Feature

Anchored Brick Veneer: What Can Go Wrong and How to Prevent This

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BRICK SYSTEMS

Anchored brick veneer is a cladding system that is designed with a structural backup wall where the brick is then structurally tied (or anchored) to the backup wall. The brick veneer acts as a rainscreen, with an air cavity and water-resistant barrier that allows any rainwater that penetrates the brick veneer to migrate along the rear face of the brick toward a drainage system (flashing and weeps) that directs the rainwater to the outside. This system recognizes that brick and mortar are porous and manages the flow of rainwater, so it does not migrate into the backup wall or the interior of the building.

Photo 1. *The American Brewery, built in Baltimore, Maryland, in 1863 (rebuilt in 1887).*

Composite brick walls are a structural system that utilizes the full thickness of the brick for the strength of the wall, and they are usually made up of two or more wythes (vertical columns of brick) that are fully mortared together. These wythes may be reinforced or plain (unreinforced). Composite brick walls are mass walls and were historically used in the construction of buildings until the mid-20th century (and are still used today). Composite walls absorb moisture yet are thick enough that the moisture is typically stored in the outer wythes of brick and then dries out between weather events. Flashing is still required at floor lines, parapets, and openings to direct absorbed moisture to the exterior as it migrates toward these areas.

ATTRIBUTES, SUSTAINABILITY, AND BENEFITS OF BRICK

Brick has many positive attributes, including aesthetics (warmth, beauty, and scale), long-term performance, and sustainability. Brick has been in use for thousands of years. Its origins can be traced back to 7000 BCE, when brick use was discovered in southern Türkiye. Early bricks were made from clay and sun-dried to harden. Later, the ancient Egyptians mixed the clay with straw. (A similar process was used to make adobe, used by the Native Americans for centuries.) In 3,500 BCE, fired brick was invented.[1]

Examples of brick can be found throughout the world; however, one does not have to look far to see its beauty and contribution to our historic and contemporary architecture. For example, Baltimore, MD, has used brick for more than two centuries (**Photo 1**).

Photo 2. *Sealant separation at a window secured to wood framing due to shrinkage of the wood framing and expansion of the brick veneer. Photo from Rimkus Archives.*

Photo 3. *Sealant separation at a window secured to wood framing due to shrinkage of the wood framing and expansion of the brick veneer. Photo from Rimkus Archives.*

Brick is sustainable. According to the Brick Industry Association (BIA), brick is recyclable and can be reused in construction or crushed and used for sub-base materials or permanent landscaping mulch. Brick contributes to energy efficiency by absorbing heat and releasing it later (thermal mass), has a long lifespan (100 years), and is easy to maintain.[2]

To fully utilize sustainability in brick, care must be taken to design the brick veneer for compliance with the codes and with a basic understanding of its material properties to avoid failures and costly repairs. For a material that, when properly designed and constructed, can last 100 years (or more), the benefits of sustainability are greatly compromised if failures appear within the first 10 to 20 years, or less, due to improper design and/or installation.

MATERIAL PROPERTIES

There are several material properties related to brick, including its compressive, shear, and flexural tensile strengths; elastic modulus; and the expansion of brick. These properties are primarily structural in nature and should be specified for its intended use by the designer. More detailed information regarding these properties can be found in BIA, "Brick Masonry Material Properties," Technical Notes 3A,[3] and The Masonry Society, "Building Code Requirements for Masonry Structures," TMS 402, Chapter 4.2.[4]

Temperature, moisture absorption, freezing, and creep cause material properties in brick to constantly move in different directions and at different rates. Brick continues to expand over time, and results in a net growth of brick compared to other materials like wood or concrete that experience shrinkage as the wood dries out or as the concrete cures. Unlike concrete, brick is made from clay. Brick or concrete will experience expansion and contraction due to temperature changes; however, brick will also gradually absorb moisture over time, causing it to expand (not shrink), reaching most of its maximum size within the first several years after installation. Brick will not return to its original size; the expansion due to moisture retains a net growth that is permanent. The expansion of brick due to temperature change is nearly the same as the expansion due to absorption of moisture. Two other components affecting the growth of brick are creep and freezing, though these have a smaller overall impact on brick. The designer should be familiar with the material properties of brick veneer when used with a wood-framed back-up wall, the brick veneer stresses at corners and openings and the best practices for sizing and placement of expansion joints to prevent unsightly cracks or gaps at window openings.

Properties of Brick Veneer Anchored with a Structural Wood-Framed Backup Wall

Wood framing will shrink as it dries out, in contrast to brick, which expands over time. Wood shrinkage adjacent to expanding brick should be accounted for at openings in the brick veneer or else sealant can split and result in gaps at windows, doors, and other sizable openings (**Photo 2** and **3**). The anticipated shrinkage of wood must be added to the calculated expansion of the brick veneer. Given the current trends to construct midrise buildings with wood framing that are typically five or six stories in height, the overall shrinkage of the wood is a function of its overall length and the deadload of the structure. Framing must be designed to minimize shrinkage and horizontal expansion joints, supported by steel shelf angles, are recommended at each floor to accommodate the anticipated net movement due to expansion of the brick and shrinkage of the wood framing or damage can occur.

Properties of Brick at Corners, Offsets, and Openings

How does brick veneer behave? The brick will move in all directions and stress tends to build up at building corners and openings (**Fig. 1**).[5]

Designing for Expansion Joints

The movement of brick requires that large areas of brick veneer be divided up into smaller areas by installing expansion joints to minimize the stress on the brick veneer and prevent cracking. Adequately sized brick areas for appropriate stress relief are just part of the equation; how the brick is supported is just as important when it comes to minimizing stress due to differential building movements, deflection and/or movement of the supporting shelf angle. Assuming a 100-degree Fahrenheit (38°C) change in temperature as a rule of thumb, these factors together result in a combined movement

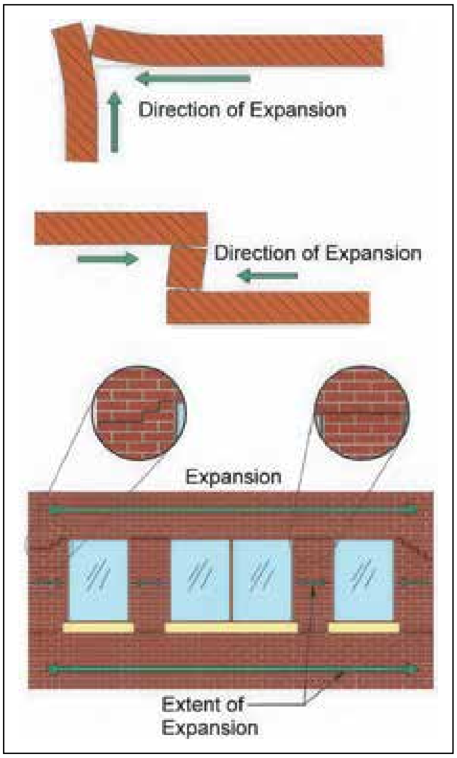

Figure 1. *Movement of brick veneer at corners, offsets, and punched openings. Image from BIA, TN 18A, pp. 4-5, May 2019.*

of 0.0009*L* (where *L* equals the length of the wall, or the distance between expansion joints).[6]

So, what is the recommended expansion joint strategy? The BIA has the following recommendations for vertical expansion joints:[5]

- Brickwork without openings: 25 ft (7.6 m.) o.c.
- Multiple openings in brickwork: 20 ft (6.1 m.) o.c.
- Widen the joints for parapet walls when the joints are more than 15 ft (4.6 m.) o.c.; or separate with a horizontal joint and then place another joint midway at the parapet wall.
- Place joints at or near corners (within 2 ft) (0.6 m.), offsets, wall intersections, changes in substrate (backing system), and changes in brick support.

For horizontal joints:

- Locate immediately below shelf angles with a minimum ¼ in. joint (0.6 cm.) and compressible filler within the joint.

When detailing the expansion joint, a backer rod and sealant must be provided to reduce moisture intrusion through the brick veneer and to reduce infestation by insects (you don't want a beehive behind your brick!). Some sealants can compress as much as 50%, so the calculated joint width should be doubled to accommodate the sealant.

It's not just the vertical joints where the sealant limitations must be factored into joint size. As noted earlier, brick moves in each direction, and an undersized joint can cause sealant to squeeze out of horizontal joints (**Photo 4**). The horizontal joint should be located below the steel shelf angle with compressible filler.

Expansion Joints at Building Corners and Offsets

Placing the vertical expansion joint within 2 ft (0.6 m.) of the corner is preferred since it is convenient for a typical mason, who can reach 2 ft (0.6 m.) around the corner (**Fig. 2**).[5]

The location of the vertical expansion joint from the corner (2 ft or 0.6 m.) is then added to the distance to the next vertical expansion joint on the adjacent wall so you do not exceed your calculated distance between expansion joints. Corner crack failures are usually located within 4 in. (10.1 cm.) of the outside corner (the nominal thickness of a brick) and are usually caused by insufficient or lack of vertical expansion joints to accommodate movement (**Photo 5** and **6**).

Expansion Joints at Punched Openings

For brickwork with regularly spaced punched openings, the brick will move more above and below the openings (long brick panels) than between the openings (shorter brick panels).[5] A natural location for the joint would be at the opening corner; however, the supporting loose

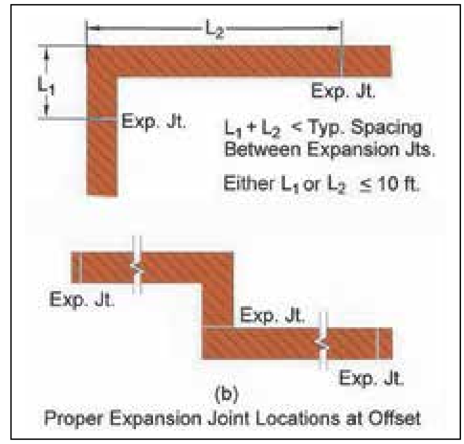

Figure 2. *Expansion joints near corners and offsets. Image from BIA, TN 18A, pp. 4-5, May 2019.*

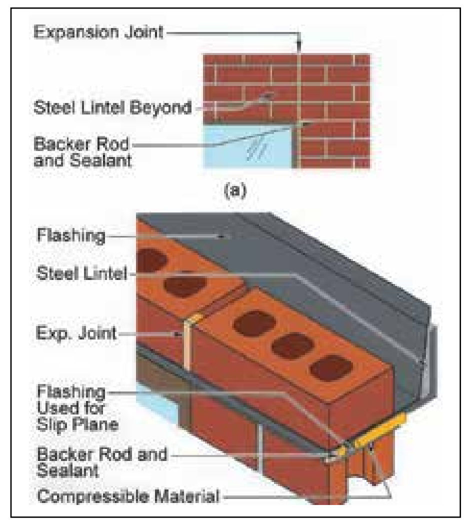

Figure 3. *Detail of an expansion joint at a punched opening corner. Image from BIA, TN 18A, p. 6, May 2019.*

laid lintel would require flashing to function as a slip plane on the expansion joint side of the lintel to move independently from the adjacent brick (**Fig. 3**). This allows the lintel bearing end

Photo 4. *Compressed sealant at a horizontal movement joint. Photo from Rimkus Archives.*

Photo 5. *A corner crack in the anchored brick veneer. Photo from Rimkus Archives.*

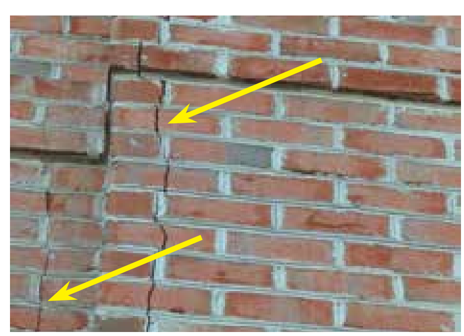

Photo 6. *A corner crack in the anchored brick veneer. Photo from Rimkus Archives.*

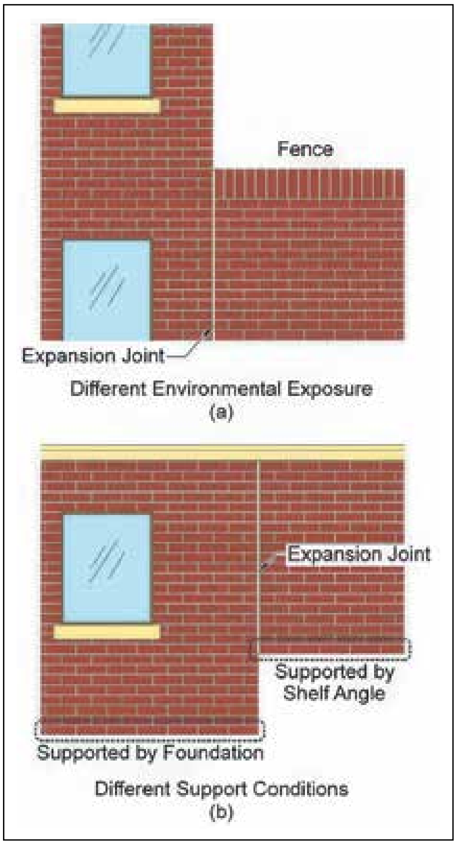

Figure 4. *Expansion joints at different environmental exposure and support conditions. Image from BIA, TN 18A, p. 6, May 2019.*

that overlaps the vertical expansion joint to move independently from the movement in the adjacent brick.

Expansion Joints Differing Adjacent Conditions

Expansion joints should also be provided at different environmental exposures, such as a fence or parapet wall, or when supported by different conditions (**Fig. 4**).[5]

BRICK VENEER CODE REQUIREMENTS

The building codes commonly used throughout the United States are the International Building Code (IBC) and the International Residential Code (IRC), each published by the International Code Council. Always verify with local jurisdictions regarding amendments and the currently effective edition of the code. For this presentation, the 2024 editions of the IRC and IBC were used. The IRC is limited to one- and two-family dwelling units that do not exceed three stories above grade plane.[7] The IBC applies to all buildings, and you have the option to use the IRC if you have a residential building that meets the applicable limitations noted above.

Both codes include brick veneer requirements and reference TMS 402 for specific brick veneer requirements. The 2022 edition of the TMS was referenced in this presentation. This article does not discuss the National Building Code of Canada or local provincial/territorial codes. The reader should consult with local codes for applicable guidance.

2024 IRC

The 2024 IRC allows the design of anchored brick veneer to comply with the prescriptive requirements within the IRC (Section 703.8) or applicable provisions of TMS 402 (2022),[4] TMS 403 (2017),[8] or TMS 404 (2022).[9]

The use of anchored brick veneer with a backing of wood-framed or cold-formed steel is limited to the "first story above grade plane and shall not exceed 5 inches in thickness." Exceptions that allow the use of brick more than one story above grade plane include the following:

- Buildings in Seismic Design Categories A, B, and C that are supported above a noncombustible foundation.
- Detached one- and two-family dwellings in Seismic Design Categories D(0), D(1), and D(2) as permitted above a noncombustible foundation.

Generally, the exceptions allow the following:

- Up to 30 ft (9.1 m.) and three stories in Seismic Design Categories A, B, and C if wood framed (plus an additional 8 ft (2.44 m.) at the gable end).
- Up to 30 ft (9.1 m.) and three stories (plus an additional 8 ft (2.44 m.) at the gable end) in Seismic Design Category D(0) if wood-framed and each story does not exceed 11 ft 7 in. (3.5 m.) or up to 13 ft 7 in. (4.1 m.) per story if meeting specific exceptions). Cripple walls are not allowed. (A cripple wall is a type of raised foundation wall framed in wood that is susceptible to earthquake damage.)
- Up to 20 ft (6 m.) in Seismic Design Categories D(1) and D(2), or 30 ft (9.1 m.) (plus an additional 8 ft [2.44 m.] at the gable end), if wood-framed and the lower 10 ft (3.1 m.) has a backing of a concrete or masonry wall. Cripple walls are not allowed.

The fasteners for the ties must be secured to the structural stud or into a wood structural panel (Table R703.8.4[1]). Table R703.8.4[1] establishes the type of tie, fastener, and air space allowed for fastening to structural studs (**Fig. 5**).

An air space of 1 in. (2.54 cm.) nominal is allowed for corrugated or wire ties, up to 4⅝ in. (11.7 cm.) for smaller-diameter adjustable wire ties, and between 4⅝ and 6⅝ in. (11.7 and 16.8 cm.) for larger-diameter adjustable wire ties.

Each veneer tie shall support not more than 2.67 ft^2 (0.25 m^2) of wall area and not exceed 32 in. (81 cm.) o.c. in the horizontal direction or 24 in. (61 cm.) o.c. in the vertical direction. In Seismic Design Category D or C (for townhouses) or in wind areas with design pressures exceeding 30 psf (0.48 kpa), then each tie shall not exceed 2 ft^2 (0.18 m^2) of wall area.

What About Drainage?

Section R703.1.1.1 states, "The exterior wall envelope shall be designed and constructed in a manner that prevents the accumulation of

TABLE R703.8.4(1)TIE ATTACHMENT AND AIRSPACE REQUIREMENTS

BACKING AND TIE	MINIMUM TIE	MINIMUM TIE FASTENER[a]	AIRSPACE[b]	
Wood stud backing with corrugated sheet metal	22 U.S. gage (0.0299 in.) × $^7/_8$ in. wide	8d common nail[c] ($2^1/_2$ in. × 0.131 in.)	Nominal 1 in. between sheathing and veneer	
Wood stud backing with adjustable metal strand wire	W1.7 (No. 9 U.S. gage; 0.148 in. dia.) with hook embedded in mortar joint[d]	8d common nail[c] ($2^1/_2$ in. × 0.131 in.)	Minimum nominal 1 in. between sheathing and veneer	Maximum $4^5/_8$ in. between backing and veneer
Wood stud backing with adjustable metal strand wire	W2.8 (0.187 in. dia.) with hook embedded in mortar joint[e, f]	8d common nail[c] ($2^1/_2$ in. × 0.131 in.)	Greater than $4^5/_8$ in. between backing and veneer	Maximum $6^5/_8$ in. between backing and veneer
Cold-formed steel stud backing with adjustable metal strand wire	W1.7 (No. 9 U.S. gage; 0.148 in. dia.) with hook embedded in mortar joint[d]	No. 10 screw extending through the steel framing a minimum of three exposed threads	Minimum nominal 1 in. between sheathing and veneer	Maximum $4^5/_8$ in. between backing and veneer
Cold-formed steel stud backing with adjustable metal strand wire	W2.8 (0.187 in. dia.) with hook embedded in mortar joint[e, f]	No. 10 screw extending through the steel framing a minimum of three exposed threads	Greater than $4^5/_8$ in. between backing and veneer	Maximum $6^5/_8$ in. between backing and veneer

For SI: 1 inch = 25.4 mm.

a. All fasteners shall have rust-inhibitive coating suitable for the installation in which they are being used, or be manufactured from material not susceptible to corrosion.
b. An airspace that provides drainage shall be permitted to contain mortar from construction.
c. In Seismic Design Category D_0, D_1 or D_2, the minimum tie fastener shall be an 8d ring-shank nail ($2^1/_2$ in. × 0.131 in.).
d. Adjustable tie pintles shall include not fewer than 1 pintle leg of wire size W2.8 (MW18) with a maximum offset of $1^1/_4$ inches.
e. Adjustable tie pintles shall include not fewer than 2 pintle legs with a maximum offset of $1^1/_4$ inches. Distance between inside face of brick and end of pintle shall be a maximum of 2 inches.
f. Adjustable tie backing attachment components shall consist of one of the following: eyes with minimum wire W2.8 (MW18), barrel with minimum $^1/_4$-inch outside diameter, or plate with minimum thickness of 0.074 inch and minimum width of $1^1/_4$ inches.

Figure 5. *2024 IRC Table R703.8.4(1). Image cropped by Rimkus.*

water…and a means of draining to the exterior water that penetrates the exterior cladding."

Weep holes should be spaced at 33 in. (84 cm.) o.c. and located immediately above the flashing.

2024 IBC

The 2024 IBC differs from the 2024 IRC in that anchored masonry veneer requires compliance with Sections 1404.7 through 1404.10 as well as Sections 13.1 and 13.2 of TMS 402.[10] For anchored brick veneer, IBC defaults only to chapters 13.1 and 13.2 of TMS 402, since Sections 1404.8 through 1404.10 are specific to anchored stone veneer, slab-type veneer, and terra cotta veneer.[10] IBC Section 1402.2 requires exterior walls to include a drainage system that provides a means to drain water that enters the assembly to the exterior.

TMS 402

TMS 402 (2022)[4] is used as a basis here, but other editions may currently be in effect, so the chapter numbers and requirements may differ from what referenced below. The requirements for brick veneer ties are primarily located in TMS 402 Chapter 13 (IBC requires compliance with Sections 13.1 and 13.2).

Section 13.1 includes general requirements for the system to comply with the weather, structural, fire, and thermal requirements of the legally adopted building code. It requires the veneer to accommodate deformations and differential movement, states that the deflection of structural elements supporting masonry shall not exceed *L*/600 and includes loading limitations on the face of the anchored veneer within a 5-by-5 ft (1.5-by-1.5 m.) area. Section 13.1 also requires compliance with TMS 402 Part 1 and Chapter 4, which address contract document requirements, definitions, and quality assurance.

Section 13.2 provides the requirements for anchored masonry veneer. The code allows for two paths: Prescribed Design Method or Engineered Design Method. This article will generally address the Prescribed Design Method, as it relates to masonry with a running bond. A running bond is how brick is usually constructed, where the vertical joints in the row of bricks above and below a brick line up with the middle of the brick unit. The Prescribed Design Method includes Basic and Enhanced options. The Enhanced path generally requires the ties to be spaced closer together to meet increased surface pressures and/or seismic design categories.

Regarding the veneer ties, the specified requirements for most uses include the following:

- The thickness of the mortar bed joint should be at least twice the thickness of the veneer tie.
- Deflection limits for the backup wall for wind and seismic loads
- Requirements for lintels above openings
- Isolation of the sides and top of the anchored veneer in Seismic Design Categories C, D, E, and F; support at each floor; and added movement joints.
- For water penetration resistance, flashing and weep holes to resist water migration below the drainage plane (water-resistant barrier) with a minimum of 1 in. (2.54 cm.) air cavity and weep holes spaced no more than 33 in. (84 cm.) o.c.
- General anchored veneer requirements (TMS Table 13.2.2.3)[4]: Brick veneer can be anchored to a supporting backup wall using several types of acceptable brick veneer ties, depending on the substrate, height, and cavity width. The type of tie required depends on the use of the building (single-family home or not), and the type of structural backup wall (wood-framed, steel-stud framed, or concrete masonry unit). The appropriate veneer ties, including spacing requirements, and attachment are essential to the long-term performance of brick veneer. There are numerous types of acceptable veneer ties. Following are some basic examples:
    - ❑ Corrugated sheet metal ties (for use on wood-framed residential buildings, 1 in. (2.54 cm.) cavity width and no more than 30 ft (9.1 m.) high or 38 ft (11.6 m.) at a gable end. The fasteners must be within ½ in. (1.2 cm.) of the right-angle bend (**Fig. 6**).

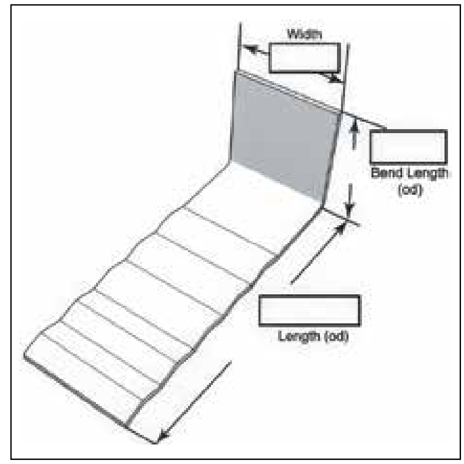

Figure 6. *Corrugated sheet metal tie—Hohmann and Bernard product sheet. Image cropped by Rimkus.*

    - ❑ Sheet metal ties (for use on wood-framed substrate, limited to 4 in. (10.1 cm.) cavity width and a height limit of 30-ft (9.1 m.) or 38 ft (11.6 m.) at the gable end. The ties come in corrugated or noncorrugated configurations (**Fig. 7**).
    - ❑ Adjustable ties (for use on wood-framed/cold-formed/concrete, or concrete masonry unit substrates, limited to 4 in. (10.1 cm.) cavity width and up to 6 in. (15.2 cm.) cavity width with additional requirements. May exceed 30 ft (9.1 m.) or 38 ft (11.6 m.) at the gable end for wood-framed and cold-formed metal stud backing if designed for differential movement, and must meet pullout resistance requirements for concrete backing (**Fig. 8**).

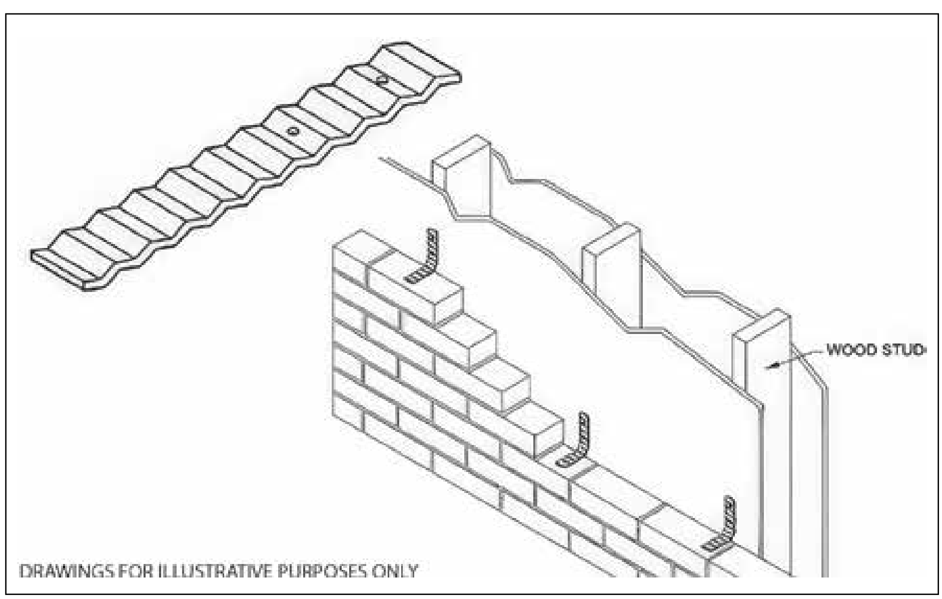

Figure 7. *Sheet metal tie—Heckmann Building Products sheet. Image cropped by Rimkus.*

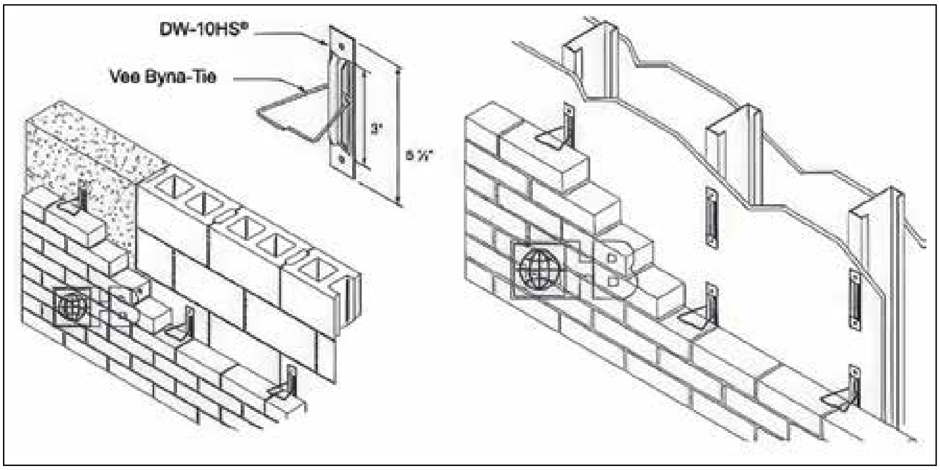

Figure 8. *Adjustable brick tie—Hohmann and Bernard. Image cropped by Rimkus.*

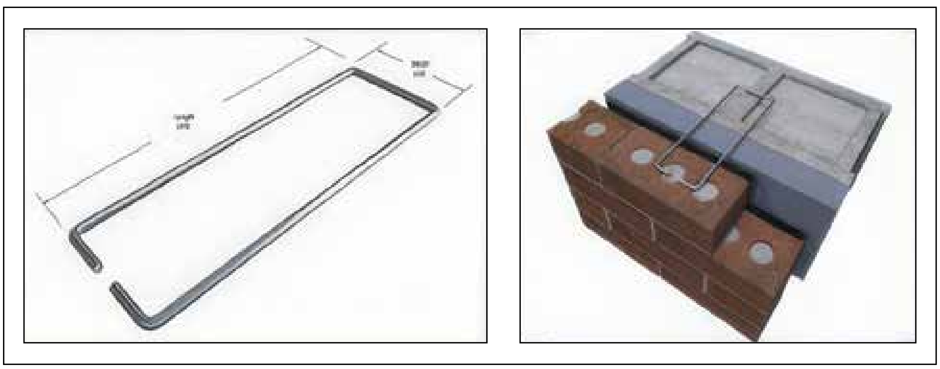

Figure 9. *Nonadjustable unit wire tie—Heckmann Building Products cut sheet. Images cropped by Rimkus.*

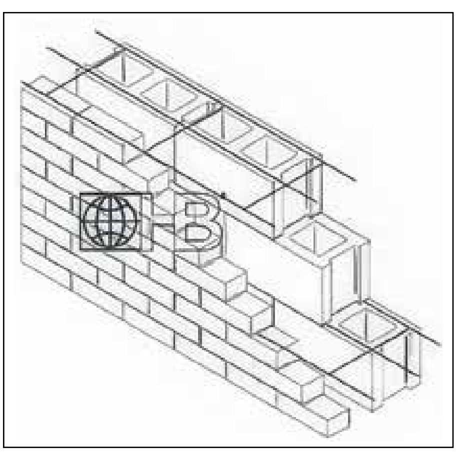

Figure 10. *Ladder-type joint reinforcement tie—Hohmann and Bernard. Image cropped by Rimkus.*

- ❑ Adjustable, unit wire, and joint reinforcement ties (for use with clay [brick] or concrete unit masonry substrates), limited to 6 in. (15.2 cm.) air cavity. Must meet pullout resistance requirements (**Fig. 9** and **10**).

- Out-of-plane corbelling (per Section 5.6). Corbelling is the out-of-plane projection or recession of a row of bricks).
  - ❑ Solid units or units with holes grouted solid must be used.
  - ❑ The maximum projection from the face of the wall must not exceed one-half of the nominal brick wythe.
  - ❑ Each corbelled brick projection must not exceed one-half of the nominal unit height and one-third of nominal brick wythe.
  - ❑ Total corbelling is limited to no more than a 1 in. (2.54 cm.) offset from rear face of brick units. This will generally be the limiting factor when modular size brick units are used.
  - ❑ Note: brick supported by steel shelf angles would "corbel" beyond the lip of the angle. This means a minimum of ⅔ of the brick must be supported by the angle.
- Fastener pullout resistance shall have a minimum design strength of 335 pounds (152 kg.) or an allowable load of 200 pounds (90.7 kg.).
- Cavity width (not drainage space) is from face of framing (not the face of the sheathing).
- Veneer tie specifications (Table 13.2.2.4)
- Veneer tie spacing requirements for Basic and Enhanced prescriptive design methods:
  - ❑ Basic: 2.67 ft^2 (0.25 m^2) per tie, no more than 24 in. (61 cm.) spacing in either direction.
  - ❑ Enhanced: 1.78 ft^2 (0.16 m^2) per tie, no more than 16 in. (40.6 cm.) spacing in either direction (this meets recommended spacing from manufacturers).

CAVITY WALL DRAINAGE

In addition to the requirements of movement joints, proper brick support, and the requirements for veneer ties and veneer tie spacing, the IRC, IBC, and TMS all have requirements for cavity wall drainage. Cavity wall drainage is essential to prevent the buildup of rainwater that may bypass any overlap joints in the water-resistant barrier or other flashing systems, resulting in corrosion of steel elements and fasteners and deterioration of the sheathing and framing. The BIA provides information on "proper design, detailing and construction to minimize water penetration into or through a wall system" (**Fig. 11** and **12**).[11] This includes the following:

- Through-wall flashing locations and installation and termination recommendations
- Water-resistant barrier recommendations
- Air-barrier recommendations
- 1 in. (2.54 cm.) minimum drainage cavity
- Weep requirements (referenced earlier)

Through-wall flashing is an impervious material of, and is essential for, the drainage system. Through-wall flashing materials may include sheet metal, flexible copper fabric, polyvinyl chloride, and bituminous (self-adhered) membranes. Through-wall

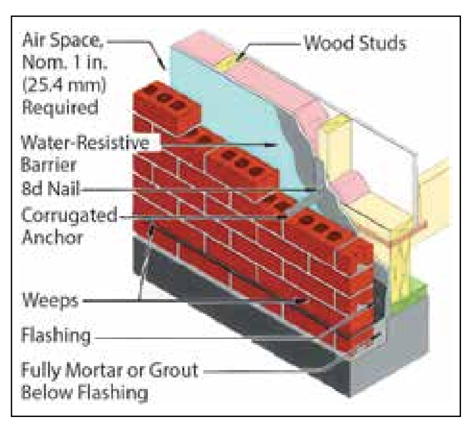

Figure 11. *Brick veneer with wood framing. Image from BIA TN 7 page 3. Image cropped by Rimkus.*

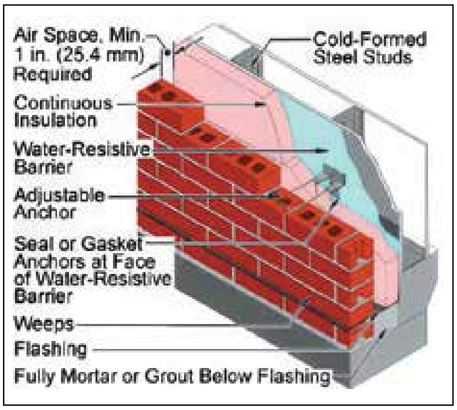

Figure 12. *Brick veneer with cold-formed steel framing. Image from BIA TN 7, p. 3. Image cropped by Rimkus.*

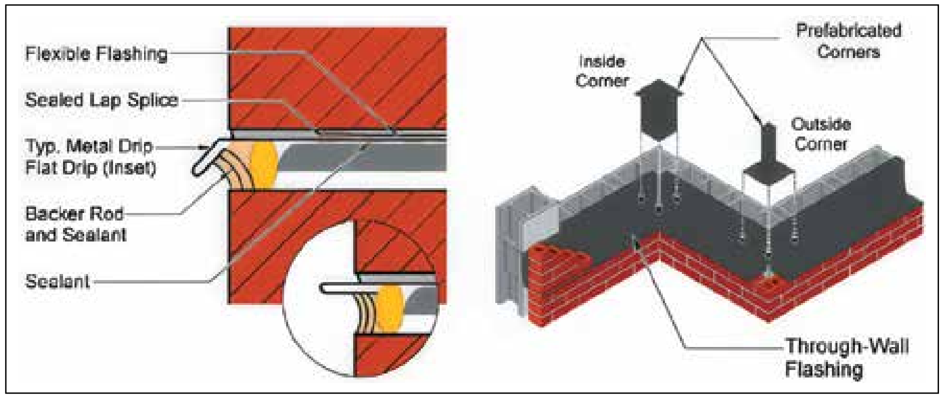

Figure 13. *Drip edge and through-wall flashing. Image from BIA TN 7, p. 6. Image cropped by Rimkus. The through-wall flashing selected must be compatible with other materials and components. The BIA recommends that the system of flashing, water-resistant barrier, sealants, and any adhesives and primer be sourced from a single manufacturer to confirm compatibility.*

flashing is required at the base of walls, windowsills, window lintels, shelf angles, projections, chimneys, tops of walls, and roofs. Flashing must extend vertically at least 8 in. (20.3 cm.) above the horizontal leg. The BIA recommends that a metal drip edge insert be provided at the exterior (**Fig. 13**).

The BIA recommends end-dams in flashing to prevent moisture from migrating behind the flashing. Weep tubes or wicks should be spaced no more than 16 in. (40.6 cm.) o.c., and open-head joint weeps no more than 24 in. (61 cm.) o.c. (closer than the 33 in. [84 cm.] maximum spacing allowed in the IRC and TMS) (**Fig. 14**).

There are several critical flashing locations that must be addressed. These include the base of the wall (no more than 10 in. [25.4 cm.] above grade) and consider ground treatment, such as mulch and the slope of the grade. If the brick veneer extends below grade, then fully grout the collar joint below the flashing (**Fig. 15**).

Other critical areas include lintels, windowsills, and shelf angles. As noted earlier, provide for end dams at window flashing at windowsills and lintels (**Fig. 16** and **17**).

COMMON ANCHORED BRICK VENEER FAILURES

In addition to the corner cracks noted above, other examples of cracking include:

Stairstep Pattern Cracks

Stairstep-pattern cracks are usually wider on one end and can taper to a hairline width on the other end. They are typically caused by differential movement within the field of brick, either by unequal foundation settlement or by movement on one end or the other of the steel angle

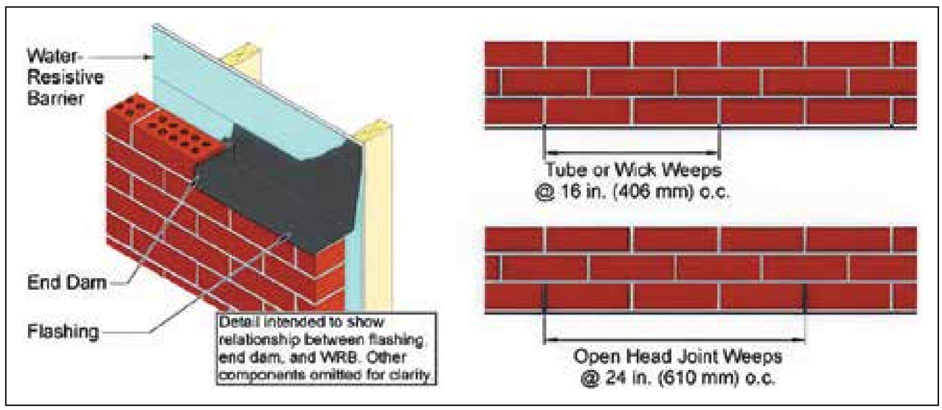

Figure 14. *End dams and weep spacing. Image from BIA TN 7, p. 7. Image cropped by Rimkus.*

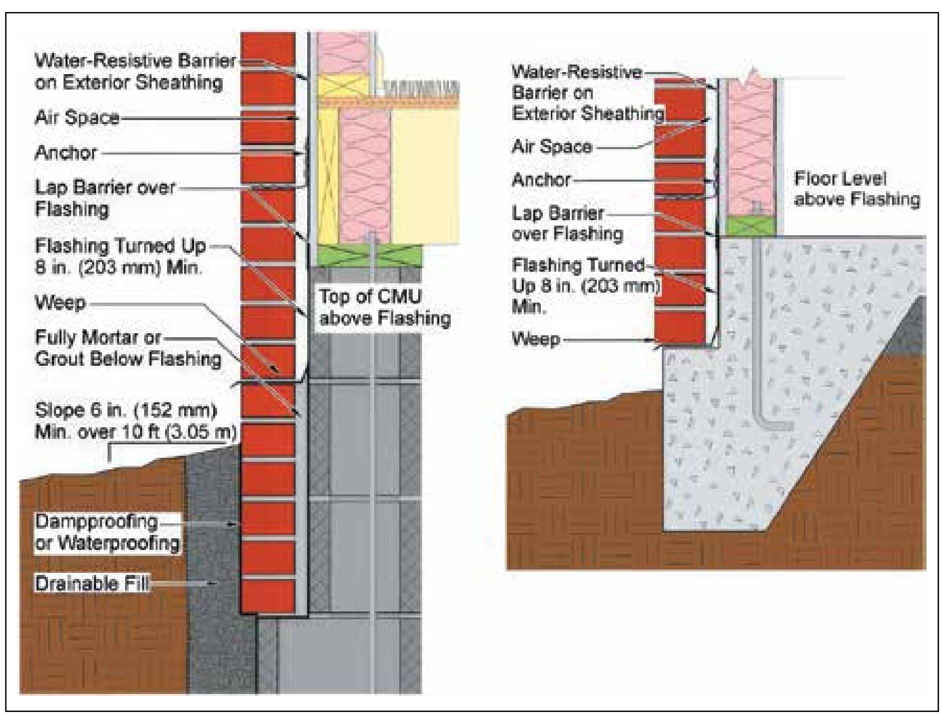

Figure 15. *Base of wall flashing. Image from BIA TN 7, p. 9. Image cropped by Rimkus.*

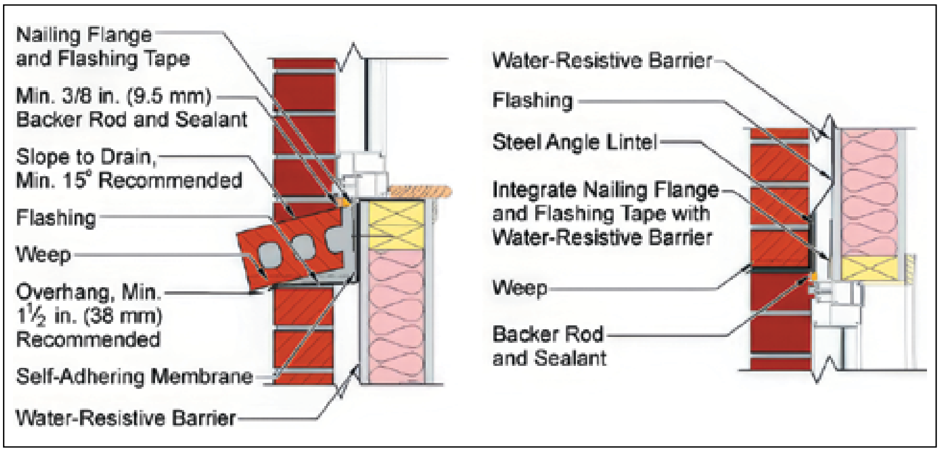

Figure 16. *Windowsill and lintel flashing. Image from BIA TN 7, p. 10. Image cropped by Rimkus.*

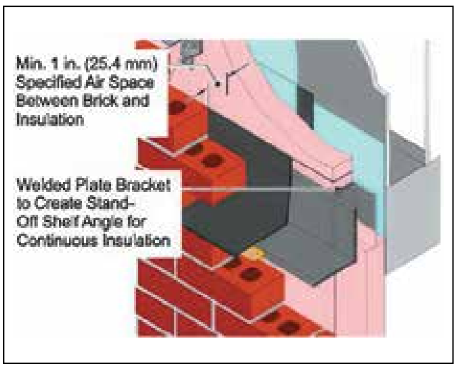

Figure 17. *Stand-off steel lintel detail. Image from BIA TN 7, p. 11. Image cropped by Rimkus.*

lintel due to insufficient torque of the anchor bolts. By pointing downward in a perpendicular direction from the crack, one can approximate the location where the differential movement occurred. IRC, IBC and TMS 13.1 require that the building meet structural requirements to limit differential movement (**Photo 7**).

Vertical Cracks

Vertical cracks are failures typically caused by an undersized steel angle (lintel). When the angle deflects, a vertical crack occurs that is wider at the bottom than at the top (The TMS limits deflection to *L*/600) (**Photo 8**).

Horizontal Cracks

Horizontal cracks are typically caused by insufficient or lack of horizontal movement joints or movement of the shelf angle due to insufficient torque of the anchor bolts. The TMS contains commentary that references BIA, Technical Notes 18A, for expansion joint requirements (**Photo 9** and **10**).

Spalling

Spalling failure can be caused by several factors, such as age-related deterioration of the brick, or by allowing it to retain moisture, become soft, or flake off fragments due to the freeze/thaw cycle (aka spalling). Nonpermeable paint can also trap moisture within the brick. Spalling can also result from inadequate allowance for movement joints or from embedded items within the brick. For historic brick buildings, the use of incompatible portland cement mortar over the existing lime-rich mortar can result in spalling. For more information on spalling, see BIA, Technical Notes (**Photo 11** and **12**).

Bowed Brick

Bowed brick veneer is typically caused by failed brick veneer ties, which allow the brick to move outward, resulting in separation gaps at the windows and vertical and diagonal cracks at the stress points. IRC, IBC and TMS specify requirements for brick veneer ties (**Photo 13** through **15**).

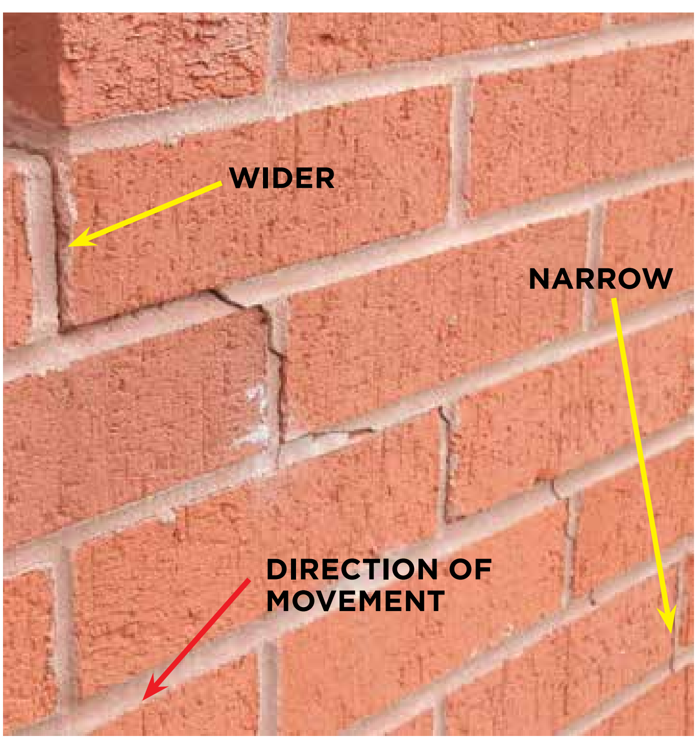

Photo 7. *A stair-step-pattern crack. Photo from Rimkus Archives.*

Photo 8. *A vertical crack. Photo from Rimkus Archives.*

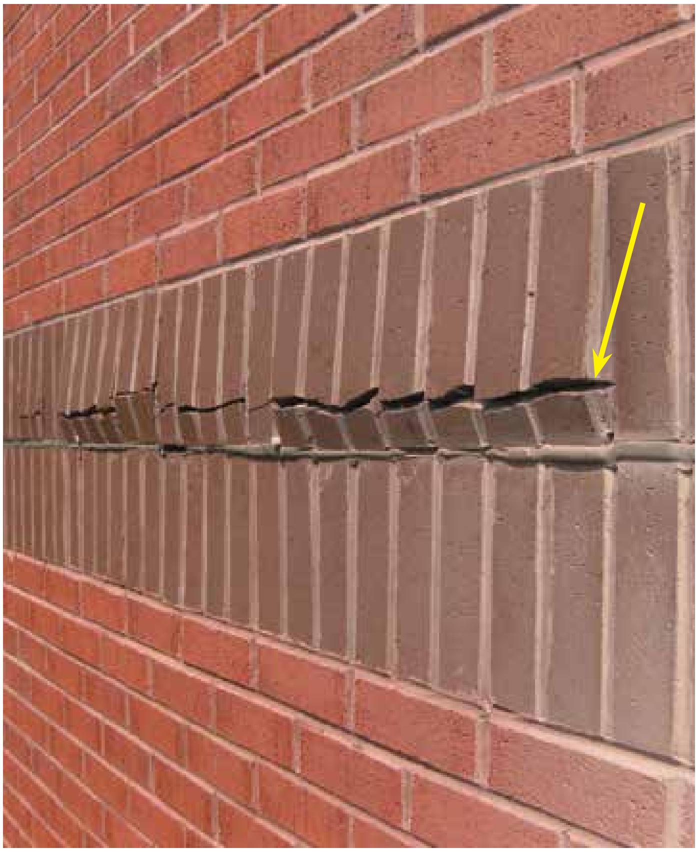

Photo 9. *A horizontal crack. Photo from Rimkus Archives.*

Photo 10. *A view of the steel shelf angle below a horizontal crack. Photo from Rimkus Archives.*

Photo 11. *Spalled brick. Photo from Rimkus Archives.*

Photo 12. *Spalled and fractured brick due to compression. Photo from Rimkus Archives.*

Photo 13. *Bowed brick veneer. Photo from Rimkus Archives.*

Photo 14. *Joint separation at the window in a bowed brick veneer wall. Photo from Rimkus Archives.*

Photo 15. *A vertical crack in a bowed brick veneer wall. Photo from Rimkus Archives.*

Photo 16. *Efflorescence on the brick-and-mortar joint surfaces. Photo from Rimkus Archives.*

Efflorescence

Efflorescence develops when excess moisture in the masonry causes the salts in the mortar and brick to dissolve and to crystalize on the surface as the moisture dries out. It appears as a white, powdery surface deposit (**Photo 16**).

CORRELATION ISSUES WITH CODES/STANDARDS

"Cavity width" as defined by TMS varies when compared to "air space" as used in IRC—inconsistent when using corrugated sheet metal ties. Although TMS and IRC require a minimum 1 in. (2.54 cm.) drainage plane (air space in IRC), TMS limits the "cavity width" when installed on a wood-framed backup wall to 1 in. (2.54 cm.). The TMS cavity width is from the stud face to the back face of the brick, effectively making the joint approximately ½ in. (1.3 cm.) when you subtract the sheathing. The TMS commentary says that both requirements can be satisfied within the tolerances of each, yet tolerances are not clearly specified other than that some mortar droppings are allowed within the air cavity. The TMS code allows an alternative to measure the cavity width from the face of the sheathing if the sheathing has a bearing stress of 100 psi (689 kpa) or the ties used to penetrate the sheathing to the light frame backing have a compressive strength of 200 psi (1379 kpa). Best practice is to provide at least a 1 in. (2.54 cm.) drainage plane to meet the TMS strength requirements for the sheathing. Another option is to use an adjustable tie where up to a 6 in. (15.2 cm.) cavity width per TMS is allowed (the IRC allows up to 6⅝ in. (16.8 cm.).

There are variables for veneer tie spacing, as noted in IRC and TMS. IRC allows the veneer ties to be spaced no more than 32 in. o.c. (81 cm.) horizontal and no more than 24 in. o.c. (61 cm.) vertical, whereas TMS limits the spacing to no more than 24 in. o.c. (61 cm.) in either direction. The maximum brick area per tie in both codes is limited to 2.67 ft^2 (0.25 m^2). For seismic zones, TMS limits the area per tie to 1.78 ft^2 (0.16 m^2), and IRC limits it to 2 ft^2 (0.18 m^2). Most exterior wall studs are at 16 in. (40.6 cm.) o.c. Given the modular size of brick (3 units per 8 inches or 2.67 in. (6.8 cm.) each, you can greatly simplify and satisfy all TMS and IRC requirements by spacing at 16 in. (40.6 cm.) o.c. each way. Also, a common recommendation from veneer tie manufacturers is to space the ties at 16 in. (40.6 cm.) o.c. each way (one tie for every 1.77 ft^2 [0.16 m^2] of brick veneer).

IRC and TMS also specify that weep holes can be spaced no more than 33 in. (84 cm.) o.c. BIA recommends that when wick weeps are used, spacing shall not exceed 16 in. (40.6 cm.) o.c.; when open-head-joint weeps are used, then spacing shall not exceed 24 in. (61 cm.) o.c. Use of weep tubes is not recommended by the BIA.[11] It is recommended that the designer comply with BIA recommendations, which are stricter than the IRC or TMS.

CONCLUSION

Designing for anchored brick veneer can be very complex due to the numerous code requirements. The proper selection of the brick veneer system, placement of flashing, and expansion joints are critical to the long-term performance of anchored brick veneer. The codes and industry standards noted in this paper vary in requirements, and the best practice would be to follow the strictest of requirements, identifying potential stress points in the brick veneer during design and design and placement of expansion joints to minimize the stress and accommodate expansion. Provide clear details at all flashing locations and brick veneer expansion joints, locate all expansion joints on the exterior elevation drawings, and provide clear and concise specifications. Equally important is the need for active quality assurance observations during construction at regular intervals.

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