



Technical Notes on Brick Construction

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BRICK MASONRY CAVITY WALLS INTRODUCTION

Abstract: This *Technical Notes* covers brick masonry cavity walls. Description of the properties of cavity walls, including structural properties, water penetration resistance, fire resistance, and thermal and sound transmission properties are included. Theories for structural design are introduced. Recommendations for cavities, flashing, expansion joints, ties and other related subjects are covered.

Key Words: brick, cavity wall, design, expansion joints, fire resistance, flashing, structural, thermal resistance, ties, veneer.

INTRODUCTION

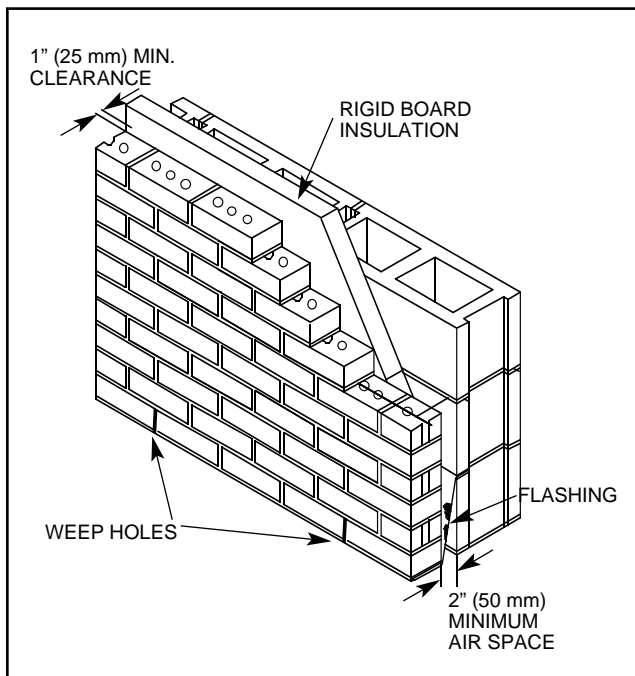
Brick masonry cavity walls consist of two wythes of masonry separated by an air space connected by corrosion-resistant metal ties (see Fig.1). The exterior masonry wythe can be solid or hollow brick, while the interior masonry wythe can be solid brick, hollow brick, structural clay tile, or hollow or solid concrete masonry units. The selection for each wythe depends on the required wall properties and features. A cavity of 2 to 4 ½ in. (50 to 114 mm) between the two wythes may be either insulated or left as an air space. The interior sur-

face of the cavity wall may be left exposed or finished in conventional ways.

Cavity walls, long common in Europe, were first built in the United States as early as 1850. However, it was not until 1937 that this type of construction gained official acceptance by any building code or construction agency in the U.S. Since then, interest in and use of cavity walls in this country has increased rapidly. Extensive testing and research and empirical evidence of existing cavity wall construction has been used to determine cavity wall properties and performance. Cavity walls are often regarded as the premier masonry wall system.

The early use of cavity walls in this country was limited primarily to exterior load-bearing walls, one and two-stories in height. In the 1940's, designers of high-rise buildings began to recognize the advantages of cavity walls and used them as curtain and panel walls in structural frame buildings. Today, masonry cavity walls are used extensively throughout the United States in all types of buildings. See Fig. 2. The primary reasons for their popularity are: excellent rain penetration resistance, fire resistance, thermal capabilities and sound transmission resistance.

A brick cavity wall is differentiated from a brick veneer with masonry backing by how the designer considers load resistance by the exterior wythe. The exterior wythe of a *cavity wall* is designed to resist loads by stresses developed in that wythe. Further, both wythes resist out-of-plane loads by stresses in each wythe. These stresses, whether axial, flexural or shear, must be less than the corresponding allowable stresses. The exterior wythe of a brick *veneer wall* transfers out-of-plane loads to the backing and is not subject to limitations of the allowable stress values. No axial loads are applied to the veneer wythe. Out-of-plane lateral loads



Typical Cavity Wall
FIG. 1



Carnegie Hall Tower, New York City
FIG. 2

are transferred by metal ties to the backing which is designed for the full load. Shear stresses generated by the veneer's weight are ignored. Other design issues, such as water penetration resistance, fire resistance, thermal, and sound transmission, are the same for either brick masonry cavity walls or brick veneer over a masonry backing; therefore, such information in this *Technical Notes* is appropriate for both types of wall systems.

Some parts of the country use the term "reinforced cavity walls" to denote a multi-wythe masonry wall with grout placed between the wythes. This should actually be considered a multiwythe grouted masonry wall. Since the definition of a cavity wall includes an air space, this type of wall is not truly a cavity wall.

This *Technical Notes* discusses the properties of cavity walls, and the proper design to achieve these properties. Other issues in this *Technical Notes* series deal with materials, detailing and proper construction practices for cavity walls.

PROPERTIES OF CAVITY WALLS

Structural Properties

Properly designed, detailed and constructed cavity walls may be used in any building requiring load-bearing or non-loadbearing walls. The increased flexibility by the separation of the wythes and the use of metal ties permits more freedom from differential movement between the wythes. This is extremely important in today's construction which makes use of many combinations of dissimilar materials.

The structural behavior of cavity walls is complex because of the interaction of the wythes, ties and support conditions. Typically, the inner wythe of a cavity wall is designed to support the weight of floors, roofs

and live loads. The outer wythe is mainly non-load-bearing. Out-of plane loads are shared by the wythes in proportion to their stiffnesses and the stiffness of the connecting ties. Walls tied together by brick headers (masonry bonded hollow walls or utility walls) behave differently from walls tied together by metal ties. Therefore, this *Technical Notes* addresses only metal-tied walls. Information on masonry bonded hollow walls (utility walls) can be found in other technical literature [1].

Resistance to Moisture Penetration

One of the major functions of an exterior wall is to resist moisture penetration. A brick masonry cavity wall, properly designed and built, is virtually resistant to water penetration through the entire wall assembly. The outside wythe may permit some moisture penetration, but the overall design of the cavity wall assembly accommodates this expected infiltration. It should be assumed that wind-driven rain will penetrate the exterior wythe of brick masonry. A cavity wall is designed as a drainage wall system, so that any moisture which does penetrate the exterior wythe will run down the back face of the exterior wythe to the bottom of the cavity where it is diverted to the outside by flashing and weep holes. For further discussion of moisture penetration, refer to the *Technical Notes 7 Series*.

Rain Screen Walls. Cavity walls can also be designed as pressure-equalized rain screen walls. This wall system provides compartmented air spaces with vents at the top and bottom of the cavity allowing wind pressures to equalize between the cavity and the exterior. In theory, the outer wythe is essentially an open rain screen that eliminates water penetration due to air pressure differences. Although pressure-equalized rain screen walls can provide increased resistance to water penetration, they are more difficult to design, detail and construct. They are typically used in projects located in areas which receive high volumes of wind-driven rain and when resistance to water penetration is of prime concern. Refer to *Technical Notes 27* for more information on pressure-equalized rain screen walls.

Condensation. Although moisture penetration due to wind-driven rain may be a major concern, condensation may also be a problem in certain climates and occupancies. Differences in humidity between inside and outside air will cause vapor flow within the wall and, unless controlled, this vapor may condense within the wall under certain temperature conditions. This condensation may contribute to efflorescence when soluble salts are present, corrosion of metal ties or disintegration of the masonry units. A condensation analysis, as described in *Technical Notes 7D*, will help determine the points in a wall system where condensation may occur. Information found in the **Air Barriers and Vapor Retarders** section of this *Technical Notes* and *Technical Notes 7C* should be used for the design against condensation.

Thermal Properties

Heat losses and heat gains through masonry walls can be minimized by the use of cavity wall construction. The separation of the exterior and interior wythes by the cavity eliminates or reduces thermal bridging and allows a large amount of heat to be absorbed and dissipated in the outer wythe and cavity before reaching the inner wythe and the building interior. The cavity provides an excellent location to incorporate insulation in the wall assembly. Insulation can be placed in the air space by using a rigid board attached to the backing or by completely filling the air space with granular fill or foam. Insulation may also be placed in the cores of the backing wythe, such as granular fill in concrete block. Finally, the interior side of the cavity wall may be finished with insulation and gypsum board.

Steady-state U-values can range from 0.33 BTU/ (hr • °F • ft²) [1.9 W / m² • K] for an 8-in. (200 mm) uninsu-

lated cavity wall to 0.06 BTU/ (hr • °F • ft²) [0.34 W / m² • K] for a 16 in. (400 mm) cavity wall with 2-in. (50 mm) polyisocyanurate board insulation. Table 1 lists R-values for typical cavity walls. Table 2 lists R-values of the materials used in brick masonry cavity walls. Table 3 lists thermal properties of interior finishes used in combination with cavity walls. For example, using Table 3, combine a 12 in. (300 mm) brick and block cavity wall with extruded polystyrene in the cavity (R-value of 9.5), with 1½ in. (38 mm) extruded polystyrene insulation between metal furring strips at 16 in. (400 mm) o.c. (R-value of 4.6) resulting in a total R-value of 14.1. Thermal properties are further enhanced when considering the mass effect of masonry. Thus, considerable energy savings can be realized by the use of cavity walls. Refer to *Technical Notes* 4 Series for U-values of materials and assemblies.

TABLE 1
R-Values of Typical Cavity Walls^{1,9}

Wall System	Insulation Type (see footnotes)				
	None	1" (25 mm) MEPS ²	1" (25 mm) XEPS ³	1" (25 mm) polyiso ⁴	Perlite
8 in. (200 mm) brick & brick cavity wall; 3 in. (75 mm) brick, 2 in. (50 mm) air space	3.0	6.9	8.1	12.4	5.3 ⁵
10 in. (250 mm) brick & brick cavity wall; 4 in. (100 mm) brick, 2 in. (50 mm) air space	3.2	7.1	8.3	12.6	5.5 ⁵
10 in. (250 mm) brick & block cavity wall; 4 in. (100 mm) brick, 4 in. (100 mm) normal weight block, 2 in. (50 mm) air space	3.6	7.5	8.6	12.9	5.9 ⁵
12 in. (300 mm) brick & block cavity wall; 4 in. (100 mm) brick, 6 in. (150 mm) lightweight block, 2 in. (50 mm) air space	4.5	8.3	9.5	13.8	6.9 ⁵
14 in. (356 mm) brick & block cavity wall; 4 in. (100 mm) brick, 6 in. (150 mm) lightweight block, 4 in. (100 mm) air space	4.5	12.2 ⁶	14.5 ⁶	20.6 ⁶	6.9 ⁷
14 in. (356 mm) brick & block cavity wall; 4 in. (100 mm) brick, 8 in. (200 mm) normal weight block, 2 in. (50 mm) air space	3.7	7.6	8.7	13.0	4.7 ⁷
14 in. (356 mm) brick & block cavity wall; 4 in. (100 mm) brick, 8 in. (200 mm) lightweight block, 2 in. (50 mm) air space	5.2	9.1	10.2	14.5	6.2 ⁸
16 in. (400 mm) brick & block cavity wall; 4 in. (100 mm) brick, 8 in. (200 mm) normal weight block, 4 in. (100 mm) air space	3.7	11.4 ⁶	13.7 ⁶	19.9 ⁶	4.7 ⁷
16 in. (400 mm) brick & block cavity wall; 4 in. (100 mm) brick, 8 in. (200 mm) lightweight block, 4 in. (100 mm) air space	5.2	12.9 ⁶	15.2 ⁶	19.3 ⁶	6.2 ⁸

¹Based on values from Ref. 6

²MEPS = molded extruded polystyrene (beadboard)

³XEPS = extruded expanded polystyrene

⁴polyiso = foil-faced polyisocyanurate

⁵Perlite = cavity filled with perlite

⁶2 in. (50 mm) insulation

⁷CMU cells filled with perlite

⁸CMU cells filled with EPS inserts

⁹1 (hr•°F•ft²)/BTU = 0.176 (m²•K)/W

TABLE 2
R-Values of Typical Cavity Walls^{1,9}

Material	R-Value, hr•°F•ft ² /BTU (m ² •K/W)
Interior Air Film Exterior Air film	0.17 (0.03) 0.68 (0.12)
Brick 3 inch (75 mm) 3½ inch (92 mm)	0.16 per inch (0.011 per cm) 0.48 (0.08) 0.58 (0.10)
Air space 1 inch (25 mm) 2 inch (50 mm) 4 inch (100 mm)	1.25 (0.220) 1.23 (0.216) 1.23 (0.216)
Insulation molded extruded polystyrene extruded expanded polystyrene polyisocyanurate	3.85 per inch (0.267 per cm) 5.0 per inch (0.346 per cm) 7.04 per inch (0.488 per cm)
Concrete Masonry Units 4 inch (100 mm) 6 inch light weight (150 mm) 8 inch normal weight (200 mm) 8 inch light weight (200 mm)	0.92 (0.16) 1.80 (0.32) 1.04 (0.18) 2.55 (0.45)

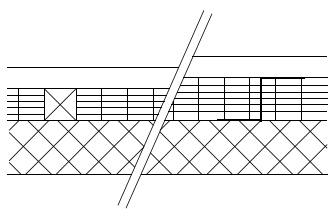
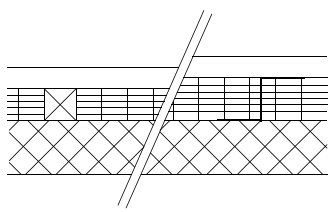
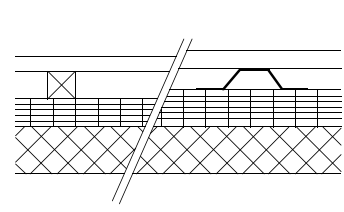
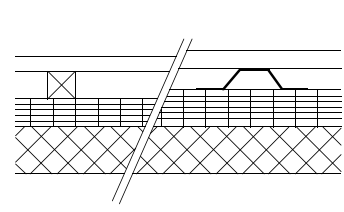
Thermal Mass. Brick masonry exhibits superior thermal mass, that is, the ability to store and slowly release heat at a later time. These properties help shift the peak heating or cooling loads to off-peak times and reduce the peak temperatures. Current energy codes take thermal mass into account by requiring a lower R-value for mass walls, such as brick cavity walls (see *Technical Notes 4B*).

Passive solar design can be used in conjunction with cavity wall construction to take full advantage of masonry's thermal mass properties. Solar design techniques, such as the use of building orientation, daylighting and thermal mass, can provide both comfort and energy savings for the owner and occupants. It is best to incorporate passive solar techniques in a building during the preliminary design phase. *Technical Notes 43 Series* has information on passive solar design techniques. Other references are available to assist in design [4, 8].

Fire Resistance

The results of fire resistance tests clearly show that brick masonry cavity walls have excellent fire resistance. Fire resistance ratings of brick masonry cavity

TABLE 3
Thermal Properties for Interior Finishes^{1,2}

Interior Finish	R-Value, hr•°F•ft ² /BTU			
	Insulation Between Furring Strips		Furring Strips Over Continuous Insulation	
				
Wood furring, rigid insulation and ½ in. (13 mm) gypsum board	16 in. (400 mm) o.c.	24 in. (600 mm) o.c.	16 in. (400 mm) o.c.	24 in. (600 mm) o.c.
¾ in. (19 mm) extruded polystyrene	3.6	3.8	5.4	5.4
¾ in. (19 mm) polyisocyanurate	4.6	5.0	6.9	6.9
1½ in. (38 mm) extruded polystyrene	5.9	6.5	9.2	9.2
1½ in. (38 mm) polyisocyanurate	7.3	8.2	12.2	12.2
Metal furring, rigid insulation and ½ in. (13 mm) gypsum board				
1 in. (25 mm) extruded polystyrene	3.8	4.2	6.6	6.6
1 in. (25 mm) polyisocyanurate	4.5	5.1	8.6	8.6
1½ in. (38 mm) extruded polystyrene	4.6	5.4	9.1	9.1
1½ in. (38 mm) polyisocyanurate	5.4	6.4	12.1	12.1

¹The values in this table can be added to those in Table 1 to achieve the total R-value of the wall.

²1 (hr•°F•ft²)/BTU = 0.176 (m²•K)/W

TABLE 4
Typical Fire Ratings of Cavity Walls

Wall Assembly	Fire Ratings, Hours
10 in. (250 mm) brick cavity wall (solid brick), 2 in. (50 mm) air space, walls filled solid at combustible framing members	2
8 in. (200 mm) brick cavity wall (solid brick), 2 in. (50 mm) air space	3
10 in. (250 mm) brick cavity wall (solid brick), 2 in. (50 mm) air space, no combustible members framed in	4
9 in. (230 mm) solid brick and concrete block, 1 in. (25 mm) air space, UL Design No. U902	4

walls range from 2 to 4 hr, depending upon the wall thickness and other factors (see Table 4). Due to their high fire resistance properties, brick walls make excellent fire walls or building separation walls for compartmentation in buildings. By using compartmentation, the spread of fire can be halted. *Technical Notes* 16 Series describes fire ratings and applicable design conditions.

An alternative way of determining the fire resistance of a cavity wall assembly is by using the calculated fire resistance method. This approach is approved by the model building codes for determining fire ratings of walls that are not physically tested by ASTM E 119 Test Methods for Fire Tests of Building Construction and Materials. The fire rating of cavity walls can be calculated using *Technical Notes* 16B.

Sound Transmission

Resistance to transmission of sound in masonry construction is accomplished in two ways: the use of heavy massive walls or the use of discontinuous construction. The cavity wall employs both techniques, i.e., the massiveness of the two masonry wythes plus the partial discontinuity of the cavity.

In cavity wall construction, the air space provides a partial isolation of the two wythes. Sound on one side of a cavity wall causes vibration of a wythe. Because of the separation and cushioning effect of the air space and the massiveness of the masonry, the vibration is dampened and greatly reduced. A 10-in. (250 mm) brick cavity wall with brick backing has a Sound Transmission Class (STC) rating of 50, which is usually sufficient for substantially reducing typical outside noises entering the building through the wall. For more information on sound transmission, see *Technical Notes* 5A.

DESIGN OF CAVITY WALLS

The successful design of cavity walls depends on proper attention to four elements: appropriate design, proper detailing, selection of quality materials and execution of good workmanship. All four elements must be satisfied to produce a successful cavity wall.

Structural Design

There are many various design procedures for cavity

walls. Both rational and empirical design methods are used. Rational design methods currently use working stress analysis. Limit states or strength design methods are now being written. Other methods such as a modified yield line approach, fracture line approach and elastic performance of cracked panels have been proposed for the design of unreinforced walls. However, insufficient data and lack of recognition by model building codes relegate these methods to use as special systems for design.

The structural design of cavity walls should follow either rational or empirical methods. The rational design method is based on the properties of the wall materials and engineering analysis. This method may be used for any structure where high loads are likely or where tall walls are a necessity. The empirical method is generally satisfactory for one and two-story buildings consisting of light construction with limited floor spans and wall heights; and for multistory buildings where unsupported wall heights are not excessive.

Rational Design. The design of cavity walls is governed by model building codes. Most of these reference the ACI 530/ASCE 5/TMS 402 *Building Code Requirements for Masonry Structures*, also known as the Masonry Standards Joint Committee (MSJC) Code [2]. The Uniform Building Code incorporates similar design requirements for cavity walls [9]. Seismic design requirements are also stipulated in these building codes based on site location. A detailed design of cavity walls is not covered in this *Technical Notes*. For design aids and examples of design procedures, several books listed in the **REFERENCES** section should be consulted [5, 7].

The MSJC Code requirements differentiate between multiwythe walls as those with composite or non-composite action. Composite action requires a transfer of shear stress between wythes so that the wythes act as a single element in resisting loads. The wythes must be bonded with a filled collar joint and metal ties or with masonry headers. Therefore, all cavity walls are classified as non-composite walls and must be designed using those requirements. When non-composite action occurs, each wythe is designed to individually resist the effects of imposed loads. In order for both wythes to carry part of the

vertical load, the floor or roof system must bear on both wythes or on a spreader beam bearing on both wythes. Typically, the wythe closest to the center of the span of horizontal members resists the resulting vertical load and the associated shear forces. Out-of-plane loads are apportioned to wythes based upon their relative stiffnesses.

The rational design method used in the MSJC Code is allowable stress design. Individual wythes may be either reinforced or unreinforced. See the *Technical Notes 3 Series* for more information on the MSJC Code.

Empirical Design. Chapter 9 of the MSJC Code presents empirical requirements for masonry structures. These requirements are based on past proven performance and pre-dates rational design methods. According to the 1995 edition of the MSJC Code, the empirical requirements in Chapter 9 may be applied to the following masonry elements:

1. The main lateral force resisting system for buildings in Seismic Performance Category (SPC) A and all other masonry elements for buildings in SPC A, B and C.
2. Buildings subject to a wind velocity pressure not exceeding 25 psf (1.2 kPa).
3. Buildings not exceeding 35 ft (10.7 m) in height when the masonry walls are part of the main lateral load resisting system.

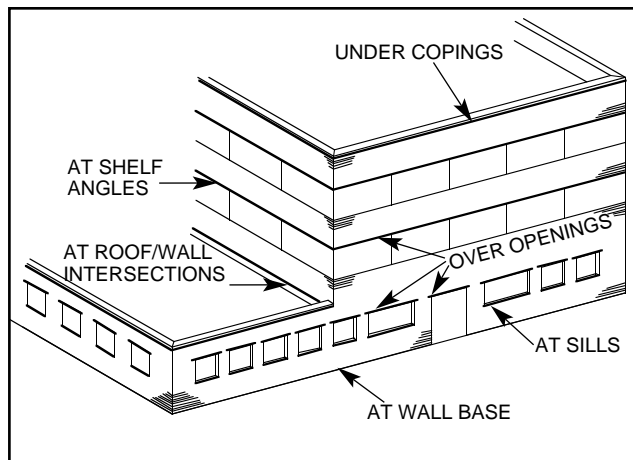
The empirical requirements may not be applied to structures resisting horizontal loads other than those due to wind or seismic events.

The MSJC Code contains limits on the ratios of wall thickness to distance between lateral supports. These limits provide controls on the flexural tensile stresses within the wall and limit possible buckling under axial loads. Maximum h/t or l/t ratios and minimum thicknesses used for determining distances between lateral supports are consistent with past masonry standards. Definitions for height (h), length (l) and thickness (t) for use in the lateral support ratios for cavity walls are as follows:

- h = the vertical distance or height between lateral supports;
- l = the horizontal distance or length between lateral supports; and
- t = the sum of the nominal thicknesses of the inner and outer wythes.

Further information on empirical design of brick masonry is provided in *Technical Notes 42 Revised*.

Seismic Issues. As with other loading, the seismic loads from other elements applied to the wythes are resisted by the loaded wythes. This requires each loaded wythe to meet prescriptive seismic reinforcement requirements. For seismic loading due to wall weight, if the tie spacing and stiffnesses are adequate, the wythes will share the out-of-plane load in proportion to their relative rigidities. In such instances, the seismic force can be resisted by just one wythe. In many cases, the inner wythe is reinforced according to the minimum reinforcement requirements prescribed by the code and



Flashing Locations
FIG. 3

the brick exterior wythe is treated as a veneer. Proper ties, reinforcement or isolation joints may be required in specific seismic performance categories (zones).

Architectural Design

Cavity. The cavity or air space between wythes should be between 2 in. (50 mm) and 4½ in. (114 mm). Air spaces less than 2 in. (50 mm) can not practically be kept free from mortar bridging. Air spaces greater than 4½ in. (114 mm) do not allow the normally prescribed ties to properly transfer lateral loads. Air spaces different from these can be used, but care in design and construction would be required. If larger air spaces are used additional ties and/or thicker ties may be necessary. 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). This allows the mason to lay the brick properly and for the wall to still function as a drainage wall. Mortar protrusions should not contact the insulation as this is a direct path for water. These air space requirements also allow for tolerances in construction.

Since it is assumed that water never crosses the air space, parging of the cavity face of either wythe is neither necessary, nor recommended. In cases where mortar could bridge the cavity, where mortar droppings fill the bottom of the cavity due to poor workmanship, or when a pressure-equalized rain screen wall is designed, a coating or membrane on the exterior face of the masonry backing may be prudent. To be effective, the coating or membrane must be continuous over the backing and be sealed at interfaces with other elements or materials. Consideration must be given to the effects of movement on the coating or membrane.

Flashing and Weep Holes. Flashing and weep holes collect water that enters a wall and directs it back to the exterior. Flashing should be provided at the base of the wall, above and below all wall openings, at the tops of walls, beneath copings, and any other discontinuities in the air space, such as recessed courses or shelf angles. Fig. 3 shows typical flashing locations.

Since flashing is a bond break, the tensile strength of the wall at that location is assumed to be zero. The shear stress will also be reduced. The structural design of the building should address these issues appropriately.

Flashing and weep holes should be located above grade level. If the wall continues below the flashing at the base of the wall, the space between the exterior wythe and the interior wythe should be filled with mortar or grout to the elevation of the flashing.

Flashing should be securely fastened to the interior wythe and extend through the face of the exterior brick wythe. The flashing should be turned up at least 8 in. (200 mm) and embedded in the inner wythe. Flashing should be carefully installed with no punctures or tears. Where flashing is required to be lapped, the ends of the flashing should be overlapped a minimum of 6 in. (150 mm) and the laps properly sealed to avoid water running between the sections. Where the flashing is not continuous, such as over and under openings in the wall, the ends of the flashing should be turned up approximately 1 in. (25 mm) into a head joint in the exterior wythe to form an end dam. Prefabricated flashing pieces may be available to help form the detail. Typical flashing details are shown in *Technical Notes* 21B Revised and 7 Revised.

Weep holes must be located immediately above all flashing. Open head joint or vent weep holes should be spaced no more than 24 in. (600 mm) o.c. Weep holes formed with wick materials or with round tubes should be spaced at a maximum of 16 in. (400 mm) o.c.

Drainage materials, such as pea gravel or plastic mesh, can be used at the base of the cavity when mortar droppings are a high probability. Although these drainage materials are not always necessary, they may help keep the cavity and the weep holes from being totally blocked by mortar. However, the use of these materials does not negate the importance of good workmanship and keeping the cavity clean from mortar droppings. When pea gravel is used, its depth should not exceed 2 to 3 in. (50 to 75 mm). Consideration should be given to the weight of the gravel on the flashing, the presence of salts in the gravel and the size of the pea gravel to keep it from flowing out of open weep holes. These types of materials may interfere with walls that are designed for air circulation in the cavity.

Ties. Wall ties provide a connection between the inner and outer wythes of a cavity wall, and may accommodate differential movements between the wythes. Tie spacing requirements for cavity walls differ slightly from those of brick veneer with masonry backing. Non-composite walls (cavity walls) designed in accordance with the MSJC Code permit a maximum spacing of 36 in. (910 mm) o.c. horizontally and 24 in. (610 mm) o.c. vertically. In addition, the spacing for W1.7 size ties must be no more than one tie for every 2.67 ft² (0.25 m²); and for W2.8 size ties, no more than one tie for every 4.5 ft² (0.42 m²). Adjustable ties must be

spaced at no more than 16 in. (400 mm) o.c. in each direction and no more than one tie for every 1.77 ft² (0.16 m²).

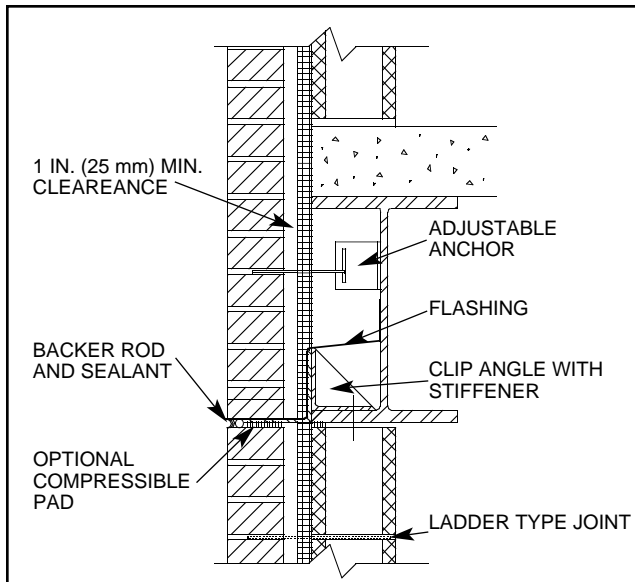
When designing the exterior wythe as a veneer, the tie spacing depends on the type of tie. For adjustable two-piece ties and ties with a wire size of W 1.7, the spacing should be no more than one tie for every 2.67 ft² (0.25 m²); and for all other ties, no more than one tie for every 3.5 ft² (0.33 m²). The maximum spacing for ties in a brick veneer are 32 in. (810 mm) o.c. horizontally and 18 in. (460 mm) o.c. vertically. Drips in the ties reduce the strength of the tie, therefore, the wall area per tie must be reduced by 50 percent. More information on ties can be found in *Technical Notes* 44B.

Foundations. Foundations of brick, concrete masonry or concrete are used to support brick masonry cavity walls. It is recommended that the thickness of the foundation or foundation wall supporting the cavity wall be at least equal to the total thickness of the cavity wall less 2 in. (50 mm). The brick exterior wythe may be corbeled out over the top of the foundation; however, the overhang may not be more than one-third of the brick's thickness nor more than one-half its height per course.

A bond break is recommended between the exterior brick wythe and the foundation. Differential movement between the brick and concrete or concrete masonry foundation and cracks emanating from the foundation can be avoided by placing a bond break, such as a flashing material, on top of the foundation. However, it must also be remembered that the flashing or bond break changes the end condition of the wall. The wythes separated from the foundation by flashing should be designed as a simply-supported or pinned end walls, not as a fixed end condition. If the exterior brick wythe is designed as a veneer then this is not a concern.

The exterior brick wythe should start above grade. Brick used below grade must be properly waterproofed with a waterproof membrane or coating. Weep holes should not be placed below grade.

Shelf Angles. Shelf angles are used in buildings to accommodate vertical movement by allowing an expansion joint to be placed beneath the angle. Shelf angles must be accompanied with horizontal expansion (soft) joints, as shown in Fig. 4. The need for shelf angles in a building depends on the type of structure, height of building, location of windows, window size and other factors. The decision to use shelf angles should be based on the effects of differential movement, type of tie system and connection of the exterior brick wythe to other building components. The MSJC Code gives no limits for the placement of shelf angles in cavity walls or in brick veneer with backings of concrete or concrete masonry. For low-rise structures, less than 30 ft (9.1 m), it is advisable to have the brick wythe bear on the foundation wall. For multi-story structures the effects of differential movement should be considered. The lo-



Shelf Angle on a Steel Frame Building
FIG. 4

cal building code may dictate the placement of shelf angles and their required height from the foundation.

Care should be taken to ensure proper anchorage and shimming of the angles to prevent excessive deflection or rotation. These movements may create problems in construction and induce concentrated loads in the masonry below. The maximum deflection and rotation should be no more than the size of the space below the angle.

Shelf angles should *not* be installed as one continuous member. Spaces should be provided at intervals to permit thermal expansion and contraction of the steel to occur without causing distress to the masonry. Shelf angles must provide continuous support around corners. As at the foundation, at least 2/3 of the brick wythe thickness must bear on the shelf angle.

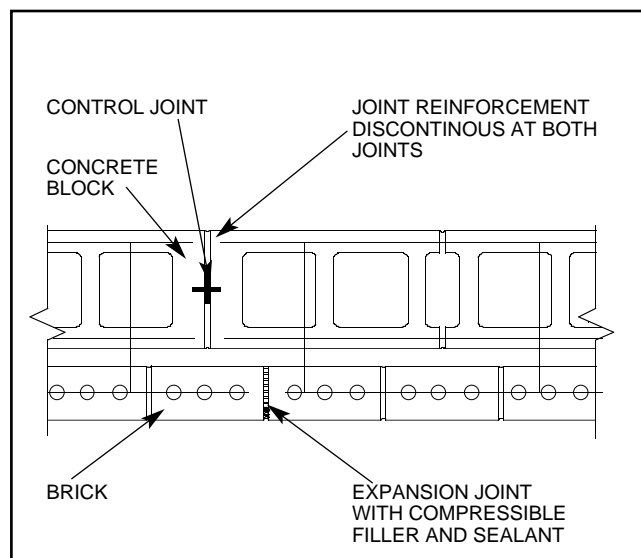
Expansion Joints. All building materials change dimension with changes in temperature. Most building materials, with the exception of glass and metals, change dimension with changes in their moisture content. Brick undergoes a permanent moisture expansion. All materials will deform when subjected to loads. And, some materials, notably those with cement matrices, will deform plastically (creep) when loaded. Building frames are subject to movements from applied vertical and horizontal loads. Concrete and concrete masonry frames and members, in addition to the above, are subject to drying shrinkage. Since many cavity walls are built of dissimilar materials, there will be differential movement between these materials. All of these movements must be considered in the design and construction of the wall system. Problems, such as cracking, can arise if these movements are not recognized and accommodated.

In order to prevent distress in the masonry, vertical and horizontal expansion joints are used to accommo-

date movements. No single recommendation for the positioning and spacing of vertical and horizontal expansion joints can be applicable to all structures. Each building must be analyzed to determine the potential movements, and provisions must be made to permit such movement or to resist stresses resulting from such movements. Expansion joints must also be designed, located and constructed so not to impair the integrity of the wall. The movement of the exterior brick wythe due to thermal and moisture expansion may be greater than the movement in solid or composite walls exposed to the same environment. This is due to the greater temperature differences between wythes and the absence of vertical loads. For further information, see *Technical Notes 18 Series*.

A distinction should be made between the use of the terms expansion joint and control joint. An *expansion joint* is used to separate brick masonry into segments to prevent cracking due to an increase in size. The joints are formed of highly *elastic* materials placed in a continuous, unobstructed opening through the brick wythe, see Fig. 5. This allows the joints to close as a result of an increase in size of the brickwork. A *control joint* is used in concrete or concrete masonry to create a plane of weakness which, used in conjunction with reinforcement or joint reinforcement, controls the location of cracks due to a reduction in volume resulting from shrinkage and creep. A control joint is usually a vertical opening through the concrete masonry wythe and may be formed of *inelastic* materials. A control joint will open rather than close. This distinction is made so that the wrong type of joint is not used in either material. These vertical movement joints do not have to be placed at the same location in a wall.

Horizontal Expansion Joints - If the brick is supported on shelf angles attached to the structural frame, horizontal expansion (soft) joints should be placed im-



Movement Joints in a Cavity Wall
FIG. 5

mediately beneath each angle. This is particularly important in reinforced concrete frame buildings because of frame shortening. Horizontal expansion joints may be constructed by leaving an air space or by placing a compressible material under the shelf angle. Using a compressible pad, such as a preformed foam pad may assist in keeping debris out of that space. Mortar should never be placed in this space. In either case, the joint must be sealed at the exterior face with a suitable elastic sealant and backer rod.

Parapets. Of all the masonry elements used in buildings, probably the most difficult to adequately detail is the parapet wall. Designers have tried many different ways to design parapets to minimize cracking, leaking and displacement. Some experts believe that the only sure way to avoid parapet problems is to eliminate the parapet altogether. However, they are frequently required by building codes or for architectural or fire safety considerations.

The detail shown in Fig. 6 is suggested as one method of building a parapet. For cavity wall construction, it is recommended that the cavity continue up through the parapet, thereby maintaining the separation between the outside wythe and the inner wythe. In ad-

dition, the backing wall of the parapet may be need to be reinforced and attached to the structural frame. Expansion joints should extend up through the parapet. Expansion joints should also be placed near corners to avoid displacement of the parapet.

Parapet copings should provide a drip on at least one side of the wall. Metal, stone, and fired clay copings of various designs usually provide this feature. The back side of the parapet should be constructed of durable materials, preferably the same material that is used in the front side of the parapet. They should not be painted or coated, but must be left free to “breathe.” Unless copings are impervious with watertight joints, place through-wall flashing in the mortar bed immediately beneath them and firmly attach the coping to the wall below with mechanical anchors. The joints between precast concrete and stone copings should be raked out to two times the width of the joint and filled with a backer rod and sealant.

Thermal Design

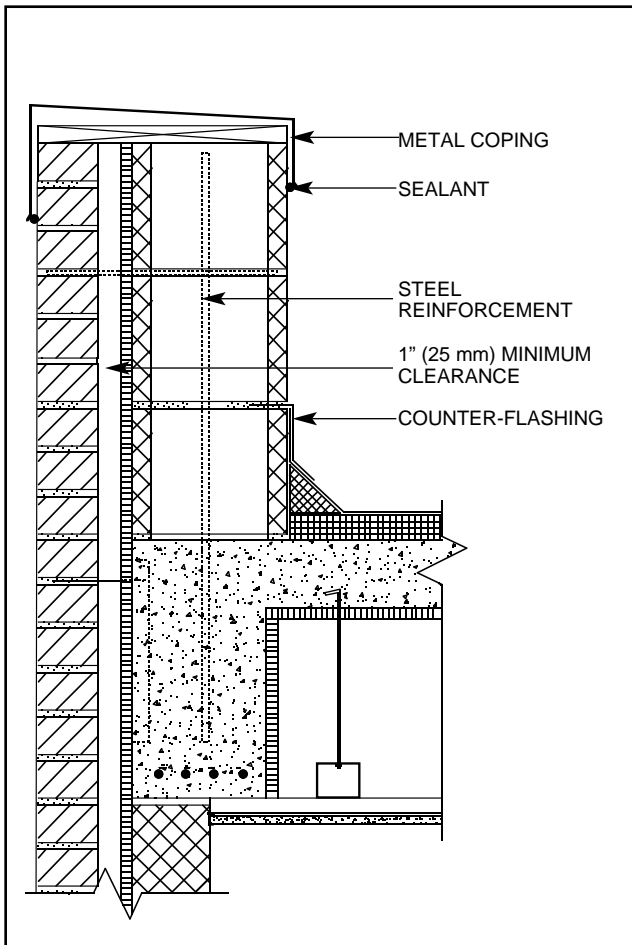
Since energy costs to heat and cool a building over its life are greater than the initial construction cost of the building, good energy design is important. Local climate and building codes may dictate the level of thermal performance necessary for a particular building. Depending on these requirements, insulation may need to be included in the cavity wall. Heavy-weight walls, such as cavity walls, have good thermal mass properties; therefore, required R-values are less than those required for lighter-weight walls.

When insulation is necessary in brick masonry cavity walls, several locations can be used. Insulation can be placed: 1) in the cavity; 2) in the cells of hollow unit backing; or 3) on the inside of the interior wythe using studs or furring strips. The location of the insulation influences the energy performance of the building and the drainability and constructability of the wall.

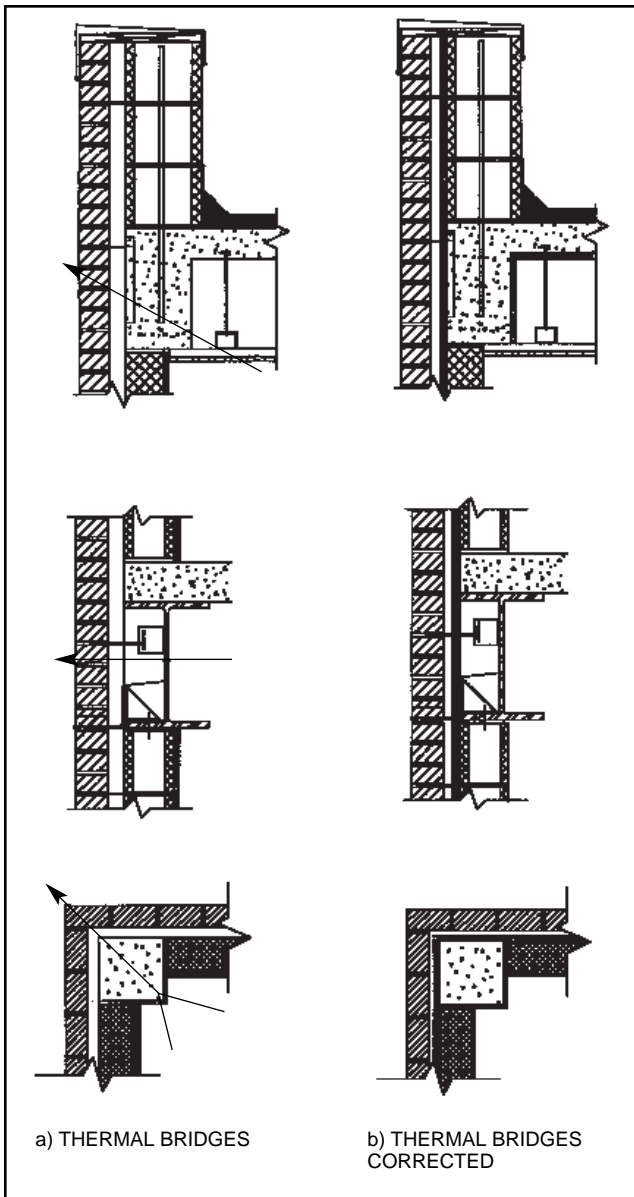
Newer types of insulation strategies, such as foam-filled cavities, drainage mats attached to insulation and drainable mineral fiber insulation used in the air space should have a good track record of in-place performance before they are considered. Manufacturer’s technical data should be carefully reviewed.

Thermal Bridges. A thermal bridge is a component or assembly through which heat (or cold) is transferred at a substantially higher rate than through the surrounding wall. A thermal bridge can degrade a wall’s thermal performance or allow condensation to occur more easily. Examples of thermal bridges in cavity wall construction are slab edge details, corner columns and roof parapets (see Fig. 7). Metal ties can be considered a thermal bridge; however, the effect of ties are negligible. Insulation placement is usually the easiest way to avoid thermal bridging.

Air Barriers and Vapor Retarders. Air leakage through the building envelope can severely degrade the thermal performance of a wall, and increase space con-



Cavity Wall Parapet
FIG. 6



Thermal Bridges in Cavity Walls
FIG. 6

ditioning loads and the chance for condensation. Air leakage carries heat and moisture between the inside and outside of the building. Infiltrating air is not filtered or conditioned, and its rate can not be controlled. The control of air leakage is important to the thermal performance of the building. The need for air barriers and vapor retarders is dependent upon climate, building use and the construction assembly. What works in one situation may not be appropriate for another. Therefore, each building must be examined on a case-by-case basis. Typically, extreme climates that have very cold winters or very humid summers are candidates for air retarders and vapor barriers. Moderate climates are less likely to require these membranes. In many cases, an air barrier may be more effective than a vapor retarder since air leakage can carry several hundred times more water vapor than vapor movement.

Air barriers must provide continuity, airtightness, structural integrity and durability. Since the placement of an air barrier is usually not critical, it is often located on the exterior face of the inner wythe. This allows for a solid surface on which to attach (adhere) the air barrier, although there may be discontinuities at the structural frame or penetrations through the wall. For walls with insulation placed in the air space, the insulation protects the air barrier from temperature extremes. Continuity of the air barrier is of utmost importance. The air barrier must be kept free from punctures and tears, and it must be continuous over the entire wall assembly by sealing any penetrations. Materials include paring, elastomeric membranes or insulation. More information on materials is found in *Technical Notes 21A Revised*.

Vapor retarders are used to slow or stop the rate of water vapor transmission through a wall. An effective vapor retarder decreases the potential for condensation in a wall. A low vapor permeance classifies the material as a vapor barrier. Although this value is usually taken as less than 1 perm ($57 \text{ ng/Pa} \cdot \text{s} \cdot \text{m}^2$), the perm rating should be based on the entire wall design and the vapor pressure difference across the wall. A vapor retarder should have the same characteristics as an air barrier, i.e. continuity, low permeance, structural integrity and durability. The preferred location of the vapor retarder is on the high vapor pressure side of the wall. Most people know the saying “on the warm side of the wall.” In climates dominated by heating, the vapor retarder would be located on the inside of the wall and in cooling climates near the exterior. These rules are often too simplistic and do not cover many parts of the country. Therefore, it is suggested that a condensation analysis be run on the wall in question based on the local climate. This will provide an accurate depiction of any potential problem. *Technical Notes 7C and 7D* discuss condensation and analysis procedures.

A potential problem can occur where the construction materials and their location may create a double vapor retarder. This may trap water between the two barriers with no chance for evaporation. When specifying materials, such as interior wall coverings, make sure the permeance is high enough to avoid the entrapment of vapor. A membrane may serve as both an air barrier and vapor retarder. This is true of many elastomeric coatings used in cavity wall construction. In this case, use the more critical design requirement and apply that to that material.

SUMMARY

This *Technical Notes* provides an introduction to brick masonry cavity walls and discusses their various properties. Information is provided for the proper design of cavity walls. Cavity wall use will continue and recommendations found in this *Technical Notes* will improve building performance.

The information and suggestions contained in this

Technical Notes are based on the available data and the experience of the engineering staff of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information contained in this *Technical Notes* are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.

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