Technical Notes on Brick Construction

28B REVISED

November 1999

Brick Industry Association 11490 Commerce Park Drive, Reston, Virginia 20191

BRICK VENEER
BRICK VENEER/STEEL STUD WALLS

Abstract: This *Technical Notes* addresses the considerations and recommendations for the design, detailing, materials selection and construction of brick veneer/steel stud walls. This information pertains to behavior of the veneer, differential movement, ties and anchors, air space, detailing, selection of materials and construction techniques.

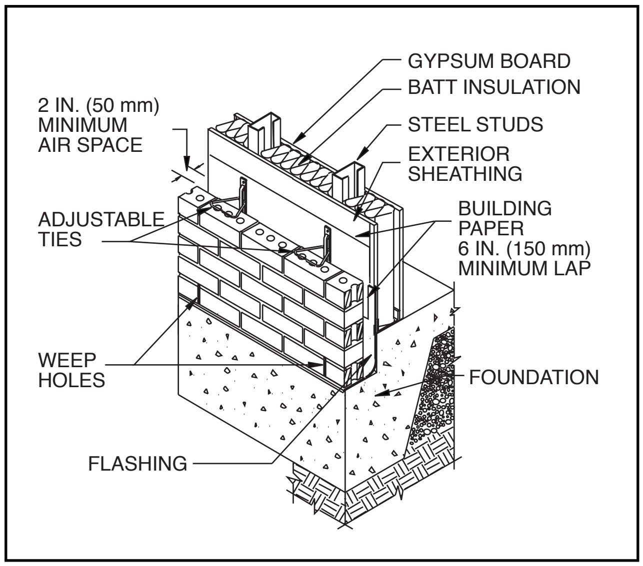
Key Words: anchors, brick, brick veneer, design, elastic properties, masonry, permeability, stability, steel studs, stiffness, walls.

INTRODUCTION

Introduced in the 1960's, the brick veneer/steel stud wall system has evolved into a successful construction method used in a wide variety of commercial, industrial and institutional structures which include such building types as schools, churches, hospitals and office buildings. These buildings usually have structural frames of steel or reinforced concrete. Unlike residential construction, they generally are not designed with overhangs, eaves or gutters to protect the veneer and frequently incorporate parapets. They also are usually taller than residential structures. Consequently, commercial brick veneer/steel stud wall systems have greater exposure to their environment than their residential counterparts. For this reason, it is important to closely observe proper design, detailing and construction practices to ensure that expected and required levels of performance are met.

The brick veneer/steel stud wall system is considered an anchored veneer wall. An anchored veneer is a brick wythe secured to and supported laterally by the backing through anchors (ties) and supported vertically by the foundation or other structural elements. The veneer transfers out-of-plane load directly to the backing and is not considered to add load-resisting capacity to the wall system. Anchored brick veneer with steel stud backing consists of a nominal 3 or 4 in. (75 to 100 mm) thick exterior brick wythe mechanically attached to a steel stud backing system with corrosion-resistant metal ties so as to create a prescribed air space between the veneer and the backing system. (See Fig. 1)

This *Technical Notes* is one of four in a series dealing with brick veneer. This issue addresses brick veneer with steel stud backing in commercial construction. Other issues in the series discuss other types of brick veneer wall systems.



Brick Veneer/Steel Stud Wall
FIG. 1

PROPERTIES OF BRICK VENEER/ STEEL STUD WALLS

The brick veneer/steel stud wall system offers several advantages over other claddings. The system demonstrates superior performance in many of the specific areas of concern for designers, contractors and property owners such as attractive appearance, high resistance to water penetration, low thermal transmission rate, ease of construction and low maintenance.

Aesthetics

Brick is available in a large variety of colors, textures, glazes and coatings. In addition, many sizes are manufactured and special shapes can be created to achieve a broad range of units. Add to this the ability to achieve multiple bond patterns, the use of colored mortars and interesting masonry detailing, and the creative possibilities are nearly endless. For further information on sizes and patterns, refer to *Technical Notes* 10B and 30.

Ease of Construction

The steel studs and exterior sheathing of a brick veneer/steel stud wall can be constructed prior to laying the brick veneer wythe. This allows the building to be closed-in and placed under-roof quickly. Thus, interior work can begin with brick masonry construction following at a convenient time. Further, other trades can be scheduled to work and not interfere with the mason. In addition, the weight of a brick veneer/steel stud wall is less than a wall constructed of brick and concrete masonry units. Thus, perimeter framing member sizes and seismic forces used in the design may be reduced.

Moisture Resistance

Brick veneer construction incorporates a drainage cavity to deter water penetration into the building. This air space creates a physical separation between the brick wythe and the inner steel stud wall. When wind-driven rain penetrates the veneer wythe, the cavity allows the water to drain down the back face of the brick. This water is then collected at the base of the wall by flashing and channeled out to the exterior through weep holes. When properly designed and constructed, a brick veneer/steel stud system is resistant to water penetration through the entire assembly. For additional information, see *Technical Notes* 7 Series.

Thermal Properties

Brick veneer systems incorporating a cavity can greatly reduce the amount of heat transmission through the system. This air space provides a thermal separation between the brick wythe and other system components, increasing the resistance of the entire wall system to heat loss or gain. Further, brickwork has a high thermal mass giving it the ability to store and slowly release heat over time. This is taken into account in current energy codes by allowing a lower R-value for walls with masonry. In addition, closed-cell rigid board insulation can be placed inside the cavity for additional thermal resistance. With the board insulation located outside of the steel stud wall, there is increased resistance to heat transmission and reduced thermal bridging. For further information, refer to *Technical Notes* 4 Series.

Fire Resistance

Brick masonry has superior fire resistance. Building codes may require that exterior walls have a fire resistance rating based on fire separation distance, size of building and occupancy classification. They may require protection from one or both sides, depending on whether the fire separation distance is more or less than 5 ft (1.5 m) respectively. A nominal 4 in. (100 mm) brick wythe has a fire resistance period of 75 minutes resulting in a 1 hour fire resistance rating and can provide this protection for the exterior surface of the wall. Fire resistance ratings may increase to 2 or 3 hours for an entire assembly which includes brick. For additional information, see *Technical Notes* 16 Series and *Engineering & Research Digest* ***UL Fire Ratings***.

Acoustical Properties

Brick veneer walls with cavities are well suited as sound insulators. Three mechanisms reduce the sound transmitted through the wall. The hard surface of the brickwork reflects a large portion of sound waves. The mass of the brickwork absorbs another portion of sound energy. The remaining sound energy which makes its way through the brick wythe must continue through the air space and the sheathed studs. This air space separates the brick from the steel studs causing a dampening effect. With only ties bridging the cavity, a further reduction in sound wave propagation is realized due to discontinuous construction. Finally, the energy must vibrate the sheathing and stud to reach the inside of the building. Additional information on sound transmission can be found in *Technical Notes* 5A.

STRUCTURAL DESIGN

Brick veneer/steel stud walls must resist loads as prescribed by the governing building code(s). For exterior, nonbearing walls, these loads are typically due to wind and seismic events. Although a veneer is defined as a nonstructural facing, brick veneer does resist loads. Certainly the weight of the brick is supported by the brickwork itself. But brickwork also contributes to the resistance of out-of-plane loads. In addition, in-plane forces caused by the weight of the brickwork are also resisted internally, including in-plane loads generated by seismic events. Returns and offsets in the veneer wythe can also act as flanges and cause in-plane loads on the wall.

Steel studs can be designed to be non-loadbearing or loadbearing. Both non-loadbearing and loadbearing studs provide backing for the brick wythe by resisting any out-of-plane loads such as those from wind or seismic events. Loadbearing studs also serve as part of the structural system of a building by supporting a portion of the gravity load or acting as shear walls while non-loadbearing studs only support their own weight.

Building Codes

Minimum standards for brick veneer/steel stud walls are established in the model building codes adopted by most local jurisdictions. Some of these codes reference the ACI 530/ASCE 5/TMS 402 *Building Code Requirements for Masonry Structures*, also known as the Masonry Standards Joint Committee (MSJC) Code [Ref. 2]. Within this Code, there is an entire chapter devoted to masonry veneers which outlines prescriptive, as well as alternate, design requirements for anchored masonry veneers. To determine code provisions for a building in a specific area, the local building code jurisdiction should be consulted.

System Behavior

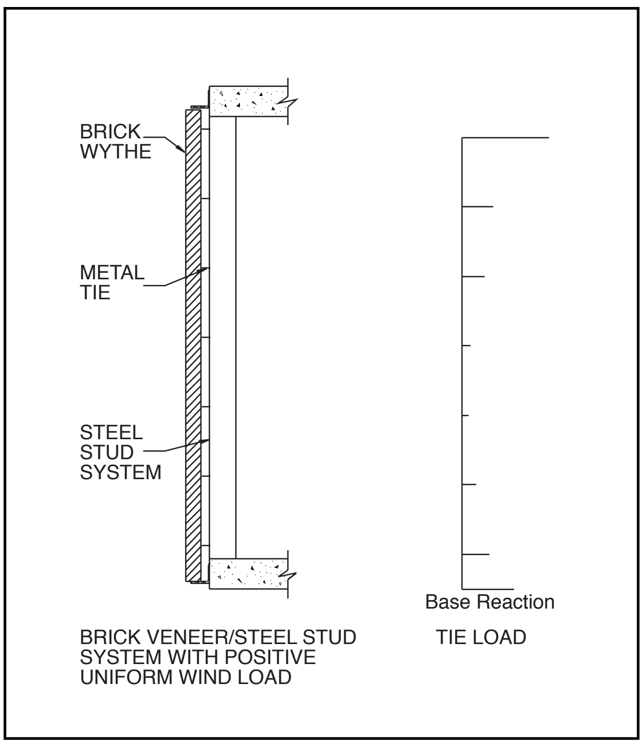
Together, brick veneer and steel studs resist out-of-plane loads by each taking a portion of the load relative to its flexural stiffness, span length, and the ability of the ties to transfer the load. The flexural stiffness of the brick is substantially greater than that of the steel stud backing. In addition, the brick veneer typically spans a greater distance than the steel stud system (see Fig. 2). Consequentially, the brick initially carries most of the load, acting similar to a one-way beam. Deflections in the brick wythe are transmitted to the steel studs through the ties. Ties nearest the top and bottom of the steel stud transfer more load than those located near the center of the span. Frictional forces at the support for the veneer resist a portion of the load.

As the masonry continues to deflect, flexural tensile stresses developed in the veneer may cause cracking near the center at the largest moment concentration. This occurs when the modulus of rupture of the brickwork has been exceeded. The veneer will subsequently act as two separate segments allowing no stress across the crack. Thus, each segment will act as a one-way beam spanning between the tie nearest the crack and the respective tie at the top or bottom of the veneer.

Steel Studs

Steel studs must be designed to provide adequate out-of-plane support for all loads imposed on the wall system. This is done by establishing a maximum deflection limit on the stud while maintaining steel stress values in the stud within permissible limits. This deflection is calculated assuming the entire out-of-plane load is resisted by the studs alone, neglecting contribution of the brick veneer. While a number of design tables are based on a stud deflection of stud span length divided by 360 (L/360), using this criterion may permit more deflection than the veneer is able to tolerate without visible cracking and resulting water damage. Therefore, to obtain sufficient backing stiffness, *the allowable out-of-plane deflection of the studs should be restricted to L/600 using service level loads.* Such deflection criterion will allow a maximum crack width of about 0.015 inches (0.38 mm) in the brick veneer wythe for typical floor-to-floor dimensions. Studs surrounding all openings in the veneer should be designed with loads based on the tributary area of the opening. Further criteria for loadbearing studs include providing adequate bearing capacity for the gravity loads.

The flanges of the steel studs must be laterally braced to resist compression in bending. This can be accomplished by fastening sheathing or board materials, such as gypsum sheathing, plywood or cement board, to each side of the stud. In general, rigid board insulation should not be considered as adequate bracing. Alternatively, if sheathing or board materials are not installed or are only installed on one side of the stud, bracing can be provided by steel straps or channels attached either horizontally or diagonally. However, it is suggested to provide sheathing on both sides to help support the moisture barrier and any interior finishes. The design of the bracing should follow appropriate codes and technical literature. [Ref. 10]



Initial Moment and Tie Load Distribution
FIG. 2

Ties

Metal anchors or veneer ties transfer load between the brick veneer and either the studs or the structural frame of the building. The load which is transferred through a given wall tie depends on many factors. Such factors include: tie stiffness; the backing element the tie is fastened to (the building frame or the steel stud); where the tie is fastened relative to the backing element's span; where the tie is located relative to the brick veneer's span; and whether any cracks have occurred in the veneer.

For walls having shelf angles at each floor level with either no windows or punched window openings in which brick veneer supports the header lintel, ties located near the bottom and top of the floor that are attached directly to the building frame will have the highest load. In one test performed for this configuration, the tie connected closest to the shelf angle supporting the veneer to the building frame carried just over 30% of the total out-of-plane load of the vertical strip on the story it served [Ref. 1].

With brick veneer supported on a shelf angle above a window band, the ties at the floor level will typically carry the highest load. Again, ties which are fastened directly to the building frame will carry more load than those attached to the studs.

Seismic Design

As the possibility and potential intensity of seismic activity increases, certain seismic provisions should be employed in brick masonry as with all building materials. These requirements are specified in the model building codes. Some of these codes reference the MSJC Code. Refer to the appropriate building code to determine specific seismic provisions.

The veneer chapter in the MSJC Code addresses seismic provisions for anchored veneers. It stipulates that brick veneer built in Seismic Performance Category (SPC) C should have its sides and top isolated from the structure to prevent seismic loads from being imparted to the veneer. This can be accomplished with expansion joints normally used in brick veneer structures.

Brick veneer constructed in SPC D should comply with all provisions of SPC C and have the weight of the veneer supported independently at each story. Further, it should reduce the area of wall supported by each tie to 75 percent of the area it supports in a non-seismic area and include a continuous single-wire joint reinforcement with a minimum wire size of W1.7 (MW 11) at a maximum spacing of 18 in. (460 mm) o.c. vertically.

Brick veneer in SPC E should comply with all provisions SPC D and provide vertical expansion joints (isolation joints) at all returns and corners. In addition, joint reinforcement must be mechanically connected to ties with clips or hooks. Further information on seismic ties can be found under Ties in the DETAILING section.

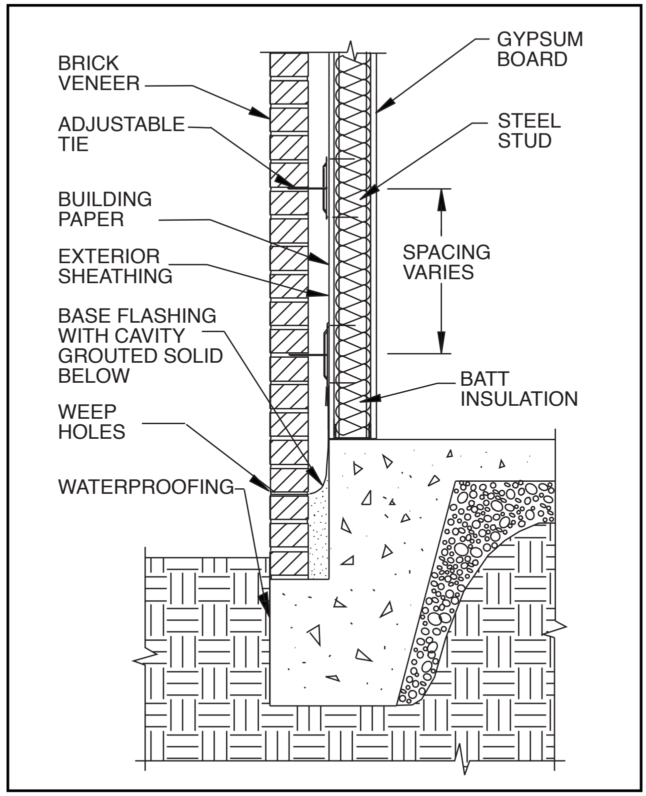
DETAILING

Foundations

Although some building codes permit the support of brick veneer on wood foundations, it is recommended that the weight (gravity load) of the veneer be supported on concrete or masonry foundations or other noncombustible structural supports. The brick wythe may extend below grade if it is properly detailed and constructed to minimize water penetration. A typical foundation detail is shown in Fig. 3. Locating base flashing and weep holes a minimum of 6 in. (150 mm) above grade will allow the drainage system to function properly. Base flashing should extend through the full wythe of the veneer to preclude any moisture from migrating by capillary action up through the brickwork.

Brick below the base flashing should be detailed as a barrier wall system by completely filling the cavity with grout or mortar to minimize water penetration. Ties should be located within the grouted cavity according to the same spacing as in the brick veneer above grade. Backing for the brick wythe below grade should be concrete or masonry instead of steel studs. This is due to the high lateral pressures encountered below grade from earth, water and any surcharge loads.

Soil immediately adjacent to the brickwork should be thoroughly drained or the brick wythe exterior waterproofed below grade. Self-adhesive waterproofing membranes with protection board to prevent damage during backfill operations can prevent water from penetrating the brick. Drainboards with integral filter fabric and waterproofing membrane can also drain water to the foundation drain tile system. A french drain between the soil and the wall consisting of a gravel fill with a fabric filter surround and drain tile below sloped a minimum of ⅛ in./ft (10 mm/1 m) can also provide some drainage.



Wall Section at Foundation
FIG. 3

Drainage Cavity

The drainage cavity or air space provides a means to drain water which penetrates the brick wythe. The air space between the back of the brick and the sheathing should be a minimum of 2 in. (50 mm) in order to minimize the possibility of mortar bridges in the cavity. Air spaces should be a maximum of 4½ in. (114 mm) when size and spacing of ties are prescribed by building codes. If the cavity is wider than 4½ in. (114 mm), additional or stronger ties may be required. When rigid board insulation is placed in the air space, the clear distance from the back side of the brick to the exterior side of the insulation must be no less than 1 in. (25 mm).

The cavity must be kept clean of mortar and mortar droppings in order to function properly. When a high probability of mortar falling into the cavity exists, drainage materials may be specified at the base to catch mortar droppings or prevent mortar from entering the cavity respectively. These materials are usually made of a plastic mesh or fabric porous enough to allow passage of water, but which catch or deter mortar from collecting at the bottom of the cavity. While it is not mandatory to include drainage materials in brick veneer/steel stud walls, they may help in keeping the cavity open. However, the use of drainage materials should not preclude good workmanship and an effort to keep the air space clean.

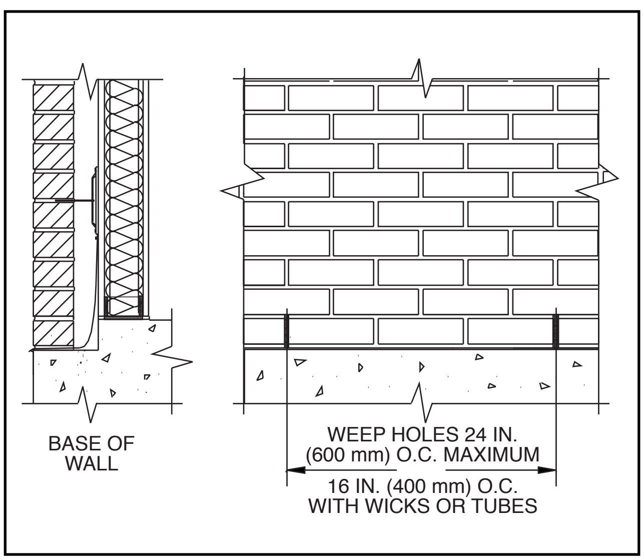
Flashing and Weep Holes

Flashing collects water at the bottom of the air space and directs it toward weep holes which channel it to the exterior face of the wall. Flashing must be placed at all points where the cavity is interrupted. These include above and below all wall openings, above all shelf angles, at the base of the wall and under the coping at parapets. Flashing should extend vertically up the backing a minimum of 8 in. (200 mm). If drainage materials which catch mortar are placed at the bottom of the cavity, flashing at the base of the wall may need to extend higher on the backing. The moisture barrier on the backing should lap the top of the flashing a minimum of 2 in. (100 mm). Individual flashing pieces should be overlapped at least 6 in. (150 mm) and sealed to avoid water running under adjacent flashing pieces. At flashing ends, such as over and under openings in the wall, the ends should be turned up into the next head joint at least 1 in. (25 mm) to form a dam to channel water out of the wall. It is imperative that flashing not stop behind the face of the brickwork.

Weep holes should be placed immediately above the all flashing to permit water to exit the wall. Weep hole spacing should not exceed 24 in. (600 mm) o.c. for open head joints, and 16 in. (400 mm) o.c. if wicks or tubes are used. Metal or plastic screens can be installed in open head joint weep holes to keep insects out of the air space. See Fig. 4.

Moisture Barrier

Moisture barriers are membranes which prevent liquid water from passing through them. Such a membrane should be located between the cavity and the sheathing or rigid insulation attached to the studs. While the drainage cavity acts to divert most water penetrating the brickwork, a moisture barrier should keep out any water which finds its way across the cavity via ties, mortar bridging or splashing. Individual pieces of moisture barrier should be installed with their edges and ends lapped at least 6 in. (150 mm). Sheathing or rigid insulation with an inherent resistance to moisture penetration may also serve as a moisture barrier when all edges and joints are completely taped or sealed.



Flashing and Weep Holes
FIG. 4

Sheathing

An exterior grade sheathing or insulation material should be installed on the exterior side of the stud. Edges and joints of insulation board that also serves as the moisture barrier should be thoroughly sealed with tape or sealant to ensure against moisture intrusion over the life of the wall. Such joint treatment will also reduce air infiltration. Careful detailing at the top of walls should provide a watertight condition. If sheathing is used to laterally brace the studs, it should be rigid to provide the required stiffness.

Steel Studs

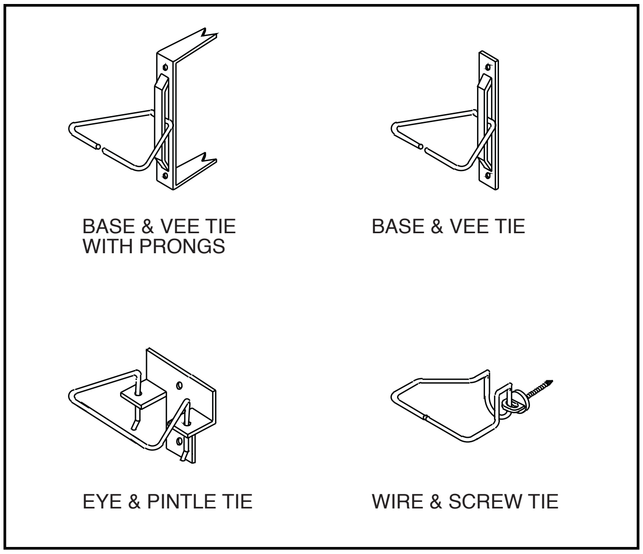
The top connection of nonbearing studs must be detailed to prevent inadvertent vertical load transfer to the studs. No rigid connection should be allowed between the top track and the studs. This allows for the structural member above the track to deflect without transferring loads to the studs.

Field welding of studs should not be permitted. Shop welding may be permitted on steel studs with a minimum of 0.068 in. (1.7 mm) thick steel or 14 gage studs. To increase quality assurance, welders and welding procedures should be qualified as specified in the AWS D1.3 by the American Welding Society. A corrosion inhibiting coating should be applied to all welded areas after welding is completed.

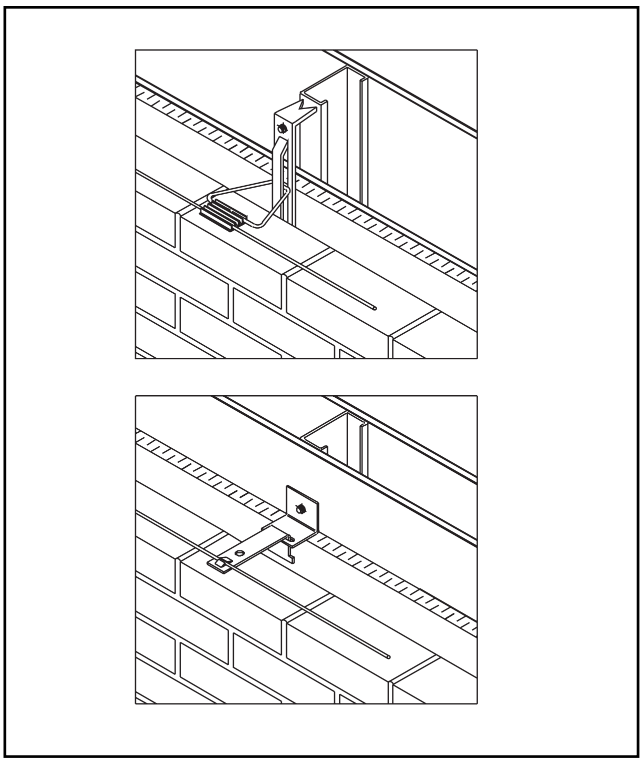
Ties

Care must be taken to anchor the masonry veneer to the backing in a manner that will permit each to move freely, in-plane, relative to the other. Anchors or ties that connect the veneer to the backing must provide out-of-plane support, resisting tension and compression, but should not resist shear. This permits in-plane differential movements between the frame and the veneer without causing cracking or distress. Corrugated ties are not permitted when brick veneer is supported by steel stud backing.

Ties should provide the capacity to transfer loads applied to a maximum of $2\frac{2}{3}$ sq ft (0.25 m^2) of wall area. Each tie should be spaced a maximum of 18 in. (450 mm) o.c. vertically and 32 in. (810 mm) o.c. horizontally. Typical ties are shown in Fig. 5. Ties in high seismic areas must be mechanically fastened to horizontal reinforcement in the brick veneer as depicted in Fig. 6. All ties must be embedded at least 1½ in. (38 mm) into the brick veneer with a minimum mortar cover of ⅝ in. (16



Tie Assemblies
FIG. 5



Seismic Tie Assemblies
FIG. 6

mm) to the outside face of the wall. They must be securely attached to the steel studs through the sheathing, not to the sheathing alone. Around the perimeter of openings, additional ties should be installed spaced at a maximum of 3 ft (1 m) o.c. within 12 in. (300 mm) of the opening.

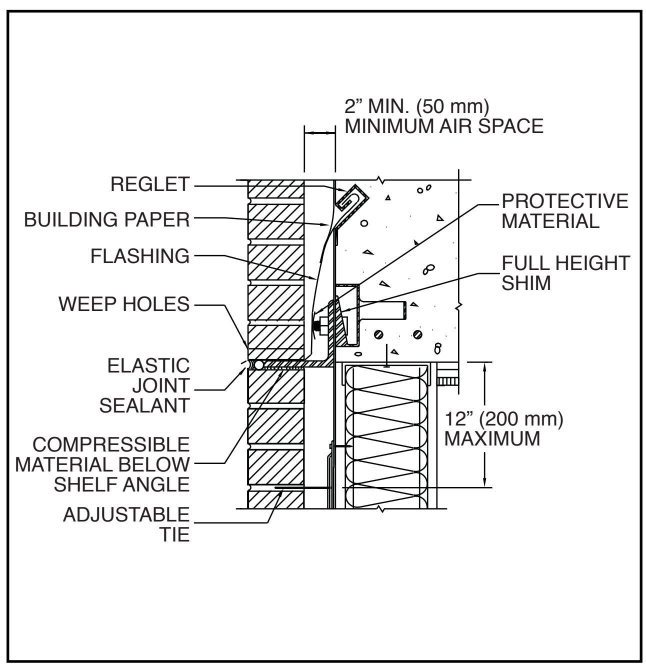
Lintels and Shelf Angles

Lintels provide support of brickwork over masonry openings and are supported by the brickwork at the ends of the opening. Shelf angles are typically installed at each floor and support the weight of the brickwork for that story. Lintels and shelf angles must be sized to have a maximum deflection between support points of L/600 or 0.3 in. (7.5 mm) and rotation of less than $\frac{1}{16}$ in. (1.6 mm). The horizontal leg of all angles should be sized to support a minimum of $\frac{2}{3}$ the thickness of the brick wythe.

Vertical expansion joints should not cross a lintel or shelf angle without making provisions for potential movement. Where an expansion joint aligns with the jamb of the masonry opening, a bond break material, such as No. 15 asphalt felt, is often included around the end of the lintel to allow the lintel to move on its supported end.

Lintels should be installed over all masonry openings unless the brick is self-supporting. Lintels can be loose steel angles, stone, precast concrete, or reinforced masonry. They should bear a minimum of 4 in. (100 mm) on brick on either side of the opening and should be sized to carry the brick veneer above them. For further information on lintels, refer to *Technical Notes* 31B.

Shelf angles should consist of steel angles sized and installed to carry the brickwork above. Structures with a maximum veneer height of 30 ft (9.1 m) from foundation to top of wall and 38 ft (11.6 m) from foundation to top of gable can have their entire brick veneer supported directly on a foundation wall, footing or noncombustible support without shelf angles. Structures with brick veneer above this height should have a shelf angle at each floor. Shelf angles may be located near the floor line or at the window head. Shelf angles attached to rigid concrete or steel elements should have full height shims to reduce rotation as shown in Fig. 7. Any shelf angle attached to miscellaneous steel elements



Shelf Angle with Concrete Frame
FIG. 7

must have bracing to prevent out-of-plane movement of the wall as depicted in Fig. 8. Shelf angles should not be installed as one continuous member. Space should be provided at intervals to permit thermal expansion and contraction of the steel angle to occur without causing distress to the masonry. Lipped brick may be used above or below a shelf angle to maintain the same joint width at the angle as other joints in the brickwork.

Shelf angles should be supported by miscellaneous structural steel elements and not by steel studs. Field welding of shelf angles to studs should never be permitted since the thin wall of the steel stud increases the potential for burn-through. Further, a stud which supports a shelf angle may require additional reinforcing and may be more prone to corrosive action from exposure to the moist cavity.

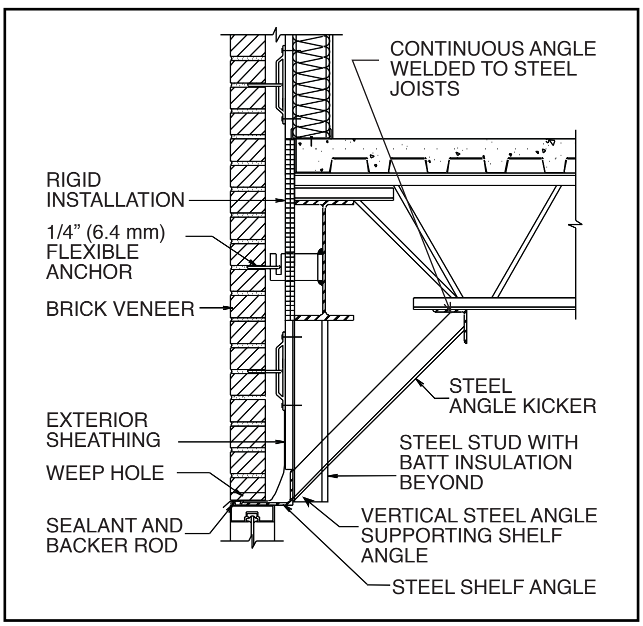
Sealant Joints

Sealant joints seal expansion joints and perimeters of openings to prevent water penetration. These joints are typically a compressible, foam backer rod with an hourglass shaped sealant overlay. Sealant joints should be free of mortar for the entire thickness of the brick veneer and closed with the backer rod and sealant. If desired, a compressible material may be included behind the backer rod.

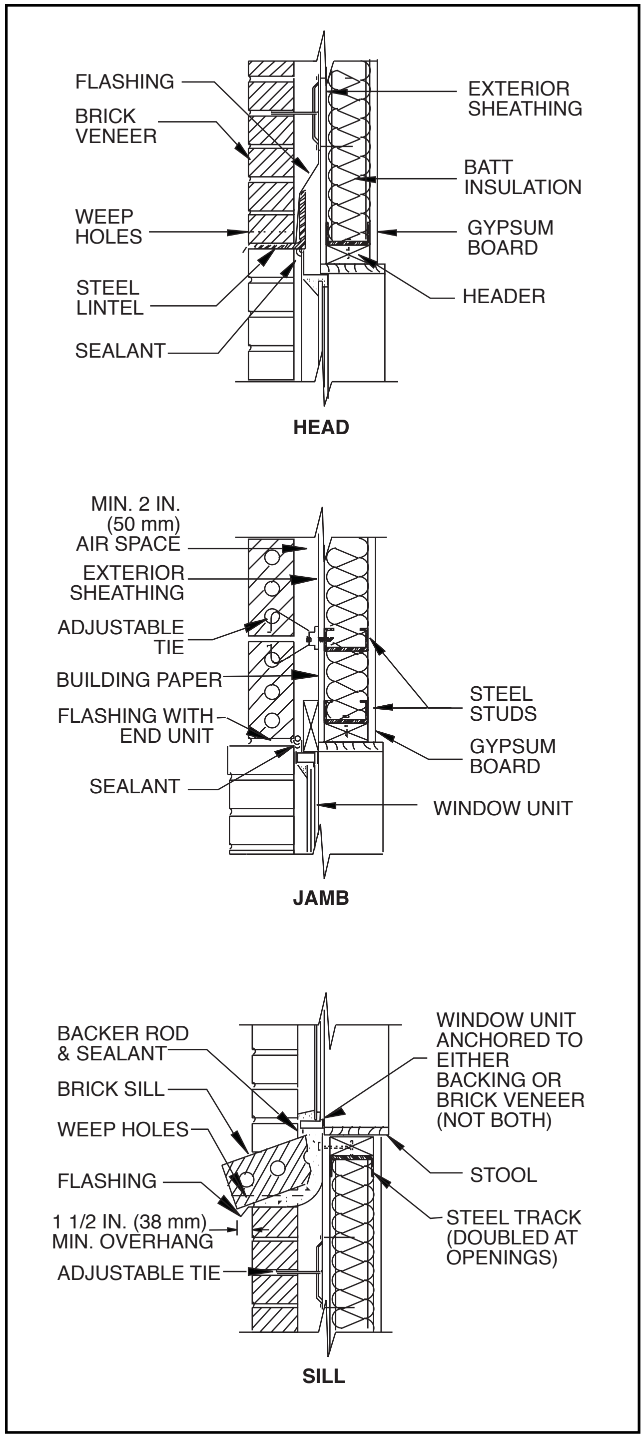
The perimeter of all exterior window frames, door frames and sleeves should be closed with a sealant joint. This joint should be between ¼ and ½ in. (6.3 and 12.7 mm) wide and ¼ in. (6.3 mm) deep. Fillet joints are not recommended, but if used, should be at least ½ in. (12.7 mm) across the diagonal.

Head, Jamb and Sill Details

Openings in brick veneer walls should be carefully detailed to prevent water from entering the brick ve-



Brick Veneer/Steel Stud Bracing System
FIG. 8



Head, Jamb and Sill Details
FIG. 9

neer/steel stud wall system. Provision should be made for movement between the brick veneer and the frame or backing. Window frames, door frames and opening sleeves should be attached to either the brick veneer or the backing, but not both. Rowlock brick sills should be angled a minimum of 15 degrees to the horizontal for drainage. (See Fig. 9)

Parapet Walls

Parapets are exposed on three sides and consequently are more susceptible to the elements. These walls are vulnerable to water penetration and condensation. Parapet walls should be avoided unless required. A gravel stop detail can be used instead of a parapet wall as shown in Fig. 10. If a parapet is required, it should be properly designed, detailed and constructed. Steel studs are not recommended as backing for parapet walls because of problems with moisture and movements. Reinforced brick masonry provides the best means of constructing parapets above brick veneer/steel stud walls as depicted in Fig. 11.

Movement Provisions

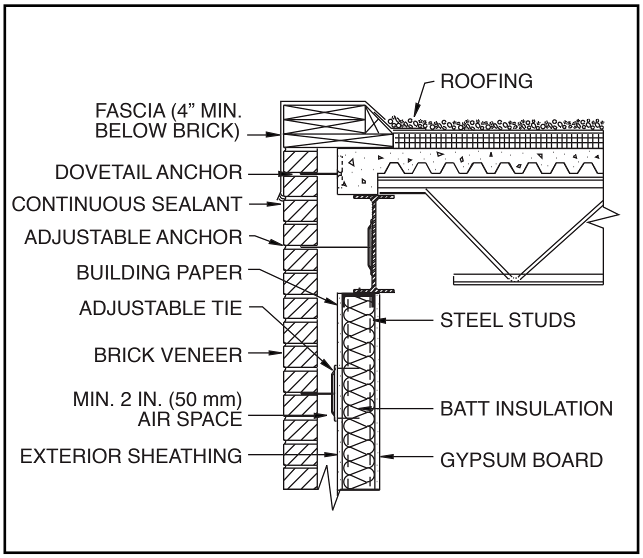
Brickwork will expand and contract as will all building components. Brick is subject to permanent expansion as a result of freezing and moisture. Brickwork is subjected to contraction from mortar shrinkage. Changes in temperature will cause brick to expand and contract. Moisture expansion can continue for years while thermal movement and mortar contraction will occur periodically, contingent upon temperature and moisture content. As a result, brickwork will continually change in size during its life within a wall.

To accommodate this movement, brick veneer should be designed in discrete sections which are allowed to move independently of each other. This is accomplished through the use of expansion joints and bond breaks detailed into the veneer. An expansion joint consists of a vertical or horizontal opening through the brick wythe that is closed with a sealant joint and elastic materials. These joints surround each section of brick and isolate them from each other. Expansion joints must be designed and constructed to permit the anticipated movement. Further, expansion joints must be located and constructed so as not to impair the integrity of the wall.

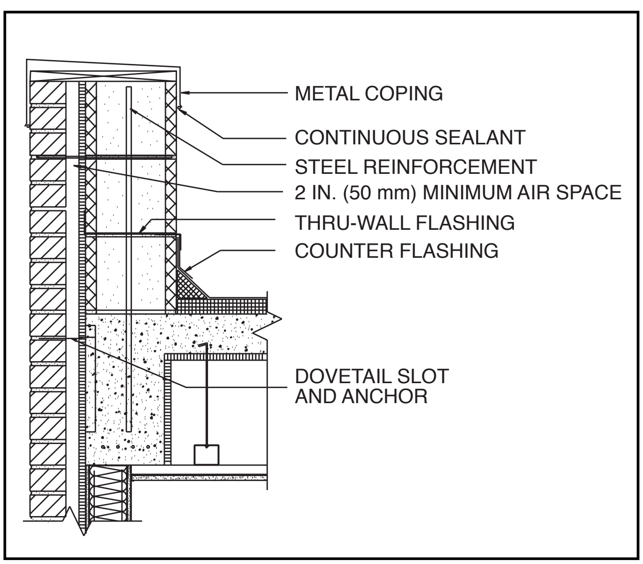
The spacing and placement of vertical and horizontal expansion joints must be done on a case-by-case basis. Each wall must be examined to determine its potential for movement based on its length, openings, offsets, corner conditions, wall intersections, means of support, changes in wall heights and parapets. These features influence the amount of movement in a wall. Any portion of wall not able to resist the resulting stresses should be isolated by an expansion joint.

Vertical Expansion Joints

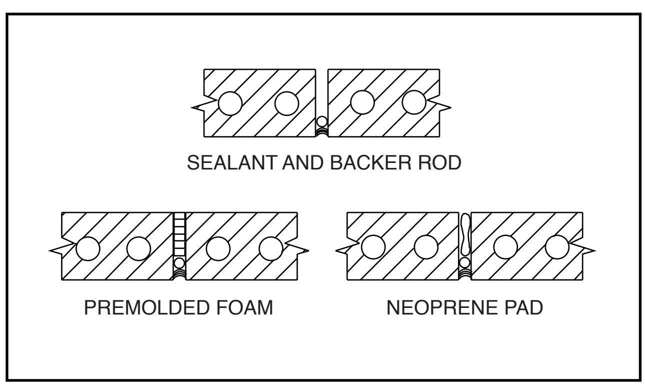
A vertical expansion joint consists of a typical sealant joint over either a compressible pad or an opening through the brick wythe. Such pads can be made of premolded foam or neoprene. (See Fig. 12) Where possible, vertical expansion joints should extend from the foundation to the top of the brickwork without deviating from vertical. When this is not possible, they can be terminated at horizontal expansion joints. Generally, the spacing of vertical expansion joints should not exceed 30 ft (9.1 m) in walls without openings. Vertical expansion joints are also recommended where site walls abut buildings and at the corners of large openings. Building corners should have a vertical expansion joint located at the corner. Alternatively, a vertical expansion joint should be located in each wall on either side



Gravel Stop
FIG. 10



Masonry Parapet Wall
FIG. 11



Expansion Joints
FIG. 12

of the corner. These two expansion joints should be located no more than 10 ft (3.0 m) from each other. Plan offsets and setbacks of a wall should also include a vertical expansion joint on inside corners.

Horizontal Expansion Joints

A horizontal expansion joint cannot function unless there is some means of supporting the brickwork above it. Usually this is accomplished by a shelf angle. All shelf angles should have a horizontal expansion joint below them. These joints are located between the bottom of the shelf angle and the brickwork below. They consist of a sealant joint and either an opening or compressible pad behind them as shown in Fig. 7.

Bond Breaks

When a different material, such as concrete masonry or precast, is incorporated into a brick wall, differential movement between the two materials is likely to occur. In such cases, a bond break should separate it from the surrounding brickwork. This break allows for movement between the two materials and diminishes horizontal or vertical cracking. A bond break is achieved by installing a layer of No. 15 asphalt felt or flashing between the other material and the mortar joint surrounding it.

For further information on movement, expansion joints and bond breaks, see *Technical Notes* 18 Series.

Horizontal Joint Reinforcement

Although not usually required for brick veneer construction, horizontal joint reinforcement can be incorporated into brick veneer walls to alleviate cracking from high internal stress or to have the brick serve as a reinforced lintel. Horizontal joint reinforcement is necessary for veneer laid in stack bond, in high seismic areas, and possibly in joints adjacent to different materials. It may be either single or double wire joint reinforcement and must have at least ⅝ in. (16 mm) mortar cover. Horizontal joint reinforcement can also be used above and below the corners of masonry openings for added strength.

Thermal Design

Insulation

All buildings must comply with energy code requirements. Such codes establish minimum standards for thermal resistance of wall assemblies for buildings. Increasing the thermal resistance of a wall is usually accomplished by adding insulation. Batt-type insulation is typically placed between studs to increase the thermal resistance of the wall. Rigid insulation can be used on the outside of the studs and serves to reduce the thermal bridging effect at the stud. An example of such a heat transmission calculation for brick veneer/steel stud walls can be found in *Technical Notes* 4. For further information on energy code compliance, refer to *Technical Notes* 4B.

Condensation

Experience has shown that most water or moisture found between steel studs in a brick veneer/steel stud wall can be attributed to condensation. Condensation occurs at the point in the wall where the temperature gradient and latent moisture exceed the dew point. If this point is within the drainage cavity, then the condensation will find its way out of the wall via the drainage system. However, if it is on the inside of the steel stud wall, then it may dampen or eventually saturate surrounding materials and may lead to further problems.

Consequently, it is recommended that a condensation analysis be conducted to determine if the potential for condensation exists in a wall. If results indicate that it may occur, then the wall design should be changed. This is usually accomplished by adding rigid board insulation inside the cavity between the brick and the exterior sheathing to increase the thermal resistance of the wall or by installing an air barrier or vapor retarder to decrease air and vapor movement through the wall. See *Technical Notes* 7C and 7D for further information.

SELECTION OF MATERIALS

Brick

Brick are usually selected on the basis of their appearance which include color, texture and size. To assure quality, brick units should conform to one of the following: ASTM C 216 Specification for Facing Brick, ASTM C 652 Specification for Hollow Brick, ASTM C 1405 Specification for Glazed Brick (Single Fired, Solid Units) or ASTM C 126 Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units. All brick units should be of Grade SW. The use of salvaged brick is not recommended since such brick may not bond properly with mortar and may be less durable. For further information on brick specifications and salvaged brick, see *Technical Notes* 9 Series and 15 respectively.

Mortar

Mortar plays an important role in the flexural strength of a brick veneer wythe. Out-of-plane strength tests of full-scale walls indicate that the bond between mortar and brick units is the most important single factor affecting wall strength when resisting horizontal joint cracking. Mortar should conform to ASTM C 270 Specification for Mortar for Unit Masonry. A designer should select the lowest compressive strength mortar that is compatible with the structural requirements of a project. The compatibility between a particular brick and mortar should be examined when determining mortar type. Flexural bond strength of a particular brick/mortar combination can be determined using ASTM C 1357 Test Methods for Evaluating Masonry Bond Strength. Type N mortar is suitable for most veneer brickwork, except in areas where wind loads exceed 25 psf (1.2 kPa) or brick are below grade, where Type S mortar should be used. Type S mortar is recommended where a high degree of flexural resistance is required and may be required in areas of higher seismic activity. Admixtures and additives for workability are not recommended since they can potentially weaken the mortar. Admixtures containing chlorides should never be used since they could greatly increase the probability of efflorescence and corrosion. For more information, refer to *Technical Notes* 8 Series.

Steel Studs

Steel studs should be a minimum of 0.043 in. (1.1 mm) thick steel or 18 gage to provide sufficient thickness to engage the threads of the screw. Studs should have a protective coating conforming to one of the following ASTM standards: 1) ASTM A 653/653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process with a minimum G90/Z275 coating designation 2) ASTM A 875/875M Specification for Steel Sheet, Zinc-5% Aluminum Alloy-Coated by the Hot-Dip Process with a minimum GF90/ZGF275 coating designation.

Sheathing

Exterior sheathing on steel studs should be rigid and suitably fastened with corrosion-resistant screws. The sheathing should be one of the following: exterior grade or water-resistant fiberglass faced gypsum sheathing or cement board, not less than 1/2 in. (13 mm) in thickness; exterior grade plywood, not less than 3/8 in. (10 mm) thick; or closed-cell insulating rigid foam not less than ½ in. (13 mm) thick conforming to ASTM C 578 Specification for Rigid, Cellular Polystyrene Thermal Insulation.

Screws

A minimum #10 self-tapping screw is recommended. Screws used to attach exterior sheathing and ties can be either carbon steel or stainless steel. Carbon steel screws should have a non-corrosive coating of zinc, polymer or composite zinc-polymer. Zinc-plated screws should be either mechanical-zinc plated according to ASTM B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel or electro-zinc plated in accordance with ASTM B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel. Polymer-coated screws do not have the self-healing properties of zinc, although they can offer acceptable, long-term protection. A composite zinc-polymer coating offers superior protection to either coating alone. Stainless steel screws are acceptable even though a galvanic potential exists between stainless steel and carbon steel. This is possible because of an area-relationship principle where the surface area of the steel stud is much larger than that of the screw which results in a decreased corrosion potential. Copper-coated screws are not recommended since they can react galvanically with steel studs having zinc coatings.

Screws incorporating an integral EPDM or neoprene sealing washer under the screw head for added water resistance are recommended. Due to the area-relationship principle mentioned above, when stainless steel screws are used with carbon steel ties, sealing washers are highly recommended.

Ties

Two-piece adjustable ties with a minimum wire size of W1.7 (MW 11) with a diameter of 0.1483 in. (3.77 mm) should be used. Eye and pintle adjustable ties should have a minimum wire size of W2.8 (MW 18) with a diameter of 3⁄16 in. (4.8 mm). Wire ties are available in a variety of standard lengths from 3 to 5 in. (75 to 125 mm) and diameters from 0.1483 to 0.2500 in. (3.77 to 6.35 mm). Ties with formed drips in the wire should not be used since they have reduced load capacity. Corrugated ties should *not* be used in conjunction with steel stud backing. They may not fully engage the stud upon initial loading and do not have sufficient compressive capacity for the given air space.

Ties should be hot-dipped galvanized in accordance with Class B-2 of ASTM A 153/153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware. In addition, ties should have a maximum horizontal out-of-plane mechanical play of 1⁄16 in. (1.6 mm) and should not deform over 0.05 in. (1.2 mm) for 100-lb load in either tension or compression.

Ties incorporating an EPDM sealing membrane between the sheathing or insulation and the wall base of the tie should be considered for superior water resistance. Prongs at each end of an adjustable tie base (see Fig. 6) may also be considered to provide a mechanical connection between the tie and the stud. These prongs provide positive, independent anchorage in the event of long-term deterioration of sheathing or insulation and prevent compression of the insulation or sheathing. When using a prong-leg base, a modified asphalt pad with self-adhesive is recommended. This pad is installed under the tie base and will seal openings created by the prongs and screws in the sheathing or insulation.

Moisture Barrier

A moisture barrier is required and can be provided by No. 15 asphalt felt (building paper), certain high-density polyethylene or polypropylene plastics (housewraps) and certain water-resistant sheathings with fiberglass facings. No. 15 asphalt felt should comply with Type I of ASTM D 226 Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing.

Some plastic membranes (housewraps) may have qualities similar to those of a moisture barrier, but ascertaining the effectiveness of a particular plastic as a moisture barrier can be difficult. While felts tend to seal themselves when penetrated by fasteners, plastics may not. In addition, some plastic membranes also act as vapor retarders trapping water vapor inside the stud wall where it can condense if the temperature gradient in the wall drops below the dew point. The length of time a plastic membrane will be exposed to ultraviolet (UV) sunlight should also be considered. Most show serious degradation with 3 to 12 months exposure to UV rays. Thus, all plastic membranes should not be regarded as equivalent and caution should be used when specifying them as a moisture barrier.

Water-resistant sheathings with integral membranes must be completely sealed with tape or sealant to perform as moisture barriers. This means components providing this seal must maintain their integrity and performance when subjected to moisture and other environmental conditions over the life of the wall. These sheathing systems should also allow for the transmission of vapor unless a vapor retarder is required.

Air Barriers and Vapor Retarders

Where analysis indicates a probability of condensation, an air barrier or vapor retarder should be provided. Air barriers are plastic membrane made of polyethylene, polypropylene or polyolefin. Most allow the transmission of vapor, while some also act as air barriers. Since there is no current ASTM standard specifically for air barriers, different manufacturers provide data based on different standards, including ASTM D 726 Test Methods for Resistance of Nonporous Paper to Passage of Air and ASTM E 283 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure. When a standard is published, it will set minimum performance criteria for air leakage, structural integrity, bulk-water resistance and water-vapor resistance. However, until the standard is adopted, caution should be exercised when specifying air barriers.

Vapor retarders are made of materials similar to air barriers. While some air barriers will also inhibit vapor transfer, all vapor retarders can be air barriers if they are installed and thoroughly sealed with no tears or holes. Currently, no standards for vapor retarders exist although some manufacturers cite test data based on ASTM E 96 Test Methods for Water Vapor Transmission of Materials. However, this test does not account for fastener penetrations or joints in the retarder. Materials which qualify as vapor retarders should have a perm rating of 1 or less.

Lintels and Shelf Angles

Steel for lintels and shelf angles should conform to ASTM A 36/A36M Specification for Carbon Structural Steel. Steel angles should be a minimum of ¼ in. (6.3 mm) thick. All angles should be painted as a minimum to inhibit corrosion. Galvanized and stainless steel angles should be considered in harsh environments such as coastal areas.

Flashing

Flashing material should be waterproof and durable. It should be sufficiently tough and flexible so as to resist puncture and cracking. In addition, it should not be subject to deterioration from exposure to ultraviolet (UV) light or when in contact with metal parts, mortar, sealants or water. Flashing should also be compatible with adjacent adhesives and sealants. Flashings used in a wall system with water-resistant sheathing as the moisture barrier should be self-adhesive. Flashing materials are generally formed from sheet metals, bituminous-coated membranes, plastics or combinations thereof. The selection is largely determined by cost and suitability. Acceptable bituminous membranes do not include asphalt-impregnated felt. It is suggested that only superior materials be selected, since replacement in the event of failure is extremely expensive. See *Technical Notes* 7A Revised and Engineering & Research Digest ***Through-Wall Flashing***.

Sealants

Sealants should be selected for their durability, extensibility, compressibility and their compatibility with other materials. A sealant should be able to maintain these qualities under the temperature extremes of the climate in which the building is located. Sealant materials should be selected to comply with ASTM C 920 Specification for Elastomeric Joint Sealants. Specific sealants recommended for brick include polysulfide, solvent release acrylic, silicone and urethane sealants. A sealant primer may be required before applying some sealants on certain brick to preclude staining. Since acetoxic silicone will attack cement in mortar, it should not be applied to masonry. Oil-based caulks should not be used since they may stain the adjacent brickwork.

Backer rods should be placed behind all sealant joints. They should be closed-cell plastic foam or sponge rubber. Backer rods should be capable of resisting permanent deformation before and during sealant application, non-absorbent to liquid water and gas, and should not emit gas which may cause bubbling of the sealant. A bond breaking tape may be required with some types of backer rods. For further information on sealants, refer to ASTM C 1193 Guide for Use of Joint Sealants.

CONSTRUCTION

Storage of Materials

All materials at the job site should be stored off the ground and under adequate cover to prevent deterioration and contamination. Cements and lime should be kept dry. Foreign material must be kept out of sand. Brick should not be placed directly on the ground to preclude any potential staining from the earth.

Workmanship

Some device for measuring sand should be used when mortar is mixed at the job site. Only full bags of cements and lime should be added to the mixer unless accurate volumetric measurements are used. Re-tempering of mortar by adding water is permitted as necessary to maintain consistency. Colored mortars should not be retempered due to the possibility of changing the color during the process. All mortar should be used within 2½ hours of mixing. See *Technical Notes* 8B for further information on controls for mixing mortar.

Brick which have an initial rate of absorption (suction) of more than 30 g/min/30 in.^{2} (1.55 kg/min/m2) should be wetted and permitted to surface dry prior to laying when using mortar cement or masonry cement unless portland cement lime mortar is used. This will increase the bond between the mortar and the brick by slowing the absorption of water from the mortar. For additional information, refer to *Technical Notes* 7B Revised.

Hot or cold weather protection may be necessary if temperatures are above 90 ºF (32.2 ºC) or below 40 ºF (4.4 ºC). For summer construction when temperatures are above 90 ºF (32.2 ºC) and wind exceeds 8 mph (12.9 km/hr), mortar should be used within 2 hours of mixing and finished brickwork may need to be fog sprayed with water. For winter construction with temperatures below 40 ºF (4.4 ºC), brick units should be at least 20 ºF (-6.7 ºC) or above when mortared in a brick wall. Mortar must not be frozen and should have a temperature between 40 ºF (4.4 ºC) and 120 ºF (48.9 ºC) when placed. Additional wind breaks and enclosures may be necessary within certain lower temperature ranges. For further information, see *Technical Notes* 1 Series in addition to the *Hot and Cold Weather Masonry Construction Manual*. [Ref. 4]

Care should be taken to fill all mortar joints completely, including head joints. Conversely, any location not intended to receive mortar, such as air spaces, weep holes and expansion joints, should be kept clean and free of mortar and mortar droppings. Mortar joints should be properly tooled to enhance the water resistance of the wall by consolidating the mortar. Joints should be tooled when thumbprint hard with a jointer tool slightly larger than the joint. Concave, "V" or grapevine mortar joints are the most water resistant since they do not provide a ledge for water to remain on the brickwork.

Protection

Protection of the unfinished wall in place is extremely important. The entry of rain or snow into brickwork in progress may increase the potential for efflorescence and distress in the finished wall. Wind screens and enclosures may also be necessary in hot or cold weather.

MAINTENANCE

Most brick masonry walls are virtually maintenance free. If they are properly designed, detailed and constructed, maintenance becomes less critical. However, brick veneer/steel stud wall systems should be inspected periodically to ascertain performance and identify any potential problems. Inspections should be performed on an annual basis as a minimum and ideally on a seasonal basis (see *Technical Notes* 7F). Such an inspection should address sealant joints, plumbness of the wall, cracking, etc. In this way, repairs and corrections can be initiated prior to the occurrence of severe problems.

SUMMARY

This *Technical Notes* is one of a series which deals with brick veneer. This issue is primarily concerned with the design and construction of the brick veneer/steel stud wall system used as exterior walls in other than residential construction.

REFERENCES

1. Arumala, J.O., Brown, R.H., *Performance Evaluation of Brick Veneer with Steel Stud Backup*, College of Engineering, Clemson University, Clemson, SC, 1982.
2. *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99), The Masonry Society, Boulder, CO, 1999.
3. *Exterior Wall Construction in High-Rise Buildings*, Canada Mortgage and Housing Corporation, Ottawa, Ontario, 1991.
4. *Hot and Cold Weather Masonry Construction*, Masonry Industry Council, Lombard, IL, 1999.
5. KPFF Consulting Engineers and Computech Engineering Services, *Report on Behavior and Design of Anchored Brick Veneer/Metal Stud Systems*, September, 1989.
6. McGinley, W.M., Warwaruk, J., Longworth, J., Hatzinikolas, M., *Masonry Veneer Wall Systems*, Structural Engineering Report #156, Department of Civil Engineering, University of Alberta, January, 1988.
7. Rutila, Dean A., "Innovations in Brick Veneer", *The Construction Specifier*, Vol. 51, No. 11, October, 1998.
8. "Self Drilling Fasteners – The Basics", *The Construction Specifier*, Vol. 42, No. 9, August 1989.
9. Seminar on Brick Veneer Wall Systems, Canada Mortgage and Housing Corporation, Ottawa, Ontario, June, 1989.
10. *Specification for the Design of Cold-Formed Steel Structural Members*, American Iron and Steel Institute, Washington, DC, 1996.
11. Tuluca, Adrian, "Thermal Bridges in Buildings", *The Construction Specifier*, Vol. 49, No. 11, October, 1996.

25M©B.I.A. 11/99