfer and have a minimum mortar cover of 5/8 in. to the outside of the wall to prevent corrosion of the metal (Figure 7-2). Anchors should be placed within the mortar so that they are completely encapsulated for maximum pull-out strength. An anchor that is placed on the dry masonry and mortared only on top has only about half the strength of an anchor that is properly embedded.

Masonry veneer is typically connected to metal stud frames with 9-gauge corrosion-resistant wire anchors hooked through a slotted connector for flexibility (Figure 7-3). Anchors are attached to the studs with galvanized or stainless steel self-tapping screws. The use of brick veneer over metal stud backing is relatively recent in the long history of masonry construction. For one- and two-story buildings with lim-
ited floor-to-floor heights, the necessary stiffness might be achieved with 18-gauge studs, depending on wind load factors. Increased floor-to-floor heights, higher wind loads, and taller structures will generally require studs that are a minimum of 16 gauge. Stud spacing should not exceed 16 in. on center, and the studs should be hot-dip galvanized, especially in coastal climates and other corrosive environments.

Another method of masonry veneer attachment recognized by some building codes and by HUD “Minimum Property Standards” uses galvanized 16-gauge 2 × 2-in. paper-backed, welded wire mesh attached to metal studs with galvanized wire ties, or to wood studs with galvanized nails. Wire anchors are then hooked through the mesh, and the 1-in. space between veneer and backing is grouted solid (Figure 7-4). This is a much less common technique and offers no real advantage of performance or economy for unit masonry veneers. For construction of rubble stone veneer where coursing heights
are random, this method of attachment allows greater flexibility in the placement of anchors for proper alignment with mortar bed joints.

Where a masonry veneer is attached to concrete masonry backing, such as an above-grade foundation wall, the anchorage is usually in conjunction with the horizontal joint reinforcement used to control shrinkage cracking in the CMU. For walls in which the backing and facing wythes are both of concrete masonry, three-wire joint reinforcement can be used (Figure 7-5a). Two of the longitudinal wires are embedded in the face shell bed joints of the block and the third wire is embedded in the veneer bed joint. If the wythes are laid up at different times, however, the three-wire design makes installation awkward. Three-wire joint reinforcing should also not be used when insulation is installed in the cavity between wythes because the wires are too stiff to allow for differential thermal movement between the backing and facing wythes. For walls in which the backing and facing wythes are laid at different times, walls with clay brick facing and CMU backing, or walls which contain insulation in the cavity between wythes, joint reinforcement with adjustable ties allows differential movement between wythes and facilitates the installation of the outer wythe after the backing wythe is already in place (Figure 7-5b). The adjustable ties may be either a tab or hook and eye design.

In Seismic Zones 0, 1, and 2, masonry veneer anchors may be spaced not more than 32 in. on center horizontally and support not more than 2.67 square feet of wall area. Since the anchors are attached to the studs and must be embedded in the mortar joints, the stud spac-
ing, unit size, and coursing heights affect the exact anchor placement. If the studs are spaced 24 in. on center, the maximum anchor spacing would be 24 in. on center horizontally \( \times 16 \) in. on center vertically (every sixth course of brick or every second course of concrete block). If the stud spacing is 16 in. on center, the maximum anchor spacing would be 16 in. on center horizontally \( \times 24 \) in. on center vertically (every ninth course of brick or every third course of concrete block).

Stone veneer is attached in the same way as brick veneer, but the anchor spacing must compensate for the irregularities of mortar bed height and still meet code requirements. An anchor spacing of 16 in. on center, for example, may not accommodate the coursing height of rough stone. If vertical spacing must be increased so that anchors align properly with the bed joints, horizontal spacing may have to be decreased to stay within the maximum allowable wall area supported by each anchor.

In Seismic Zones 3 and 4, and in areas subject to wind loads of 30 psf (108 mph) or more, each veneer anchor may support a maximum of 2 sq. ft. of wall area. This requires a stud spacing of 16 in. on center and an anchor spacing of 16 in. on center horizontally \( \times 16 \) in. on cen-

Joint reinforcement with veneer anchorage.

b. JOINT REINFORCEMENT WITH ADJUSTABLE TIES

THREE-WIRE LADDER TYPE

THREE-WIRE TRUSS TYPE

a. THREE-WIRE JOINT REINFORCEMENT
ter vertically. In Seismic Zones 3 and 4, veneer anchors must also be mechanically attached to continuous horizontal reinforcement of 9-gauge wire (W1.7). Special seismic anchors are made for such applications (Figure 7-6). Lap splices in the wire reinforcement should occur between veneer anchors. Some manufacturers also make prefabricated joint reinforcement with adjustable seismic veneer anchors for block walls with brick veneer.

7.2 Veneer Support Above Grade

Where a portion of a masonry veneer wall occurs over a lower roof area or balcony, support can be provided in one of two ways. The Code requires that a steel angle be installed to carry the masonry and that the angle either be attached to and supported by the stud frame, or resting on framing members sized to carry the additional load with a maximum deflection of \( \frac{1}{600} \) of the span (Figure 7-7). The masonry should not rest directly on the wood framing or sheathing. Where veneer supported above grade adjoins masonry supported on the foundation, a control or expansion joint is required to prevent cracking caused by differential movement. If the masonry is above a sloping roof, the supporting angles may be attached to the studs as a series of short sections which step down the slope. Masonry installed on a sloping angle must be leveled with a mortar bed and will not be as stable.

7.3 Lintels and Arches

Noncombustible lintels of steel, reinforced masonry, stone, concrete, precast concrete, and cast stone are typically used to span openings in masonry veneer walls. Masonry arches perform the same function of supporting the masonry above the opening and transferring the weight to the wall sections on either side. Arches carry loads in compression, but lintels act as flexural members spanning horizontally from one support to the other (Figure 7-8). Lintels must resist compressive, bending, and shear stresses (Figure 7-9). Lintels and arches must be analyzed to determine the loads which must be carried and the resulting stresses which will be created in the member. Many of the cracks that appear over door and window openings result from excessive deflection of lintels which have been improperly or inadequately...
Supporting masonry veneer above grade. *(from Council of American Building Officials, One and Two-Family Dwelling Code, Falls Church, VA).*
designed, and arches may crack because of structural instability.

The most common method of supporting the masonry above openings is with loose steel angle lintels. A length of steel angle rests on the masonry on either side of the opening but is not attached to the backing wall. It should have a minimum bearing length of 4 in. on each side of the opening and be positioned so that it supports at least \( \frac{2}{3} \) of the masonry thickness. Loose steel lintels allow the work to proceed quickly without the need for temporary shoring or a curing period. Cast stone and precast concrete lintels also provide immediate support but require two workers or more for lifting the heavy sections in place. Cast stone lintels are popular because they add elegant detailing with greater strength and lower cost than natural stone. A minimum end bearing of 8 in. is recommended for cast stone, reinforced concrete, and CMU lintels.

When masonry is laid in running bond, it creates a natural, corbeled arch (Figure 7-10). In fact, before true masonry arches were invented, corbeled arches, vaults, and domes were used to span openings. Lintels must be designed to carry the weight of the masonry inside the triangle formed by the line of such arching action. This triangular area has sides at 45° angles to the lintel, and its height is therefore one-half the span length (Figure 7-11). Outside this area, the weight of the masonry is assumed to be carried to the supporting abutments by natural arching. For this assumption to be true, however, the arching action must be stabilized by 8–16 in. of masonry above the top of the triangle. If arching action cannot be assumed to occur because of inadequate height above the load triangle, or because the masonry is not laid in running bond, the lintel must be sized to carry the full weight of
the wall above its entire length (Figure 7-12). When arching action is assumed, the lintel requires temporary support until the mortar has cured sufficiently to allow the masonry to assume its share of the load.

Arching action produces an outward horizontal thrust at each support or abutment. The abutments, therefore, must have sufficient mass to resist this force. If the opening is near a corner or close to another opening, or if an expansion or control joint occurs at the side of the opening, it may again be necessary to size the lintel large enough to carry all of the loads above its entire length, without assuming any arching action in the masonry. Once the total load on the lintel is known, it can be appropriately sized by an engineer to resist the calculated stresses. Lintel deflection should be limited to $1/600$ of the span to avoid cracking the masonry.

Steel angles are the simplest lintels to use for masonry veneers and are suitable for openings of moderate width such as windows and doors. For wider openings such as garage doors, double lintels or steel beams with suspended plates may be required (Figure 7-13). The horizontal leg of a steel angle should be at least 3 in. wide to adequately support a nominal 4-in. wythe of brick, block, or stone. Generally, angles should be a minimum of $1/4$ in. thick to satisfy code requirements for exterior steel members. Precast concrete, reinforced masonry,
and cast stone lintels are also used to span openings in masonry veneer walls. Span length for any type of lintel will depend on the strength of the member. In steel lintels, increasing size and thickness provide greater strength. In concrete and masonry lintels, reinforcing steel increases strength and span capabilities. CABO requirements provide that lintels in masonry veneer walls may have maximum spans as provided in Figure 7-14.

Arches may be constructed in various forms such as segmental, elliptical, Tudor, Gothic, semicircular, parabolic, flat or jack arches (Figure 7-15). The semicircular and segmental are perhaps the most popular and widely used arch forms in contemporary design and construction. The primary structural advantage of an arch is that under uniform loading conditions, the stress is principally compression rather than tension. This is very efficient structurally since masonry’s...
resistance to compression is greater than its resistance to tension. Arches generally are selected as an alternative to lintels not because of their efficiency, however, but because their style suits the architectural design of the home. Arches whose spans do not exceed 6 ft. are called minor arches, and they are most often used in building walls over door and window openings. Major arches whose spans are wider than 6 ft. require engineering design. The terminology used to describe the various parts of an arch are illustrated in Figure 7-16.

The steps in building a masonry arch are simple, but good workmanship is essential. Arches are constructed over temporary shoring or centering to carry the dead load of the material and other applied loads until the arch itself is completed and the mortar has cured to sufficient strength (Figure 7-17). Cut two \( \frac{3}{4} \)-in. plywood sections to the size and shape shown on the architectural drawings and nail them on either side of 2\( \times \)4s (Figure 7-18). If the arch is a single brick wythe in
thickness, lay the 2×4s flat. If the arch is more than one wythe thick with the soffit exposed such as at an entry porch, lay the 2×4s the other way. Place the centering flat on the ground and lay out the arch pattern by positioning the masonry units around it. There should always be an odd number of units or *voussoirs* so that the center unit or *key* falls exactly at the center of the arch. All units should be full size and the joints should be spaced evenly. Mark the position of the units on the plywood to serve as a guide during construction. Place a strip of roofing felt or polyethylene over the centering to keep mortar from sticking to it. Recess the centering from the face of the wall slightly so that the mortar joints can be tooled easily. Hold the centering in place with temporary wood posts and wedges until at least seven days after the arch is completed. Begin building the arch at the ends or abutments. Lay the brick or stone from each end toward the middle. In stone arches, take care to cut and lay the stone accurately with thin joints to prevent settling of heavy units.

Brick arches can be built of special wedge-shaped brick or stone so that the mortar joints are of uniform thickness, or they can be built of standard rectangular brick with joint thicknesses varied to obtain the
Steel angle lintels.
required curvature. With standard brick the mortar joints are narrower at the bottom than at the top, but should be a minimum of \( \frac{1}{4} \) inch. Units laid in a soldier course will have a more pronounced variance in the joint thicknesses. Two or more courses of rowlocks can be more attractive, particularly with arches of relatively short span (Figure 7-19).

Although the shape and placement of each unit are most important in the structural stability of an arch, mortar keeps the units from sliding, and it is especially important that the mortar joints be completely filled. It can be difficult to achieve full joints in soldier courses because the mortar tends to slump toward the bottom of the joint as the unit is placed. Full mortar joints are easier to achieve with rowlock courses. mortar can be omitted from the bottom of the arch during construction and tuckpointed after the centering is removed. This will help avoid stains on the bottom brick surfaces and will also make it possible to tool the bottom joints properly. A wooden dowel of the

<table>
<thead>
<tr>
<th>Size of Angle For Steel Angle Lintels</th>
<th>Number of ( \frac{1}{2} &quot; ) or Equivalent Reinforcing Bars in Masonry or Concrete Lintels‡</th>
<th>Less Than One Story of Masonry Above Lintel</th>
<th>Lintel Supporting One Story of Masonry Above Opening</th>
<th>Lintel Supporting Two Stories of Masonry Above Opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 3 \times 3 \times \frac{3}{4} )</td>
<td>1</td>
<td>6'( -0 &quot; )</td>
<td>3'( -6 &quot; )</td>
<td>3'( -0 &quot; )</td>
</tr>
<tr>
<td>( 4 \times 3 \times \frac{3}{4} )</td>
<td>1</td>
<td>8'( -0 &quot; )</td>
<td>5'( -0 &quot; )</td>
<td>3'( -0 &quot; )</td>
</tr>
<tr>
<td>( 6 \times 3\frac{3}{4} \times \frac{3}{4} ) two</td>
<td>2</td>
<td>14'( -0 &quot; )</td>
<td>8'( -0 &quot; )</td>
<td>3'( -6 &quot; )</td>
</tr>
<tr>
<td>( 6 \times 3\frac{3}{4} \times \frac{3}{4} )</td>
<td>4</td>
<td>20'( -0 &quot; )</td>
<td>11'( -0 &quot; )</td>
<td>5'( -0 &quot; )</td>
</tr>
</tbody>
</table>

*Long leg of angle shall be in vertical position.
†Steel members indicated are adequate typical examples. Other steel members meeting structural design requirements may be used.
‡Depth of reinforced lintels shall not be less than 8 inches, and all cells of hollow masonry lintels shall be grouted solid. Reinforcing Bars shall extend not less than 8 inches into the support.

FigurE 7-14

Allowable lintel spans. (from Council of American Building Officials, One and Two-Family Dwelling Code, Falls Church, VA).

Masonry Veneer
appropriate size placed at the bottom of the joint will maintain the correct joint width and unit spacing (Figure 7-20). Place a full \( \frac{3}{8} \)-in. mortar joint along the top of the arch and cut adjacent units to fit against the curve.

### 7.4 Drainage Cavity

Most codes require a minimum 1-in. space between a masonry veneer and its backing and permit the space to be solidly grouted as the veneer is laid, or left open to form a drainage cavity. Anchored masonry veneers are usually designed with an open drainage cavity. Moisture will always penetrate a masonry veneer, even with good design, good detailing, and good workmanship. A certain amount of moisture penetration is expected in most climates. The greater the exposure to wind-driven rain, the more moisture will penetrate the wall. Drainage cavities increase the level of performance and the longevity of the wall system by removing moisture from the wall rapidly. This allows natural wetting and drying to occur without damage to the masonry or to the backing wall.

Wood stud walls behind a masonry veneer must be covered with either a water-repellent gypsum sheathing, a moisture-resistant insulating sheathing, or a plywood or OSB sheathing covered with moisture-resistant asphalt felt or polyolefin house wrap. Gypsum sheathing with a moisture-resistant facing is typically used over metal stud construction with additional protection against corrosion.
provided by applying a layer of 15-lb. asphalt-saturated felt or polyolefin house wrap over the sheathing. The felt or house wrap should be lapped shingle style in horizontal layers to shed moisture (Figure 7-21). If the space between the masonry and the backing is grouted, paper-backed welded wire mesh may be attached directly to the studs in lieu of sheathing.

Where masonry veneers are installed over a concrete or concrete masonry backing wall, the cavity face of the backing wall should be coated with a mastic damp-proofing to provide increased moisture resistance. Mastics can be applied by brush, roller, or spray and should be carefully worked around anchors, plumbing, and electrical penetrations to provide an adequate seal (Figure 7-22).

The drainage cavity type of veneer construction provides the best long-term serviceability, but the cavity must be fitted with flashing and weep holes as described below, and kept clear of mortar droppings for drainage to be effective. The masonry industry recommends a minimum drainage cavity width of 2 in. because it is felt that a narrower cavity is difficult for a mason to keep clean during construction. A narrow cavity is also more easily bridged by mortar protrusions, which greatly increases the likelihood of moisture leakage through any defect which might exist in the backing wall. With a clean and unobstructed cavity, moisture which penetrates the face of the masonry runs down the back of the veneer and is collected on the flashing and drained through weeps.

### 7.5 Flashing and Weep Holes

Full head and bed joints and good bond of mortar to units will minimize moisture penetration directly through the face of a masonry
Masonry veneer, but it is virtually impossible to entirely prevent moisture from entering a masonry wall. Masonry veneer walls require the installation of flashing and weep holes for the collection and discharge of moisture which penetrates the exterior wall face or condenses within the wall. This is true regardless of whether the space behind the veneer is intentionally left open for drainage or grouted solidly with mortar. The flashing is used to intercept and collect moisture at strategic locations within the wall, and weeps are used to direct the moisture to the outside of the wall.
Masonry flashing can be made of metal, rubberized asphalt, plastic, or rubber sheet membranes and other composite materials. There are several criteria to consider in selecting flashing materials:

- Imperviousness to moisture penetration
- Resistance to corrosion from the caustic alkalies in mortar
- Resistance to puncture, abrasion, and other damage during construction
- Formability
- Resistance to environmental deterioration

Cost should be considered only after other criteria are met. The quantity of flashing in a building is relatively small, and even a big savings in material cost is seldom significant in the overall project budget.

Plastic flashings are widely used in residential construction. They are inexpensive and easy to handle, and many are tough and resilient. Polyvinyl chloride (PVC) flashings are the most common among the plastic flashing materials. They are homogeneous and impermeable to...
moisture, and most retain good flexibility even in low temperatures. Thin plastic flashings are also easily torn or punctured during construction, so thickness should be a minimum of 20 mils, but preferably 30 mils or more. Puncture resistance can be added to plastic flashings with fiberglass scrim reinforcement when it is embedded between two sheets, and the overall required thickness is then greatly reduced. Metal foils can also be combined with fiberglass-reinforced plastics to form lightweight, durable flashings. Most recently, rubberized (or polymer modified) asphalt flashing materials have been introduced in the masonry industry and have enjoyed ready acceptance from design professionals and masons alike. The rubberized asphalt is self-adhering and self-healing of small punctures. Once the workers become accustomed to handling the material, it installs quickly and easily and is relatively forgiving of uneven substrates. Thorough cleaning of the substrate surface, however, is critical in obtaining good adhesion. Metal flashings such as copper and stainless steel are more commonly used in commercial construction, but on high-end homes, the extra durability provided may justify the additional cost.

Lengths of flashing should be lapped 3–4 in. and sealed so that water cannot penetrate at the seams, and the flashing should be continuous around both internal and external corners. PVC and rubberized asphalt flashings cannot tolerate UV exposure, so they are typically brought beyond the face of the wall and then trimmed flush after the masonry is in place (Figure 7-23). It is important not to stop the flashing short of the exterior wall face, or water may not be properly drained from the cavity. Rubberized asphalt flashing, when properly adhered, prevents water from flowing back underneath the membrane and re-entering the wall. A formed drip edge on metal flashing also

Trim flexible flashing flush with face of wall after installation. (photo courtesy Brick industry Association).
prevents water from flowing back into the wall. The inside leg of the
flashing should turn up about 8 in. and be tucked underneath the felt
paper or house wrap membrane, or underneath the sheathing itself
(see Figure 5-25 in Chapter 5). If the backing wall is masonry, metal
flashing should be tucked into a mortar joint and membrane flashings
carefully adhered to the face of the block.

Flashing forms only half the moisture control system in a
masonry wall. By itself, flashing collects water that enters the wall,
but weep holes are necessary to provide the drainage mechanism that
lets the water back out again. There are several types of weepholes
commonly used. The most effective, but least attractive, are open
head joints. Because mortar is left out of the head joint completely,
the system has ample drainage and evaporative capacity for even the
most severe coastal rain conditions, and so can be spaced at intervals
of 24 in. Metal weep hole ventilators and plastic grid type vents
improve the aesthetics of the open joint without obstructing free
drainage (Figure 7-24).
Plastic tube weepholes are less conspicuous in the wall than open joints, but they are also much less effective. The smaller drainage capacity requires that spacing be reduced to 16 in. on center, and much greater care in construction is also required to avoid blocking the narrow tubes with mortar droppings (Figure 7-25). Cotton wick weeps avoid the problems associated with plastic tubes but still provide better aesthetics than open joints. A length of cotton rope 10–12 in. long is placed in head joints at 16 in. on center, extending through the veneer and up into the cavity well above the height of any possible mortar droppings (Figure 7-26). The rope can be tacked to the backing wall or adhered to it with a splash of mortar to keep it from falling over during construction. After installation, the exposed portion of the
Cotton wick weeps.

Cotton wick weeps.
Figure 7-27

Veneer detailing. (adapted from Council of American Building Officials, One and Two-Family Dwelling Code, Falls Church, VA).
wick is clipped flush with the wall. Moisture in the cavity is absorbed by the cotton material and “wicked” to the outside face of the wall, where it evaporates. The rope will eventually rot, but it leaves an open hole for continued drainage. The rope must be cotton rather than nylon to be effective.

Through-wall masonry flashing must be installed at lintels above door and window openings, at window sills and ledges, and at the base of the wall. Weepholes must be installed in the first masonry course immediately above the flashing. The wall sections in Figure 7-27 illustrate basic requirements of the CABO One and Two Family Dwelling Code. Brick masonry sills should be sloped to drain water away from the window. The masonry industry recommends a minimum slope of 15 degrees. The flashing system must form a complete barrier to the passage of water. Masonry veneer should always rest on a ledge recessed below the finish floor line so that the flashing at the bottom of the drainage cavity collects and discharges moisture at this less-vulnerable location.

7.6 Expansion and Control Joints

As discussed in Chapters 4 and 5, cracking in masonry is most often related to the expansion and contraction caused by changes in moisture content. The walls of residences are relatively short in length compared to most commercial construction, so there is less accumulated movement stress to accommodate. However, stress buildup can occur even in small structures if not properly accommodated. Brick masonry expansion joints should be located near
the external corners of long building walls because the opposing expansion of the intersecting walls can crack the brick. Brick masonry expansion joints and concrete masonry control joints should also be located at offsets and changes in wall height (Figure 7-28). If the brick is resting on a poured-concrete foundation, the bond break or slippage plane created by flashing at the base of a wall will prevent the opposing movement of brick expansion and concrete shrinkage from causing foundation cracking at outside building corners (Figure 7-29).