CHAPTER 26

Exterior Wall Cladding—I (Masonry, Precast Concrete, GFRC, and Prefabricated Masonry)

CHAPTER OUTLINE

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Brick veneer buildings, illustrating one of the most widely used cladding systems in contemporary US construction, line this New York City street. Note glass-clad Bloomberg Tower (by Cesar Pelli and Associates with Schuman, Lichtenstein, Claman and Effron) in the background. (Courtesy of Emporis.)
26.1 MASONRY VENEER ASSEMBLY—GENERAL CONSIDERATIONS

Among the most commonly used veneer walls is a single wythe of brick (generally 4 in. nominal thickness), referred to as brick veneer. The backup wall used with brick veneer may be load bearing or non–load bearing and may consist of one of the following:

- Wood or light-gauge steel stud
- Concrete masonry
- Reinforced concrete

A wood stud (or steel stud) load-bearing backup wall, Figure 26.1, is generally used in low-rise residential construction. Concrete masonry, non–load-bearing steel stud, and reinforced concrete backup walls are generally used in commercial construction. In fact, brick veneer with concrete masonry backup is the wall assembly of choice for many building types, such as schools, university campus buildings, and offices.

The popularity of brick veneer lies in its aesthetic appeal and durability. A well-designed and well-constructed brick veneer wall assembly generally requires little or no maintenance. The discussion in this chapter refers to brick veneer. It can, however, be extended to include other (CMU and stone) masonry veneers with little or no change.
In a brick veneer assembly, the veneer is connected to the backup wall with steel anchors, which transfer the lateral load from the veneer to the backup wall. In this load transfer, the anchors are subjected to either axial compression or tension, depending on whether the wall is subjected to inward or outward pressure.

The anchors must, therefore, have sufficient rigidity and allow little or no movement in the plane perpendicular to the wall. However, because the veneer and the backup will usually expand or contract at different rates in their own planes, the design of anchors must accommodate upward-downward and side-to-side movement, Figure 26.2.

Anchors for a brick veneer wall assembly are, therefore, made of two pieces that engage each other. One piece is secured to the backup, and the other is embedded in the horizontal mortar joints of the veneer. An adjustable, two-piece anchor should allow the veneer to move with respect to the backup in the plane of the wall, but not perpendicular to it.

An exception to this requirement is a one-piece sheet steel corrugated anchor (Figure 26.1). The corrugations in the anchor enhance the bond between the anchor and the mortar, increasing the anchor’s pullout strength. But the corrugations weaken the anchor in compression by making it more prone to buckling. A one-piece, corrugated anchor is recommended for use only in low-rise, wood, light-frame buildings in low-wind and low-seismic-risk locations.

Galvanized steel is commonly used for anchors, but stainless steel is recommended where durability is an important consideration and/or where the environment is unusually corrosive.

The spacing of anchors should be calculated based on the lateral load and the strength of the anchor. However, the maximum spacing for a one-piece, corrugated anchor or an adjustable, two-piece wire anchor (wire size W1.7) is limited by the code to one anchor for every 2.67 ft² [1]. Additionally, they should not be spaced more than 32 in. on center horizontally and not more than 18 in. vertically, Figure 26.3.

**Air Space**

An air space of 2 in. (clear) is recommended for brick veneer. Thus, if there is 1 1/2-in.-thick (rigid) insulation between the backup wall and the veneer, the backup and the veneer must be spaced 3 1/2 in. apart so that the air space is 2 in. clear, Figure 26.4.

In a narrower air space, there is a possibility that if the mortar squeezes out into the air space during brick laying, it may bridge over and make a permanent contact with the backup wall. A 2-in. air space reduces this possibility. In a wood-stud-backed wall assembly with one-piece corrugated anchors, however, a 1-in. air space is commonly used (Figure 26.1).
The maximum distance between the veneer and backup wall is limited by the masonry code to $4\frac{1}{2}$ in. unless the anchors are specifically engineered to withstand the compressive stress caused by the lateral load. With a large gap between the veneer and the backup wall, the anchors are more prone to buckling failure.

**Support for Brick Veneer—Shelf Angles**

The dead load of brick veneer may be borne by the wall foundation without any support at intermediate floors up to a maximum height of 30 ft above ground. Uninterrupted, foundation-supported veneer is commonly used in a one- to three-story wood or light-gauge steel frame buildings, Figure 26.5(a). In these buildings, the air space is continuous
from the foundation to the roof level, and the entire load of the veneer bears on the foundation. A 1 \( \frac{1}{2} \) in. depression, referred to as the \textit{brick ledge}, is commonly created in the foundation to receive the first course of the veneer.

In mid- and high-rise buildings, the veneer is generally supported at each floor using (preferably hot-dip galvanized) steel \textit{shelf angles} (also referred to as \textit{relieving angles}). Shelf angles are supported by, and anchored to, the building’s structure. In a frame structure, the shelf angles are anchored (welded or bolted) to the spandrel beams, Figure 26.5(b). In a load-bearing wall structure, the shelf angles are anchored to the exterior walls. The details of the anchorage of a shelf angle to the structure are given later in the chapter.

A gap should be provided between the top of the veneer and the bottom of the shelf angle. This gap accounts for the vertical expansion of brick veneer (after construction) and the deflection of the spandrel beam under live load changes. The gap should be treated with a backer rod and sealant, Figure 26.6. The veneer may project beyond the shelf angle, but the projection should not exceed one-third of the thickness of the veneer.

Shelf angles must not be continuous. A maximum length of about 20 ft is used for shelf angles, with nearly a \( \frac{1}{2} \) in. gap between adjacent lengths to provide for their expansion. The gap should ideally be at the same location as the vertical expansion joints in the veneer.

\textbf{Lintel Angles—Loose-Laid}

Whether the veneer is supported entirely on the foundation or at each floor, additional dead load support for the veneer is needed over wall openings. The lintels generally used over an opening in brick veneer are of steel (preferably hot-dip galvanized) angles, Figure 26.7. Unlike the shelf angles, lintel angles are not anchored to the building’s structural frame but are simply placed (loose) on the veneer, Figure 26.8.

To allow the lintel to move horizontally relative to the brick veneer, no mortar should be placed between the lintel bearing and the brick veneer. Flashing and weep holes must be provided over lintels in exactly the same way as on the shelf angles.

\textbf{Locations of Flashings and End Dams}

As shown in Figure 26.7, flashings must be provided at all interruptions in the brick veneer:

- At foundation level
- Over a shelf angle
- Over a lintel angle
- Under a window sill

Joints between flashings must be sealed, and all flashings must be accompanied by weep holes. The flashing should preferably project out of the veneer face to ensure that the water...
will drain to the outside of the veneer (Figure 26.6). Where the flashing terminates, it must be turned up (equal to the height of one brick) to form a dam to prevent water from entering the air space, Figure 26.9.

**Flashing Materials**

Flashing material must be impervious to water and resistant to puncture, tear, and abrasion. Additionally, flashing must be flexible so that it can be bent to the required profile. Durability is also important because replacing failed flashing is cumbersome and expensive. Therefore, metal flashing must be corrosion resistant. Resistance to ultraviolet radiation is
also necessary because the projecting part of the flashing is exposed to the sun. Commonly used flashing materials are as follows:

- Stainless sheet steel
- Copper sheet
- Plastics such as
  - Polyvinyl chloride (PVC)
  - Neoprene
  - Ethylene propylene diene monomer (EPDM)
- Composite flashing consisting of
  - Rubberized asphalt with cross-laminated polyethylene, typically available as self-adhering and self-healing flashing
  - Copper sheet laminated on both sides to asphalt-saturated paper or fiberglass felt
Copper and stainless steel are among the most durable flashing materials. Copper’s advantage over stainless steel is its greater flexibility, which allows it to be bent to shape more easily. However, copper will stain light colored masonry because of its corrosion, which yields a greenish protective cover (patina). Copper combination flashing, consisting of a copper sheet laminated to asphalt-saturated paper, reduces its staining potential.

A fairly successful flashing is a two-part flashing, comprising a self-adhering, self-healing polymeric membrane and stainless steel drip edge. The durability and rigidity of stainless steel makes a good drip edge, and the flexible, self-adhering membrane simplifies flashing installation.

CONSTRUCTION AND SPACING OF WEEP HOLES

Weep holes must be provided immediately above the flashing. There are several different ways to provide weep holes. The simplest and the most effective weep hole is an open, vertical mortar joint (open-head joint) in the veneer, Figure 26.10.

To prevent insects and debris from lodging in the open-head joint, joint screens may be used. A joint screen is an L-shaped, sheet metal or plastic element, Figure 26.11(a). Its vertical leg has louvered openings to let the water out, and the horizontal leg is embedded into the horizontal mortar joint of the veneer. The joint screen has the same width as the head joints. An alternative honeycombed plastic joint screen is also available, Figure 26.11(b).

Instead of the open-head joint, wicks or plastic tubes (\(\frac{1}{4}\) in. diameter) may be used in a mortared-head joint. Wicks, which consist of cotton ropes, are embedded in head joints,

NOTE

Weep Hole Spacing

A center-to-center spacing of 24 in. is generally used for weep holes when open-head joints are used. A spacing of 16 in. is used with weep holes consisting of wicks or tubes.
Figure 26.12. They absorb water from the air space by capillary action and drain it to the outside. Their drainage efficiency is low.

Plastic tubes are better than wicks, but they do not function as well as open-head joints. They are placed in head joints with a rope inside each tube. The ropes are pulled out after the veneer has been constructed. This ensures that the air spaces of the tubes are not clogged by mortar droppings.

A sufficient number of weep holes must be provided for the drainage of the air space. Generally, a weep hole spacing of 24 in. is used with open-head joints; 16-in. spacing is used with wicks or tubes.

**Mortar Droppings in the Air Space—Mortar-Capturing Device**

For the air space to function as an effective drainage layer, it is important to minimize mortar droppings in the air space. Excessive buildup of mortar in the air space bridges the space. Additionally, the weep holes function well only if they are not clogged by mortar droppings. Poor bricklaying practice can result in substantial accumulations of mortar on the flashing. Care in bricklaying to reduce mortar droppings is therefore essential.

Additional measures must also be incorporated to keep the air space unclogged. An earlier practice was to use a 2-in.-thick bed of pea gravel over the flashing. This provides a drainage bed that allows the water to percolate to the weep holes.

A better alternative is to use a mortar-capturing device in the air space immediately above the flashing. This device consists of a mesh made of polymeric strands, which trap the droppings and suspend them permanently above the weep holes, Figure 26.13. The use of a mortar-capturing device allows water in the air space to percolate freely through mortar droppings to reach the weep holes.

**Continuous Vertical Expansion Joints in Brick Veneer**

As stated in Section 9.8, brick walls expand after construction. Therefore, a brick veneer must be provided with continuous vertical expansion joints at intervals, Figure 26.14.

The maximum recommended spacing for vertical expansion joints is 30 ft in the field of the wall and not more than 10 ft from the wall’s corner [2]. The joints are detailed so that sealant and backer rods replace mortar joints for the entire length of the continuous vertical expansion joint, allowing the bricks on both sides of the joint to move while maintaining a waterproof seal, Figure 26.15. The width of the expansion joint is \( \frac{3}{8} \) in. (minimum) to match the width of the mortar joints.

With vertical expansion joints and the gaps under shelf angles (which function as horizontal expansion joints), a brick veneer essentially consists of individual brick panels that can expand and contract horizontally and vertically without stressing the backup wall or the building’s structure.

**Mortar Type and Mortar Joint Profile**

Type N mortar is generally specified in all-brick veneer except in seismic zones, where Type S mortar may be used (see Section 22.2). A concave joint profile yields veneer with more water resistance (see Section 22.3).
(a) Mortar capturing device, as installed in air space

(b) Mortar capturing device with mortar droppings, which allows the water to find its way to the weep holes even with the droppings.

(c) Image illustrates the relative ineffectiveness of a bed of pea gravel in air space

FIGURE 26.13 Mortar-capturing device. (Photos courtesy of Mortar Net USA Ltd., producers of The Mortar Net™.)

FIGURE 26.14 Continuous vertical expansion joints in brick veneer. Note continuous horizontal joints under shelf angles. (Photo by MM.)

FIGURE 26.15 Detail plan of a vertical expansion joint in brick veneer. This illustration is the same as Figure 9.23.
Each question has only one correct answer. Select the choice that best answers the question.

1. The backup wall in a brick veneer wall assembly consists of a
   a. reinforced concrete wall.
   b. CMU wall.
   c. wood or steel stud wall.
   d. all the above.
   e. (b) and (c) only.

2. In a brick veneer wall assembly, the wind loads are transferred directly from the veneer to the building’s structure.
   a. True
   b. False

3. The anchors used to anchor the brick veneer to the backup wall are generally two-piece anchors to allow differential movement between the veneer and the backup
   a. in all three principal directions.
   b. perpendicular to the plane of the veneer.
   c. within the plane of the veneer.
   d. none of the above.

4. The anchors in a brick veneer wall assembly provide
   a. gravity load support to both veneer and backup.
   b. lateral load support to both veneer and backup.
   c. gravity load support to the veneer.
   d. lateral load support to the veneer.

5. The minimum required width of air space between brick veneer and CMU backup wall is
   a. 1 in.
   b. 1 1/2 in.
   c. 2 in.
   d. 3 in.
   e. none of the above.

6. The minimum width of air space generally used between brick veneer and wood stud backup wall is
   a. 1 in.
   b. 1 1/2 in.
   c. 2 in.
   d. 2 1/2 in.
   e. 3 in.

7. A steel angle used to support the weight of brick veneer over an opening is called a
   a. Lintel angle.
   b. Shelf angle.
   c. Relieving angle.
   d. all the above.
   e. (a) or (b).

8. A shelf angle must be anchored to the building’s structural frame.
   a. True
   b. False

9. A lintel angle must be anchored to the building’s structural frame.
   a. True
   b. False

10. In a multistory building, shelf angles are typically used at
    a. each floor level.
    b. each floor level and at midheight between floors.
    c. at foundation level.
    d. all the above.
    e. (a) and (c).

11. For a brick veneer that bears on the foundation and continues to the top of the building without any intermediate support, the maximum veneer height is limited to
    a. 40 ft.
    b. 35 ft.
    c. 30 ft.
    d. 25 ft.
    e. 20 ft.

12. A shelf angle in a brick veneer assembly must provide
    a. gravity load support to the veneer.
    b. lateral load support to the veneer.
    c. gravity load support to both veneer and backup.
    d. lateral load support to both veneer and backup.

13. In a brick veneer assembly, flashing is required
    a. at foundation level.
    b. over a lintel angle.
    c. over a shelf angle.
    d. under a window sill.
    e. all the above.

14. In a brick veneer assembly, weep holes are required at
    a. each floor level.
    b. each alternate floor level.
    c. immediately above the flashing.
    d. immediately below the flashing.
    e. 2 in. above a flashing.

15. The most efficient weep hole in a brick veneer consists of a
    a. Wick.
    b. Plastic tube.
    c. open head joint.
    d. none of the above.

16. A mortar capturing device in a brick veneer assembly is used
    a. at each floor level.
    b. at each alternate floor level.
    c. immediately above a flashing.
    d. immediately below a flashing.
    e. 2 in. above a flashing.

17. In a brick veneer assembly, vertical expansion joints should be provided at a maximum distance of
    a. 40 ft in the field of the wall and 40 ft from a wall’s corner.
    b. 30 ft in the field of the wall and 30 ft from a wall’s corner.
    c. 30 ft in the field of the wall and 20 ft from a wall’s corner.
    d. 30 ft in the field of the wall and 10 ft from a wall’s corner.
26.2 BRICK VENEER WITH A CMU OR CONCRETE BACKUP WALL

Figure 26.16 shows an overall view of a brick veneer wall assembly with a concrete masonry backup wall. The steel anchors that connect the veneer to the CMU backup wall are two-piece wire anchors. One piece is part of the joint reinforcement embedded in the CMU walls. See Figure 26.17(a). The other piece fits into this piece and is embedded into the veneer’s bed joint.

Several other types of anchors used with a concrete masonry backup wall are available, such as that shown in Figure 26.17(b). Figure 26.17(c) and (d) show typical anchors used with reinforced-concrete members.

In seismic regions, the use of seismic clips is recommended. A seismic clip engages a continuous wire reinforcement in brick veneer. Both the seismic clip and wire are embedded in the veneer’s bed joint. A typical seismic clip is shown in Figure 26.18. [See Figure 26.17(d)]
The slot in this clip engages into looped anchor and holds insulation in place, see Figure 26.18.

Joint reinforcement and looped anchor are prefabricated as one piece.

This anchor fits into the loop and is embedded into veneer's bed joint.

The slot in this clip engages into looped anchor and holds insulation in place, see Figure 26.18.

Horizontal joint reinforcement

Grout this cell and the one below.

(a) A typical anchor used with CMU back-up walls

(b) An alternative anchor for CMU back-up walls

(c) A typical anchor for concrete back-up wall, beam or column

(d) An alternative anchor for concrete back-up wall, beam or column

FIGURE 26.17 Typical anchors used with CMU and concrete backup walls.
FIGURE 26.18 A typical seismic clip.
for an alternative seismic clip.] Figures 26.19 to 26.22 show important details of brick veneer construction and a CMU backup wall.

The shelf angle and lintel angles can be combined into one by increasing the depth of the spandrel beam down to the level of the window head, Figure 26.23—a strategy that is commonly used with ribbon windows and continuous brick veneer spandrels, Figure 26.24.
Anchor connects veneer to CMU back-up wall.

Vertical reinforcement in wall (may not be needed if lateral loads are small).

Backer rod and sealant.

Rigid foam insulation (extruded polystyrene or polyisocyanurate typical).

Flashing and weep holes.

Mortar-capturing device.

Termination bar to anchor flashing to back-up.

Insulate and seal gap.

Steel dowels from spandrel beam.

Steel furring section, see Figure 17.4.

Restraint angles on both sides of CMU wall, see Figure 26.22.

Moisture barrier coating on exterior surface of CMU wall, if needed, see Figure 26.21.

Drywall.

Steel weld plate embedded in beam.

CMU lintel.

Ceiling.

Steel furring section, see Figure 17.4.

Screw-bolted anchor to CMU back-up wall.

Seal here.

Shelf angle.

Steel furring section, see Figure 17.4.

Vertical reinforcement in wall (may not be needed if lateral loads are small).

Anchor connects veneer to concrete beam.

Termination bar to anchor flashing to back-up.

Mortar-capturing device.

Flashing and weep holes.

Backer rod and sealant, see Figure 26.6.

Seal here.

Flashing.

Treated wood nailer to anchor window frame.

Lintel angle.

Weep holes.

Backer rod and sealant.

Seal here.

Ceiling.

CMU lintel.

Seal here.

FIGURE 26.19 (b) Detail of Figure 26.19(a).
FIGURE 26.20 Two alternative methods of anchoring a shelf angle to reinforced concrete spandrel beam.

(a) Shelf angle field-welded to embeds in concrete beam

(b) Shelf angle bolted to wedge inserts in concrete beam

Plate embed. Spacing of embed depends on the load carried by shelf angle and concrete strength.

Cast steel wedge insert with foam fill. The fill is removed before installing the shelf angle.

Slotted hole allows field adjustment of shelf angle.

Space for shims that extend full height of vertical leg of shelf angle.

CAST STEEL WEDGE INSERT

Washer

Shelf angle

FIGURE 26.21 The exterior surface of a CMU backup wall may be treated with a water-resistant coating before constructing brick veneer. (Photo by MM.)
**FIGURE 26.22** Two alternative methods of providing lateral load restraint at the top of a CMU backup wall. (Photos by MM.)

Dovetail restraint anchor, whose lower (cylindrical) part is encased in a plastic tube. The upper part of the anchor engages in the dovetail slot. A CMU sash unit is used in the back-up wall to engage the tube-encased leg of the anchor in the block's groove. The groove is filled with mortar.

(b) Dovetail anchors are an alternative to restraint angles. Again, spacing of anchors is a function of lateral load on wall.

**FIGURE 26.23 (Left)** With a deep spandrel beam that extends from the top of window head in the lower floor to the sill level of the window at the upper floor, the shelf angle also serves as lintel angle. (Photo by MM.)

**FIGURE 26.24 (Right)** A building with brick veneer spandrels and ribbon windows. (Photo by MM.)
26.3 BRICK VENEER WITH A STEEL STUD BACKUP WALL

The construction of brick veneer with a steel stud backup wall differs from that of a CMU-backed wall mainly in the anchors used for connecting the veneer to the backup. Various types of anchors are available to suit different conditions. The anchor shown in Figure 26.25 is used if the air space does not contain rigid foam insulation so that it is fastened to steel studs through exterior sheathing.

The anchor shown in Figure 26.26 is used if rigid foam insulation is present in the air space. The sharp ends of the prongtype anchor pierce into the insulation (not the sheathing) and transfer lateral load to the studs without compressing the insulation.

**FIGURE 26.25** A typical steel stud and brick veneer assembly without cavity insulation. (Photo by MM.)

**FIGURE 26.26** A typical steel stud and brick veneer assembly with outside insulation. (Illustration courtesy of Hohmann and Barnard, Inc.)
STEEL STUD BACKUP WALL AS INFILL WITHIN THE STRUCTURAL FRAME

Figure 26.27 shows a detailed section of brick veneer applied to a steel stud backup wall with the reinforced concrete structural frame. The deflection of the spandrel beam is accommodated by providing a two-track assembly consisting of a deep-leg track and a normal track, Figure 26.28(a). The upper track of this slip assembly is fastened to the beam. The studs and the interior drywall are fastened only to the lower track, which allows the upper track to slide over the lower track.

![Diagram](image_url)

**FIGURE 26.27** Detail of a typical steel stud and brick veneer assembly in a reinforced concrete structure.
Alternatively, a single, slotted, deep-leg slip-track assembly may be used. See Figure 26.28(b). The studs are loose fastened to the top track through the slots. The drywall is not fastened to the slotted track. The slotted track assembly is more economical and also provides a positive connection between the track and the studs.

**Steel Stud Backup Wall Forward of the Structural Frame**

In low-rise buildings (one or two stories), putting the steel stud backup on the outside of the structure allows it to cover the structural frame. Thus, the studs are continuous from the bottom to the top, requiring no shelf angles, Figures 26.29 and 26.30.

Slip connections must be used to connect the studs with the floor or roof so that the structural frame and the wall can move independently of each other. Two alternative means of providing slip connections are used, depending on the profile of the studs, Figure 26.31.
FIGURE 26.30 (a) A typical section through a low-rise (one- or two-story) steel-frame building with a brick veneer and steel stud backup wall assembly. Brick veneer is continuous from the foundation to the underside of parapet coping.
FIGURE 26.30 (b) Enlarged version of detail at floor level in Figure 26.30(a).

FIGURE 26.31 Two alternative methods of providing a slip connection between a steel stud backup wall and the floor/roof structure, depending on the profile of studs.
A brick veneer attached to a steel stud backup wall forward of the structure can also be used in mid- and high-rise buildings. Two alternative details commonly used for buildings with ribbon windows and brick spandrels are shown in Figures 26.32 and 26.33.

**WEATHER RESISTANCE OF A STEEL STUD BACKUP WALL**

Weather resistance of exterior sheathing on steel studs may be accomplished by one of the following two means:

- Using a membrane that covers the entire sheathing, such as an air-weather retarder
- Using a water-resistant tape on the joints between sheathing panels

**FIGURE 26.32** Brick spandrel with steel stud backup wall. Steel studs and brick veneer bear on bent-plate shelf angle.
Where the lateral loads are low, structural steel channels may be spaced at two or three times the spacings of steel studs.
The use of a continuous membrane conceals the joints between siding panels, making it more difficult for the masons to locate the studs to which the fasteners must be anchored. With taped joints, it is easier to locate the studs, Figure 26.34.

### 26.4 CMU BACKUP VERSUS STEEL STUD BACKUP

A major benefit of a steel stud backup wall in a brick veneer assembly (as compared with a CMU backup wall) is its lighter weight. For a high-rise building, the lighter wall not only reduces the size of spandrel beams but also that of the columns and footings, yield-
ing economy in the building’s structure. However, this benefit is accompanied by several concerns.

Steel studs can deflect considerably before the bending stress in them exceeds their ultimate capacity. Brick veneer, on the other hand, deflects by a very small amount before the mortar joints open. Open mortar joints weaken the wall and also increase the probability of leakage, corroding the anchors.

Thus, the steel stud backup and brick veneer assembly performs well only if the stud wall is sufficiently stiff. To obtain the necessary stiffness, the deflection of studs must be controlled to a fairly small value. In fact, the design of a steel stud backup wall to resist the lateral loads is governed not by the strength of studs but by their deflection.

The Brick Industry Association (BIA) recommends that the lateral load deflection of steel studs, when used as backup for brick veneer assembly, should not exceed

\[ \frac{\text{stud span}}{600} \]

where the stud span is the unsupported height of studs. For example, if the height of studs (e.g., from the top of the floor to the bottom of the spandrel beam in Figure 26.7) is 10 ft, the deflection of studs under the lateral load must be less than

\[ \frac{(10 \times 12)}{600} = 0.2 \text{ in.} \]

Increasing the stiffness of studs increases the cost of the assembly. Another concern with steel stud backup is that the veneer is anchored to the backup only through screws that engage the threads within a light-gauge stud sheet. Over a period of time, condensation can corrode the screws and the corresponding holes in studs, making the screws come loose. Condensation is, therefore, an important concern in a steel stud–backed veneer. A more serious concern is that the anchor installer will miss the studs.

By comparison with steel studs, anchoring of brick veneer to a CMU backup does not depend on screws; and hence it is more forgiving. Additionally, the anchors in a CMU backup wall are embedded in the mortar joints, and if they are made of stainless steel, their corrosion probability is extremely low.

Another advantage of a CMU backup wall is its inherent stiffness. To obtain a steel stud backup wall of the same stiffness as a CMU backup wall substantially increases the cost of the stud backup.

### 26.5 AESTHETICS OF BRICK VENEER

It is neither possible nor within the scope of this text to illustrate various techniques used to add visual interest to brick veneer facades. However, a few examples are provided:

- Use of recessed or projected bricks in the wall, Figure 26.35.
- Use of bricks of different colors or combining clay bricks with other masonry materials or cast concrete, Figure 26.36.
- Warping the wall, Figure 26.37.

![FIGURE 26.35 Use of recessed or projected bricks with different hues. The projections must be small so that the core holes in bricks are not exposed. (Photo by MM.)](image)
26.6 PRECAST CONCRETE (PC) CURTAIN WALL

Unlike brick veneer, which is constructed brick by brick at the construction site, a precast concrete (PC) curtain wall is panelized construction. The panels are constructed off-site, under controlled conditions, and transported to the site in ready-to-erect condition, greatly reducing on-site construction time.

Although the PC curtain wall system is used in all climates, it is particularly favored in harsh climates, where on-site masonry and concrete construction are problematic due to freeze hazard and slow curing rate of portland cement. Panelized construction eliminates
scaffolding, increasing on-site workers’ safety. Because panel fabrication can be done in sheltered areas, it can be accomplished uninterrupted, with a higher degree of quality control.

PC curtain walls are used for almost all building types but more often are used for mid- to high-rise hospitals, apartments, hotels, parking garages, and office buildings, Figures 26.38.

PC curtain wall panels are supported on and anchored to the building’s structural frame and are hoisted in position by cranes. See Figure 26.39(a) and (b). The panels are fabricated in a precast concrete plant and transported to a construction site.

The structural design of PC curtain wall panels is generally done by the panel fabricator to suit the fabrication plant’s setup and resources and to provide an economical product. A typical precast concrete plant generally has in-house structural engineering expertise.

In a PC curtain wall project, an important role for the architect is to work out the aesthetic expression of the panels (shapes, size, exterior finishes, etc.). This should be done in consultation with the precast plant. A great deal of coordination between the architect, engineer of record, general contractor, precast plant, and erection subcontractor is necessary for a successful PC curtain wall project.

Because of the sculptability of concrete and the assortment of possible finishes of the concrete surface (smooth, abrasive-blasted, acid-etched, etc.), PC curtain walls lend themselves to a variety of facade treatments. The use of reveals (aesthetic joints), moldings, and colored concrete further add to the design variations, Figure 26.40.

Panel Shapes and Size

Another key design decision is the size, shape, and function of each panel. These include window wall panels, spandrel panels, and column covers, Figure 26.41. The panels are generally one floor high, but those spanning two or (occasionally) three floors may be used.

PC wall panels are generally made as large as possible, limited only by the erection capacity of the crane, transportation limitations, and gravity load delivered by the panel to the structural frame. For structural reasons, the panels generally extend from column to column. Smaller panel sizes mean a larger number of panels, requiring a greater number of support connections, longer erection time, and, hence, a higher cost. If the scale of large panels is visually unacceptable, false joints can be incorporated in the panels, as shown in preceding images.

Concrete Strength

PC curtain wall panels are removed from the form as soon as possible to allow rapid turnover and reuse of the formwork. This implies that the 28-day concrete strength should be reasonably high so that when the panel is removed from the form, it can resist the stresses to which it may be subjected during the removal and handling processes.

The required concrete strength is also a function of the curtain wall’s exposure, durability requirements, shape, and size of the panels. Flat panels may require higher strength (or greater thickness) as compared to ribbed or profiled panels. Therefore, the strength of concrete must be established in consultation with the precast plant supplying the panels.

The most commonly used 28-day strength of concrete for PC curtain wall panels is 5,000 psi. This relatively high strength gives greater durability, greater resistance to rainwater penetration, and an improved in-service performance. In other words, the panels are better able to resist stresses caused by the loads, building movement, and volume changes induced by thermal, creep, and shrinkage effects.

For aesthetic and economic reasons, a panel may use two mixes—a face (architectural) mix and a backup (structural) mix. In this case, the two mixes should have nearly equal expansion and contraction coefficients to prevent undue bowing and warping of the panel. In other words, the strength, slump, and water-cement ratios of the two mixes should be nearly the same.

Because panels are generally fabricated face down on a flat formwork, the face mix is placed first followed by the backup mix. The thickness of the face

**Figure 26.38** A typical office building with precast concrete curtain wall panels. (Photo by MM.)

**Figure 26.39 (a)** A PC panel being unloaded from the delivery truck for hoisting into position by a crane. (Photo by MM.)

**Figure 26.39 (b)** PC panel of Figure 26.39(a) being hoisted to its final position. (Photo by MM.)
FIGURE 26.40 (a) Lightly abrasive blasted panels with a great deal of surface detailing. (Photo by MM.)

FIGURE 26.40 (b) The part of this panel on the left side of the reveal is lightly abrasive blasted, and the right side part is medium abrasive blasted. (Photo by MM.)

FIGURE 26.40 (c) Panel with exposed aggregate finish. (Photo by MM.)

Mix is a function of the aggregate size but should not be less than 1 in. The precaster’s experience should be relied upon in determining the thicknesses and properties of the two mixes.

Panel Thickness

The thickness of panels is generally governed by the handling (erection) stresses rather than the stresses caused by in-service loads. A concrete cover on both sides and the two-way reinforcement in a panel generally gives a total of about 3-in. of thickness. Add to this the...
thickness that will be lost due to surface treatment, such as abrasive blasting and acid etching, and the total thickness of a PC wall panel cannot be less than 4 in. However, because panel size is generally maximized, a panel thickness of less than 6 in. is rare. A thicker panel is not only stronger but is also more durable, is more resistant to water leakage, and has higher fire resistance. Greater thickness also gives greater heat-storage capacity (Chapter 5), making the panel less susceptible to heat-induced stresses.

**Mock-Up Sample(s)**

For PC curtain wall projects, the architect requires the precast plant to prepare and submit for approval a sample or samples of color, texture, and finish. The mock-up panels, when approved, are generally kept at the construction site and become the basis for judgment of all panels produced by the precast plant.

### 26.7 CONNECTING THE PC CURTAIN WALL TO A STRUCTURE

The connections of PC curtain wall panels to the building’s structure are among the most critical items in a PC curtain wall project and are typically designed by the panel fabricator. Two types of connections are required in each panel:

- Gravity load connections
- Lateral load connection

There should be only two gravity load connections, also referred to as *bearing supports*, per panel and should be located as near the columns as possible. The lateral load connections, also referred to as *tiebacks*, may be as many as needed by structural considerations, generally two or more per panel, Figure 26.42.

![Figure 26.42 Support connections for a typical floor-to-floor curtain wall panel.](image)

**NOTE**

The connection system of a PC curtain wall resembles that of brick veneer connection system and is common to all types of curtain walls. The shelf angles in brick veneer provide the gravity load connection, and the anchors between the veneer and the backup provide the lateral load connection.
**Bearing Supports**

A commonly used bearing support for the floor-to-floor panels is provided through a section of steel tube, a part of which is embedded in the panel and a part of which projects out of the panel. The projecting part rests on the (steel angle) bearing plate embedded at the edge of the spandrel beam. Dimensional irregularities, both in the panel and in the structure, require the use of leveling shims (or bolts) under bearing supports during erection.

After the panels have been leveled, the bearing supports are welded to the bearing plate. The bearing support system is designed to allow the panel to move within its own plane so that the panel is not subjected to stresses induced by temperature, shrinkage, and creep effects.

In place of leveling shims in a bearing support, a leveling bolt is often used, Figure 26.43. The choice between the shims and the bolt is generally left to the preference of the precast manufacturer and the erector. Alternatives to the use of steel tube for bearing supports are steel angles or a wide-flange (I-) section, Figure 26.44.

**Tiebacks**

A lateral load connection (tieback) is designed to resist horizontal forces on the panel from wind and/or earthquake and due to the eccentricity of panel bearing. Therefore, it must be able to resist tension and compression perpendicular to the plane of the panel.

A tieback is designed to allow movement within the plane of the panel. The connection must, however, permit...
adjustment in all three principal directions during erection. A typical tieback is shown in Figure 26.45 (see also Figure 26.44).

**Support Systems for Spandrel Panels and Infill Panels**

Support systems for a curtain wall consisting of spandrel and infill panels are shown in Figure 26.46; see also Figure 26.41(c).

**Panels and Steel Frame Structure**

PC wall panels, which create eccentric loading on the spandrel beams, create torsion in the beams. Due to the lower torsional resistance of wide-flange steel beams, PC panels used with a steel frame structure are generally designed to span from column to column and made to bear directly on them. Tiebacks, however, are connected to the spandrel beams. (Note that the rotation of the spandrel beam caused by the eccentricity of panel bearing is partially balanced by reverse rotation caused by the floor’s gravity load on the spandrel beam.)

**Clearance of Panels from the Structural Frame**

The Precast/Prestressed Concrete Institute (PCI) recommends a minimum horizontal clearance of 2 in. of precast panels from the building’s structural frame.

**26.8 Brick and Stone-Faced PC Curtain Wall**

PC curtain wall panels may be faced with thin (clay) bricks at the time of casting the panels. Generally, \( \frac{3}{4} \) to 1-in-thick bricks are used. They are available in various shapes, Figure 26.47. The bricks are placed in the desired pattern in the form, and the concrete is
placed over them. To prevent the bricks from shifting during the placing operation, a rubber template is used, within which the bricks are placed, Figure 26.48. The template aligns the bricks and allows the concrete to simulate the mortar joints.

In well-designed and well-fabricated panels, it is generally difficult to distinguish between a site-constructed brick veneer wall and a brick-faced PC curtain wall. Brick-faced panels have the same advantages as other PC curtain wall panels—that is, no on-site construction and no scaffolding.

Thin bricks need to be far more dimensionally uniform than full-size bricks. With full-size bricks, dimensional nonuniformity is compensated by varying the mortar thickness.

Because clay bricks expand by absorbing moisture from the atmosphere (moisture expansion), thin bricks should be allowed to season for a few weeks at the precaster’s plant before being used. This reduces their inherent incompatibility with concrete, which shrinks on drying.

Although moisture expansion and drying shrinkage are the major causes of incompatibilities between bricks and concrete, other differences between the two materials, such as the coefficient of thermal expansion and the modulus of elasticity, must be considered. Because of these differences, a brick-faced concrete panel is subject to bowing due to differential expansion and contraction of the face and the backup.

Bowing can be reduced by increasing the stiffness of the panel. Using two layers of reinforcement is encouraged when the thickness of the panel permits. Additionally, some precasters use reverse curvature in the panels.
The bond between concrete and bricks is obviously very important for a brick-faced concrete wall panel. The back surface of bricks used in brick-faced panels should contain grooves, ribs, or dovetail slots to develop an adequate bond. The bond between concrete and brick is measured through a shear strength test. The architect should obtain these results from the brick manufacturer before specifying them for use.

The bond between concrete and bricks is also a function of how absorptive the bricks are. Bricks with excessively high or excessively low water absorption give a poor bond. Bricks with high water absorption are subjected to freeze-thaw damage.

**STONE VENEER–FACED PC PANELS**

PC curtain wall panels can also be faced with (natural) stone veneer. The thickness of the veneer varies with the type of stone and the face dimensions of the veneer units. Granite and marble veneers are recommended to be at least 1 1/4 in. (3 cm) thick. Limestone veneer should be at least 2 in. thick.

The face dimensions of individual veneer units are generally limited to 25 ft² for granite and 15 ft² for marble or limestone. Thus, a typical PC curtain wall panel has several veneer units anchored to it.

The veneer is anchored to the concrete panel using stainless steel flexible dowels, whose diameter varies from 1/16 to 1/8 in. Two dowel shapes are commonly used—a U-shaped (hairpin) dowel and a pair of cross-stitch dowels, Figure 26.49. The dowels are inserted in the holes drilled in the veneer. The dowel holes, which are 1/16 to 1/8 in. larger in diameter than the diameter of the dowels, are filled with epoxy or an elastic, fast-curing silicone sealant. Unfilled holes will allow water to seep in, leading to staining of the veneer and freeze-thaw damage.

Because the dowels are thin and flexible, they allow relative movement between the veneer and the backup. To further improve their flexibility, rubber washers are used with the dowels at the interface of the veneer and the backup.

The depth of anchor in the veneer is nearly half the veneer thickness. Their anchorage into concrete varies, depending on the type of stone and the loads imposed on the panel.

There should be no bond between stone veneer and and the backup concrete to prevent bowing of the panel and cracking and staining of the veneer. To prevent the bond, a bond breaker is used between the veneer and the backup. The bond breaker is either a 6- to 10-mil-thick polyethylene sheet or a 1/4- to 1/2-in.-thick compressible, closed-cell polyethylene foam board. Foam board is preferred because it gives better movement capability with an uneven stone surface.

A PC curtain wall panel may be either fully veneered with stone or the veneer may be used only as an accent or feature strip on a part of the panel.

**OTHER FORM LINERS**

Because concrete is a moldable material, several geometric and textured patterns can be embossed on panel surface using form liners. An architect can select from a variety of standard form liners available or have them specially manufactured for a large project (Section 19.4).
26.9 DETAILING A PC CURTAIN WALL

A typical PC curtain wall is backed by an infill steel stud wall. The stud wall provides the interior finish and includes the insulation and electrical and other utility lines. Because the backup wall is not subjected to wind loads, it needs to be designed only for incidental lateral loads from the building’s interior (generally 5 psf). Therefore, a fairly lightweight backup wall is adequate. This contrasts with a backup stud wall in a brick veneer wall, which must be designed to resist wind loads and be sufficiently stiff to have a relatively small deflection.

Figure 26.50 shows a representative detail of a PC curtain wall with a steel stud backup wall. The space between the panels and the backup wall may be filled with rigid insulation, if needed.

JOINTS BETWEEN PANELS

Detailing the joints between panels is also a critical aspect of a PC curtain wall project. A minimum joint width of 1 in. between panels is generally recommended. Although a single-stage joint is commonly used, the preferred method is to use a two-stage joint system, consisting

![Figure 26.50 A typical PC curtain wall (schematic) detail.](image-url)
of a pair of backer rod and sealant bead combination. One backer rod and sealant bead combination is placed toward the outer surface of the joint and the other is placed toward the inner surface, Figure 26.51.

The outer seal provides a weather barrier and contains weep holes. The inner seal is continuous without any openings and is meant to provide an air barrier. The air barrier must extend continuously over a panel and across the joint between panels. The provision of the air barrier and the openings in the exterior seal makes the two-stage joint system function as a rain screen (Chapter 25).

Both inner and outer seals should be applied from the outside to avoid discontinuities at the spandrel beams and floor slabs. This requires a deep-stem roller to push the backer rod deep into the joint and a long-nozzle sealant gun.

**Insulated, Sandwiched Panels**

PC curtain wall panels with rigid plastic foam insulation sandwiched between two layers of concrete may be used in cold regions. A sandwich panel consists of an outer layer of concrete and an inner layer of concrete, in which both layers are connected together with ties through an intermediate layer of rigid plastic foam insulation.

The outer layer is a nonstructural layer, whereas the inner layer is designed to carry the entire load and transfer it to the structural frame. The panel is fabricated by first casting the concrete for the nonstructural layer. This is followed by embedding the ties and placing the insulation boards over the ties. The insulation is provided with holes so that the ties project above the insulation and are embedded in the concrete that is cast above the insulation.

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**Practice Quiz**

Each question has only one correct answer. Select the choice that best answers the question.

22. The strength of concrete used in precast concrete curtain walls is generally
   a. greater than or equal to 3,000 psi.
   b. greater than or equal to 4,000 psi.
   c. greater than or equal to 5,000 psi.
   d. none of the above.

23. Precast concrete curtain wall panels are generally
   a. cast on the construction site.
   b. fabricated by a readymix concrete plant and transported to the construction site.
   c. (a) or (b).
   d. none of the above.

24. The number of bearing supports in a precast concrete curtain wall panel must be
   a. one.
   b. two.
   c. three.
   d. four.
   e. between three and six.

25. The structural design of precast concrete curtain wall panels is generally the responsibility of the
   a. structural engineer who designs the structural frame of the building in which the panels are to be used.
   b. structural engineer retained by the panel fabricator.
   c. structural engineer retained by the general contractor of the building.
   d. structural engineer specially retained by the owner.
   e. none of the above.
26. During the erection of precast concrete curtain wall panels, the panels are leveled. The leveling of the panels is provided in the
   a. panels’ bearing supports.
   b. panels’ tieback connections.
   c. (a) or (b).
   d. (a) and (b).

27. The bricks used in brick-faced concrete curtain wall panels are generally
   a. of the same thickness as those used in brick veneer construction.
   b. thicker than those used in brick veneer construction.
   c. thinner than those used in brick veneer construction.
   d. any one of the above, depending on the building.

28. A bond break such as a polyethylene sheet membrane is generally used between the concrete and bricks in a brick-faced precast concrete curtain wall panel.
   a. True
   b. False

29. The connection between natural stone facing and the backup concrete in a stone-faced precast concrete curtain wall panel is obtained by
   a. The roughness of the stone surface that is in contact with concrete.
   b. nonmoving steel dowels.
   c. flexible steel dowels.
   d. any one of the above.

26.10 GLASS FIBER–REINFORCED CONCRETE (GFRC) CURTAIN WALL

As the name implies, glass fiber–reinforced concrete (GFRC) is a type of concrete whose ingredients are portland cement, sand, glass fibers, and water. Glass fibers provide tensile strength to concrete. Unlike a precast concrete panel, which is reinforced with steel bars, a GFRC panel does not require steel reinforcing.

The fibers are 1 to 2 in. long and are thoroughly mixed and randomly dispersed in the mix. The random and uniform distribution of fibers not only provides tensile strength, but also gives toughness and impact resistance to a GFRC panel. Because normal glass fibers are adversely affected by wet portland cement (due to the presence of alkalies in portland cement), the fibers used in a GFRC mix are alkali-resistant (AR) glass fibers.

GFRC SKIN AND STEEL FRAME

A GFRC curtain wall panel consists of three main components:
   • GFRC skin
   • Light-gauge steel backup frame
   • Anchors that connect the skin to the steel backup frame

Of these three components, only the skin is made of GFRC, which is generally $\frac{1}{4}$- to $\frac{3}{8}$-in.-thick. The skin is anchored to a frame consisting of light-gauge (galvanized) steel members, Figure 26.52. In this combination, the GFRC skin transfers the loads to the frame, which, in turn, transfers the loads to the building’s structure. The size and spacing of backup frame members depends on the overall size of the panel and the loads to which it is subjected.
**Flex Anchors**

The skin is hung 2 in. (or more) away from the face of the frame using bar anchors. The gap between the skin and the frame is essential because it allows differential movement between the skin and the frame, particularly during the period when the fresh concrete in the skin shrinks as water evaporates.

The anchors are generally $\frac{3}{8}$-in.-diameter steel bars, bent into an L-shape. To provide corrosion resistance, cadmium-plated steel is generally used for the anchors. One end of an anchor is welded to the frame, and the other end is embedded in the skin. The skin is thickened around the anchor embedment. The thickened portion of the skin is referred to as a bonding pad, Figure 26.53.

The purpose of the anchors is to transfer both gravity and lateral loads from the skin to the frame. In doing so, the anchors must be fairly rigid in the plane perpendicular to the panel; that is, they should be able to transfer the loads without any deformation in the anchors.

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**FIGURE 26.52** (b) The side and back of an L-shaped GFRC panel showing the supporting steel frame. (Photos by MM.)
However, the skin will experience in-plane dimensional changes due to moisture and temperature effects. The anchor must therefore have sufficient flexibility to allow these changes to occur without excessively stressing the skin. One way of achieving this goal is to flare the anchor away from the frame and to weld it to the frame member at the far end, Figure 26.54. The term *flex anchor* underscores the importance of anchor flexibility.

**Panel Shapes**

Like the precast concrete curtain wall panels, GFRC curtain wall panels can be made into different shapes, depending on the design of the building’s facade. The most commonly used panels are floor-to-floor solid panels (Figure 26.52), and window wall panels, Figure 26.55 and spandrel panels. A spandrel panel is essentially a solid panel of smaller height. Because the panels can be configured in several ways for a given facade, the architect must work with the GFRC fabricator before finalizing panel shapes.
26.11 FABRICATION OF GFRC PANELS

Figures 26.56 to 26.60 show the six-step process of fabricating a GFRC panel.

- **Preparing the Mold:** The mold must be fabricated to the required shape, Figure 26.56. The mold generally consists of plywood, but other materials, such as steel or plastics, may be used. A form-release compound is applied to the mold before applying the GFRC mix to facilitate the panel’s removal from the mold.

- **Applying the Mist Coat:** Before GFRC mix is sprayed on the panel, a thin cement-sand slurry coat, referred to as a mist coat, is sprayed on the mold, Figure 26.57. Because the mist coat does not contain any glass fibers, it gives a smooth, even surface to the panel. The thickness of the mist coat is a function of the finish the panel face is to receive. If the panel face is to be lightly abrasive-blasted, a 1/4-in.-thick mist coat is adequate.

- **Applying the GFRC Mix:** Soon after the mist coat is applied, GFRC mix is sprayed on the mold. See Figure 26.58(a). GFRC mix consists of (white) portland cement and sand slurry mixed with about 5% (by weight) of glass fibers. Because air may be trapped in the mix during spraying, the mix is consolidated after completing the spray application by rolling, tamping, or troweling, Figure 26.58(b).

- **Frame Placement:** After the GFRC spray is completed, the steel backup frame is placed against the skin, leaving the required distance between the skin and the frame, Figure 26.59.

- **Bonding Pads:** Finally, bonding pads are formed at each anchor using the same mix as that used for the skin, Figure 26.60.

- **Removing the Panel from the Mold and Curing:** The panel (skin and frame) is generally removed from the mold 24 h after casting and subsequently cured for a number of days. Because the panel has not yet gained sufficient strength, special care is needed during the panel’s removal.

**FIGURE 26.56** The mold of a roof cornice panel.

**FIGURE 26.57** Application of mist coat. (Photo by MM.)
The standard finish on a GFRC panel is a light abrasive-blasted finish to remove the smoothness of the surface obtained from the mist coat. However, a GFRC panel can also be given an exposed aggregate finish, which results in a surface similar to that of a precast concrete panel.

To obtain an exposed aggregate finish, the mist coat is replaced by a concrete layer, referred to as a face mix. The thickness of the face mix is about \( \frac{3}{16} \) in., and the aggregate used in the face mix is between \( \frac{1}{16} \) in. and \( \frac{1}{4} \) in. The exposure of aggregate is obtained by abrasive blasting or acid etching.
26.12 DETAILING A GFRC CURTAIN WALL

A GFRC panel is connected to the building’s structure in a system similar to that of a pre-cast concrete panel. In other words, a GFRC panel requires two bearing connections and two or more tieback connections. However, because GFRC panels are much lighter than the precast concrete panels, their connection hardware is lighter.

As with precast concrete curtain walls, the structural design of panels and their support connections is generally the responsibility of panel fabricator. Figures 26.61 and 26.62

FIGURE 26.61 Schematic details of bearing and tieback connections in a spandrel GFRC panel (see also Figures 26.62 and 26.63).
show two alternative schematics for the connection of a GFRC spandrel panel to the building’s structure.

Figure 26.63 shows a typical GFRC curtain wall detail. Because GFRC skin is thin, some form of water drainage system from behind the skin should be incorporated in the panels. Additionally, the space between the GFRC skin and the panel frame should be freely ventilated to prevent the condensation of water vapor. This is generally not a requirement in precast concrete curtain walls. A two-way joint sealant system may be used at panel junctions similar to that for PC curtain walls (Figures 26.50 and 26.51).

**FIGURE 26.62** Schematic details of bearing supports and tieback connections in a spandrel GFRC panel (see also Figures 26.61 and 26.63).
26.13 PREFABRICATED BRICK CURTAIN WALL

Prefabricated brick panels using full-thickness bricks can also be used as curtain wall panels. The façade of a building with prefabricated brick panels looks similar to that of a building with site-constructed brick veneer. In a façade with prefabricated brick panels, however, the exterior soffit can also be of bricks, giving an all-brick appearance.

Figure 26.64 shows a completed building with prefabricated exterior brick panels. The panels are L-shaped so that the wall and the spandrel and soffit elements are integrated into one panel. Figure 26.65 shows the details and various stages of erection of the panels.

Brick panels are constructed in the masonry contractor’s fabrication yard (or indoor plant) and transported to the site. They are reinforced in both directions. Reinforcement in one direction is provided by epoxy-coated steel bars placed into the core holes of bricks. The core holes are filled with portland cement–sand grout. In the other direction, galvanized steel joint reinforcement placed within the bed joints of panels is used.

In addition to reinforcing bars and joint reinforcement, a brick curtain wall panel generally requires two structural steel frames integrated into the brick panel to provide bearing...
supports and tieback connections. The details of the structural frame, used in the panels of the building of Figure 26.64, are shown in Figures 26.66 and 26.67.

A steel stud backup wall incorporating insulation, vapor barrier, and drywall is required with prefabricated brick curtain wall. Additionally, some means must be provided for the drainage of water from behind the panel.

**PRACTICE QUIZ**

Each question has only one correct answer. Select the choice that best answers the question.

30. The term GFRC is an acronym for  
   a. glass fiber-reinforced concrete.  
   b. glass fiber-reinforced cement.  
   c. glass fiber-restrained concrete.  
   d. glass fiber-restrained cement.  
   e. none of the above.  

31. A GFRC curtain wall panel consists of  
   a. a GFRC skin.  
   b. a light-gauge steel frame.  
   c. anchors.  
   d. all the above.  
   e. (a) and (b).

32. The GFRC skin is typically  
   a. 2 to 3 in. thick.  
   b. 1 1/2 to 2 1/2 in. thick.  
   c. 1 to 2 in. thick.  
   d. 1/2 to 1 in. thick.  
   e. None of the above.
33. The glass fibers used in GFRC skin are referred to as AR fibers. The term AR is an acronym for
   a. alkali resistant.
   b. acid resistant.
   c. alumina resistant.
   d. aluminum reinforced.
   e. none of the above.

34. The anchors used in GFRC panels are typically
   a. two-piece anchors.
   b. one-piece anchors.
   c. either (a) or (b), depending on the thickness of GFRC skin.
   d. either (a) or (b), depending on the lateral loads to which the panel is subjected.
   e. none of the above.

35. The GFRC skin is obtained by
   a. casting the GFRC mix in a mold similar to casting a precast concrete member.
   b. applying the mix with a trowel.
   c. spraying the mix over a mold.
   d. any of the above, depending on the panel fabricator.

36. GFRC curtain wall panels are generally lighter than the corresponding precast concrete curtain wall panels.
   a. True
   b. False

37. In prefabricated brick curtain wall panels, the bricks used are
   a. generally of the same thickness as those used in brick veneer construction.
   b. generally thicker than those used in brick veneer construction.
   c. generally thinner than those used in brick veneer construction.

38. Prefabricated brick curtain wall panels are generally fabricated
   a. in a brick-manufacturing plant.
   b. in a masonry contractor's fabrication yard.
   c. in a precast concrete fabricator's plant.
   d. at the construction site.
REVIEW QUESTIONS

1. Using sketches and notes, explain the adjustability requirements of anchors used in a brick veneer wall assembly.
2. Using sketches and notes, explain the functions of a shelf angle and a lintel angle in a brick veneer assembly.
3. With the help of sketches and notes, explain various ways by which weep holes can be provided in a brick veneer assembly.
4. Discuss the pros and cons of using a CMU backup wall versus a steel stud backup wall in a brick veneer wall assembly.
5. With the help of sketches and notes, explain the support system of a precast concrete curtain wall panel.
6. With respect to a GFRC panel, explain: (a) bonding pad and (b) flex anchor.

SELECTED WEB SITES

- Brick Industry Association, BIA (www.bia.org)
- International Masonry Institute, IMI (www.imiweb.org)
- Precast/Prestressed Concrete Institute, PCI (www.pci.org)
- Magazine of Masonry Construction (www.masonryconstruction.com)

FURTHER READING

6. Precast/Prestressed Concrete Institute (PCI). Recommended Practice for Glass Fiber Reinforced Panels.
7. Tilt-Up Concrete Association (TCA) and American Concrete Institute (ACI). The Tilt-Up Design and Construction Manual.

REFERENCES

1. American Concrete Institute: Building Code Requirements and Commentary for Masonry Structures and Specifications for Masonry Structures and Related Commentaries, ACI530/530.1.