



Annotated Design and Construction Details for Concrete Masonry

CMU-MAN-001-03



**MASONRY &
HARDSCAPES**

ANNOTATED DESIGN AND CONSTRUCTION DETAILS FOR CONCRETE MASONRY

NATIONAL CONCRETE MASONRY ASSOCIATION

The National Concrete Masonry Association (NCMA) is a not-for-profit organization whose mission is to support and advance the common interests of its members in the manufacture, marketing, research, and application of concrete masonry products. The Association is an industry leader in providing technical assistance, education, marketing, research and development, and product and system innovation to its members and to the industry.

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The material presented does not cover all possible situations but is intended to represent some of the more widely used concrete masonry construction details and other pertinent information. It is recommended that users of this manual contact local manufacturers regarding availability of particular sizes and configurations of concrete masonry units available in the vicinity of a project. A listing of producers can be found on NCMA's website at www.ncma.org.

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PREFACE

Overview of the Publication

Concrete masonry products are used in virtually all aspects of building construction, including foundations, loadbearing walls, infill walls, interior partitions, as well as exterior landscaping applications such as retaining walls and paving. This manual presents masonry details commonly used in construction and provides additional corollary information for each set of details where applicable. Each section covers a specific concrete masonry application, and includes details with side-by-side commentary. Where appropriate, the user is referred to other sections of the manual, or other references, for more complete information. The commentary information is intended to provide a brief overview of the design and/or construction considerations that apply to a particular type of construction. The commentary is not intended to include a complete discussion of each item.

A companion to this manual is the accompanying CD ROM, which includes all of the details shown herein. These details may be imported into new or existing drawings using CAD programs, allowing easy editing for specific projects.

The details and information presented represent common masonry construction practice, but may need to be modified to meet local conditions or requirements. It is the designer's responsibility to ensure local code requirements are met for the project under consideration. The governing code provisions should always take precedence over details shown in this manual.

The material presented does not cover all possible situations but is intended to represent some of the more widely used concrete masonry construction details and other pertinent information. It is recommended that users of this manual contact local manufacturers regarding availability of particular sizes and configurations of concrete masonry units available in the vicinity of a project.

Layering Map

Each detail in this manual was generated using 6 different layers. This system is intended to facilitate easy manipulation of the figures by freezing, hiding, or otherwise modifying specific components of these drawings. The layers include:

0 - This is the default layer containing the primary figure or figures in the drawing. The lineweights of this layer are mixed depending upon the specific application.

Commentary - This layer contains the commentary discussion accompanying each figure. The lineweights of this layer are set to 0.05.

Hatch - Some figures contain hatching to highlight or distinguish regions of a figure. Lineweight thicknesses are set to 0.05 for this layer.

Layout - Each drawing is scaled to be plotted on an 8 1/2 by 11 inch sheet of paper, the extents of which are established with this non-printing layer. The lineweights of this layer are default thicknesses.

Page - This layer contains the border and other identifying information for a specific detail and chapter. The lineweights of this layer are mixed depending upon the specific application.

Text - This layer contains the dimensioning and text accompanying each figure. Lineweight thicknesses are set to 0.05 for this layer.

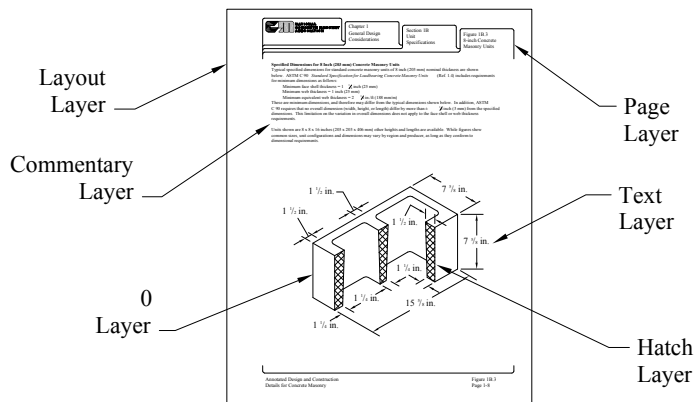


TABLE OF CONTENTS

Chapter 1 - General Design Considerations	Chapter 9 - Specialized Details
Section 1A - Modular Layout of Masonry	Section 9A - Parapets
Section 1B - Unit Properties and Specifications	Section 9B - Columns
Section 1C - Quality Assurance Testing	Section 9C - Radial Walls
Section 1D - Code Construction Tolerances	Section 9D - Banding
Section 1E - Code Detailing Requirements	Section 9E - Pilasters
Section 1F - Material Estimating	Section 9F - Glass Unit Masonry
Chapter 2 - Universal Detailing Requirements	Section 9G - Fire Wall Construction
Section 2A - Bond Patterns	Section 9H - Sound Walls
Section 2B - Mortar Joints	Section 9I - Arches
Section 2C - Control Joints	Section 9J - Masonry Floor Systems
Section 2D - Flashing and Weeps	Chapter 10 - Definitions
Section 2E - Corners	
Section 2F - Joint Reinforcement	
Section 2G - Lintels	
Chapter 3 - Single Wythe Construction	
Section 3A - Above Grade Walls	
Section 3B - Curtain Walls	
Section 3C - Infill Walls	
Section 3D - Prestressed Masonry	
Section 3E - Foundation Walls	
Chapter 4 - Multiwythe Construction	
Section 4A - Noncomposite Walls	
Section 4B - Composite Walls	
Chapter 5 - Veneers	
Section 5A - Steel Framing Backup	
Section 5B - Wood Framing Backup	
Section 5C - Concrete Masonry Backup	
Chapter 6 - Anchorage and Connections	
Section 6A - Wall to Roof	
Section 6B - Wall to Floor	
Section 6C - Wall to Wall	
Chapter 7 - Reinforcement Details	
Section 7A - Special Unit Shapes	
Section 7B - Reinforcing Bar Positioners	
Section 7C - Foundation Dowel Alignment	
Section 7D - Corners	
Section 7E - Reinforcement Intersections	
Section 7F - Changing Reinforcement Location	
Chapter 8 - Earthquake and Wind Details	
Section 8A - Earthquake Details	
Section 8B - High Wind Details	

CHAPTER 1 - GENERAL DESIGN CONSIDERATIONS

Like all construction, the process of events taking a masonry project from conception, through layout and design, and finally to construction can introduce numerous issues that require addressing prior to proceeding onto the next step in the process.

While some of these considerations (such as the choice of mortar color) have a negligible impact on the design and detailing of the structure, others require a coordinated effort to confirm compliance with building code provisions and ensure the long term serviceability of the structure. As a brief review, this chapter outlines the general design considerations that may - during one or more phases of the project - have an impact on the overall layout, design, specification, or detailing of the masonry structure. While not all-inclusive, these general topics would apply to most concrete masonry construction and should, as a minimum, be briefly considered for application to any specific project.

Some topics addressed by this chapter stem from specific Code requirements (Ref. 1.8 and 1.9) aimed at ensuring a minimum level of performance or life safety of a masonry building. These subjects include:

- Unit Specifications (Section 1B) - All concrete masonry units approved for use in construction have minimum physical properties specified by appropriate ASTM standards. Section 1B reviews and interprets these requirements for common concrete masonry units.
- Quality Assurance (Section 1C) - Ensuring that the materials specified and the construction methods used comply with the assumptions employed during the design phase is as important to the overall performance of the structure as the fundamental design. Section 1C summarizes the minimum testing and inspection requirements cited in the national masonry Code.
- Construction Tolerances (Section 1D) - While some feel that construction tolerances are strictly an aesthetic component of the overall design, they can have a significant impact on the structural performance of a masonry building as well. Section 1D reviews the tolerances for placing and constructing various masonry elements and systems in accordance with Code.
- Prescriptive Detailing (Section 1E) - Structural connections, combined with the correct placement and use of reinforcing steel, are the primary contributors to a structurally sound masonry building. As such, the Code places considerable emphasis on correctly detailing masonry structures as reviewed in Section 1E.

Other issues, such as modular coordination (Section 1A) and cost estimating (Section 1F), while not mandated by the building Code, encompass considerations that shape good design practices. Additional information covering the modular coordination of masonry construction can be found in ASTM E 835/E 835M Standard Guide for Modular Coordination of Clay and Concrete Masonry Units (Ref. 1.21).

SECTION 1A - MODULAR LAYOUT OF MASONRY

Concrete masonry structures can be constructed using virtually any layout dimension. However, for maximum construction efficiency and economy concrete masonry elements should be designed and constructed with modular coordination in mind. Modular coordination is the practice of laying out and dimensioning structures and elements to standard lengths and heights to accommodate proportioning and incorporating modular sized building materials. On occasion, modular coordination issues are not considered during the design phase. As a result, jobsite decisions take place - often in haste and at cost. When a project does necessitate a non-modular layout, further design and construction considerations need to be addressed, including:

Placement of vertical reinforcement - In construction containing vertical reinforcing steel, the laying of units in other than running (half) bond or stack bond interrupts the vertical alignment of individual confined cells. As a result, the placement of reinforcement and adequate consolidation of grout becomes difficult.

Interruption of bond pattern - In addition to the aesthetic impact a change in the bond pattern can create, building codes often contain different design assumptions for masonry constructed in running bond versus other bond patterns. Walls incorporating more than a single bond pattern may present a unique design situation.

Locating control joints - In running bond construction, the incorporation of control joints can be accomplished using only full and half-size units. Similarly, stack bond construction only requires full-size units when control joints are properly spaced and detailed. However, with other bond patterns the cutting of units may become necessary if specially dimensioned units are not used or are not available.

Modular Wall Elevations

Standard concrete masonry modules are typically 8 inches (203 mm) vertically and horizontally, but may also include 4-inch (102 mm) modules for some applications. These modules provide overall design flexibility and coordination with other building products such as windows, doors, and other similar elements as shown in Figures 1A.1 and 1A.2.

Modular Wall Sections

For door and window openings, the module size for bond patterns and layout are nominal dimensions. Actual dimensions of concrete masonry units are typically $\frac{3}{8}$ inch (9.5 mm) less than nominal dimensions, so that the 4 or 8-inch (102 or 203 mm) module is maintained with $\frac{3}{8}$ inch (9.5 mm) mortar joints. Where mortar joint thicknesses differ from $\frac{3}{8}$ inch (9.5 mm) (as may be specified for aesthetic purposes or with brick construction), special consideration is required to maintain modular design. Refer to Figure 1A.3 for an illustration of this concept.

Typically, concrete masonry units have nominal face dimensions of (height by length) 8 by 16 inches (203 by 406 mm), and are available in nominal widths ranging from 4 inches (102 mm) to 16 inches (406 mm) in 2-inch (51 mm) increments. In addition to these standard sizes, other unit widths, heights and lengths may be available from concrete masonry producers. The designer should always check local availability of specialty units prior to initiating a design.

Modular Building Layouts

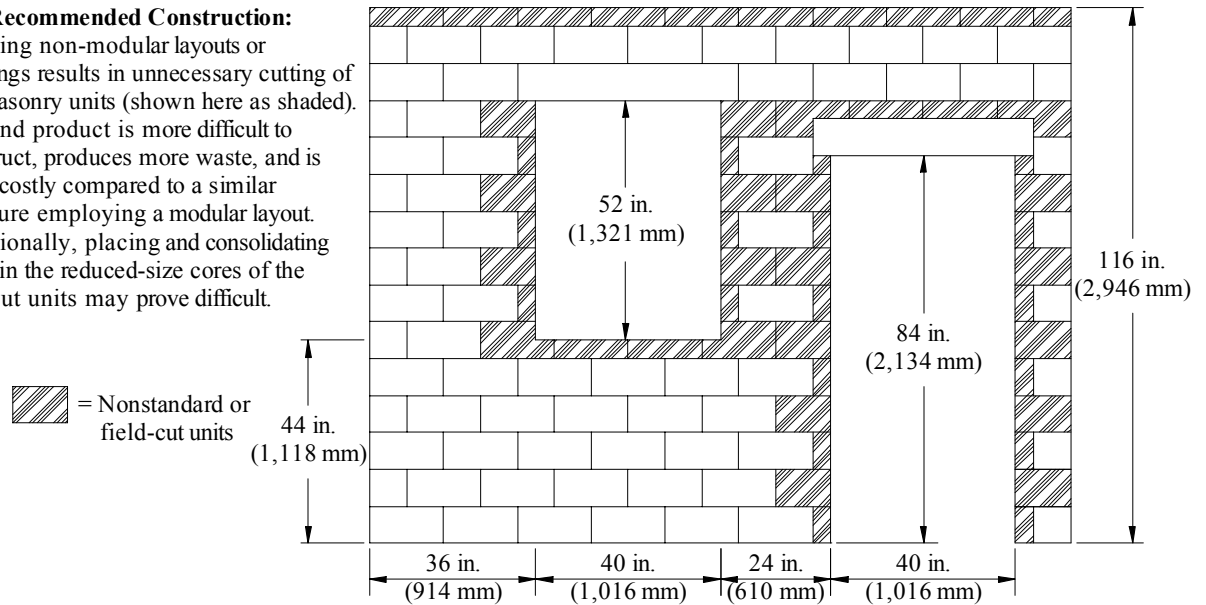
In addition to wall elevations, sections, and openings, the overall plan dimensions of a structure need also be considered, especially when using units having nominal widths other than 8 inches (203 mm). Consider, for example, a square building with outside nominal dimensions of 360 inches (30 feet) (9,144 mm), which is evenly divisible by 8 and therefore modular. Using 8-inch (203 mm) units and a running bond pattern, the walls can be constructed with minimal cutting of the units. However, if 12-inch (305 mm) wide units were used instead of the 8-inch (203 mm) units, at least one block must be cut shorter to accommodate the increased thickness of the end unit oriented perpendicular to the length of the wall. (As an alternative to cutting, specially configured corner units may be available in some regions for turning corners.) This concept is illustrated in Figure 1A.4. (Refer to Section 2E for various alternatives to laying out corners.)

Metric Coordination

One additional consideration for some projects is the incorporation of standard sized (inch-pound) units into a metric project. Similar to inch-pound units, masonry units produced to metric dimensions are 10 mm ($1\frac{3}{32}$ inch) less than the nominal dimensions to provide for the mortar joints. Thus, the nominal metric equivalent of an 8 by 8 by 16 inch unit is 200 by 200 by 400 mm (190 by 190 by 390 mm specified dimensions). Since inch-pound dimensioned concrete masonry units are approximately 2 percent larger than hard metric units, complications can arise if they are incorporated into a structure designed according to the 100 mm (3.9 inches) metric module, or vice versa. Recommendations are provided in Ref. 1.1 for the incorporation of soft metric units (standard inch-pound units) into a hard metric design project. Figures 1A.5 and 1A.6 provide recommended alternatives for incorporating soft metric units into hard metric projects.

Not Recommended Construction:

Utilizing non-modular layouts or openings results in unnecessary cutting of the masonry units (shown here as shaded). The end product is more difficult to construct, produces more waste, and is more costly compared to a similar structure employing a modular layout. Additionally, placing and consolidating grout in the reduced-size cores of the saw-cut units may prove difficult.

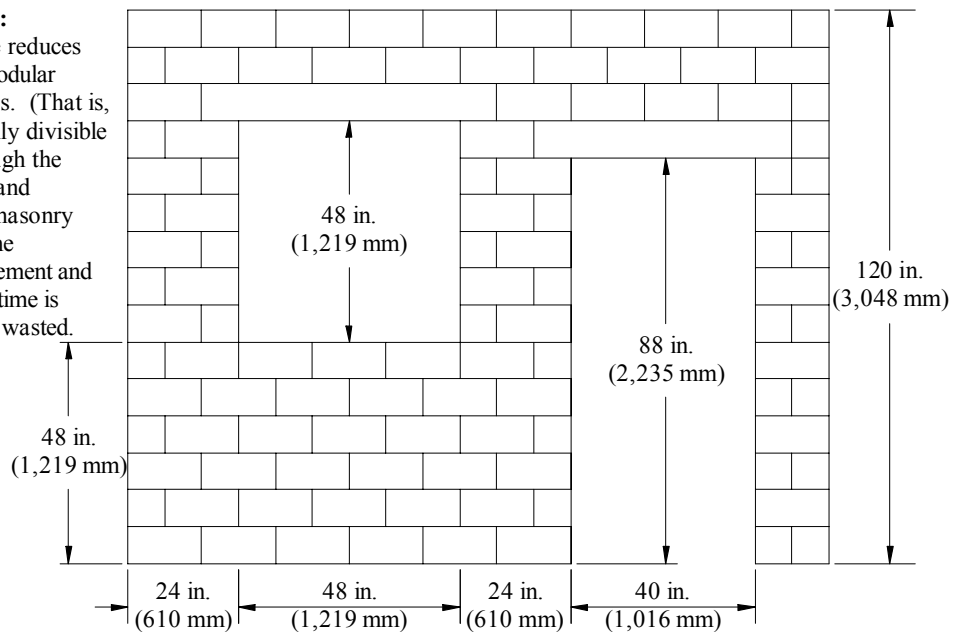


In this example, it is obvious the aesthetic impact non-modular layouts have on the final appearance of a structure. Not so obvious is the additional cost of construction. To further illustrate this concept, consider the following comparison of the modular and non-modular layouts shown here:

- Total area of non-modular layout = 122.4 ft² (11.38 m²)
- Total area of modular layout = 126.7 ft² (11.77 m²)
- Number of units used in non-modular layout = 112
- Number of units used in modular layout = 106

Recommended Construction:

The wall elevation shown here reduces cutting of units by utilizing modular openings and opening locations. (That is, each dimension shown is evenly divisible by 8 inches (203 mm).) Through the coordination of opening sizes and locations; the cells of hollow masonry units align (which facilitates the placement of vertical reinforcement and consolidation of grout), labor time is reduced, and materials are not wasted.



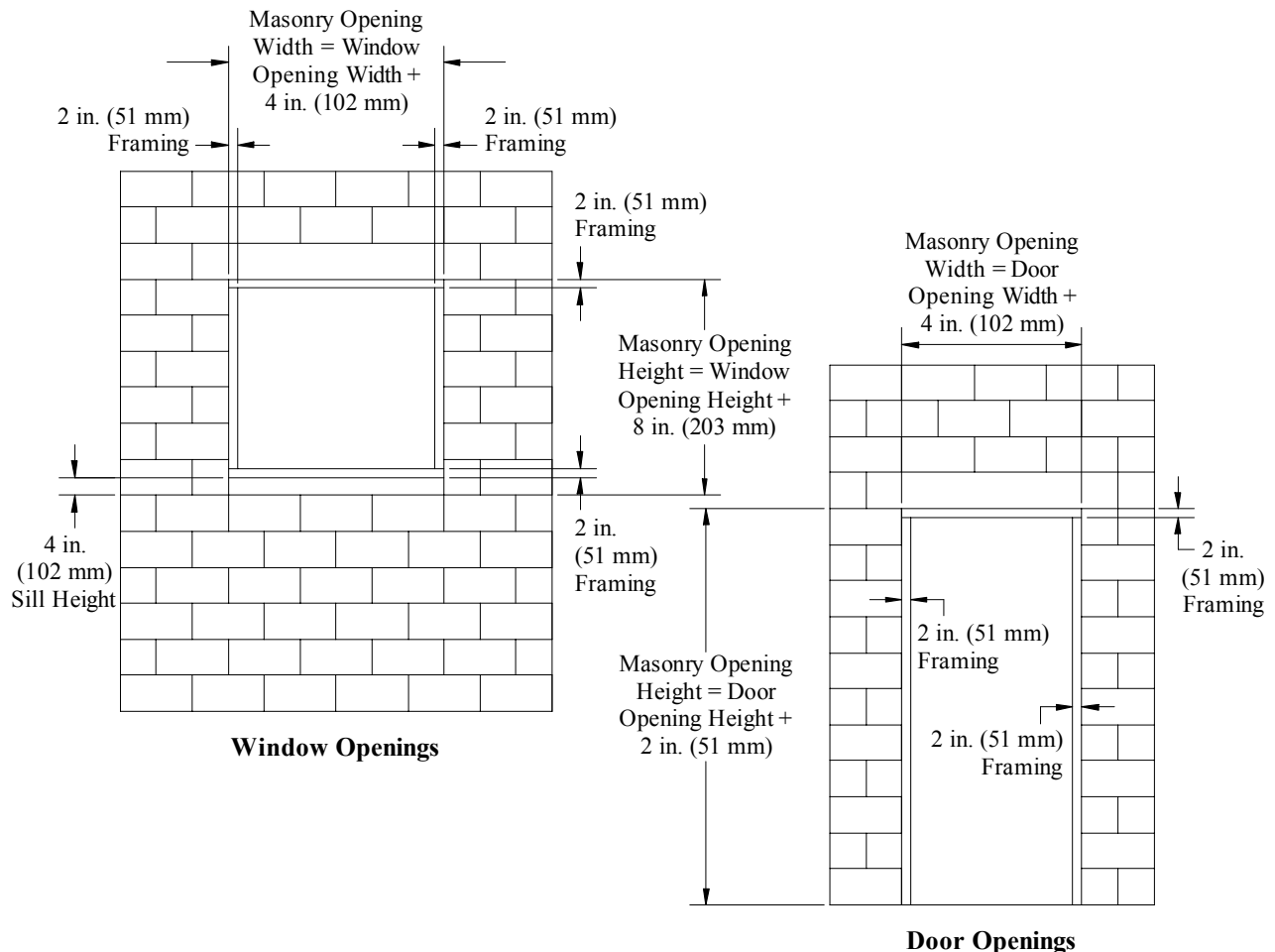
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Modular Wall Openings

The rough opening dimensions illustrated in Figure 1A.1 apply to the layout and construction of the masonry assemblage. However, to allow for fastening windows and doors to the masonry, the nominal heights and widths of these elements are slightly less.

For conventional construction methods, the widths for masonry openings for doors and windows should generally be 4 inches (102 mm) larger than the door or window width. This allows for 2 inches (51 mm) on each side of the opening for framing. The heights for masonry openings to accommodate windows are typically 8 inches (203 mm) greater than the window height. This opening size allows for 2 inches (51 mm) above and below for framing and 4 inches (102 mm) for installation of a sill at the bottom of the window. Masonry opening door heights are 2 inches (51 mm) greater than the door height leaving 2 inches (51 mm) for the door framing.

Thus, door and window widths of 28, 36, 44, and 52 inches (711, 914, 1,118, and 1,321 mm) (and so on in 8 inch (203 mm) increments) are modular and would not require cutting of the masonry. Modular window heights are any multiple of 8 inches (203 mm), with a masonry window opening 8 inches (203 mm) greater than the height of the window if a 4-inch (102 mm) sill is to be used. Similarly, a modular door height is 2 inches less than any even multiple of 8. Hence, 86 inches (2,184 mm), which would fit into an 88-inch (2,235 mm) high masonry opening, would be a modular door height. Alternatively, when an 84-inch (2,134 mm) door height is used, a 4-inch (102 mm) door buck can be placed at the top of the opening. In addition, available in some areas of the country are precast lintels containing a 2 inch (51 mm) notch to accommodate 80-inch (2,032 mm) doors.



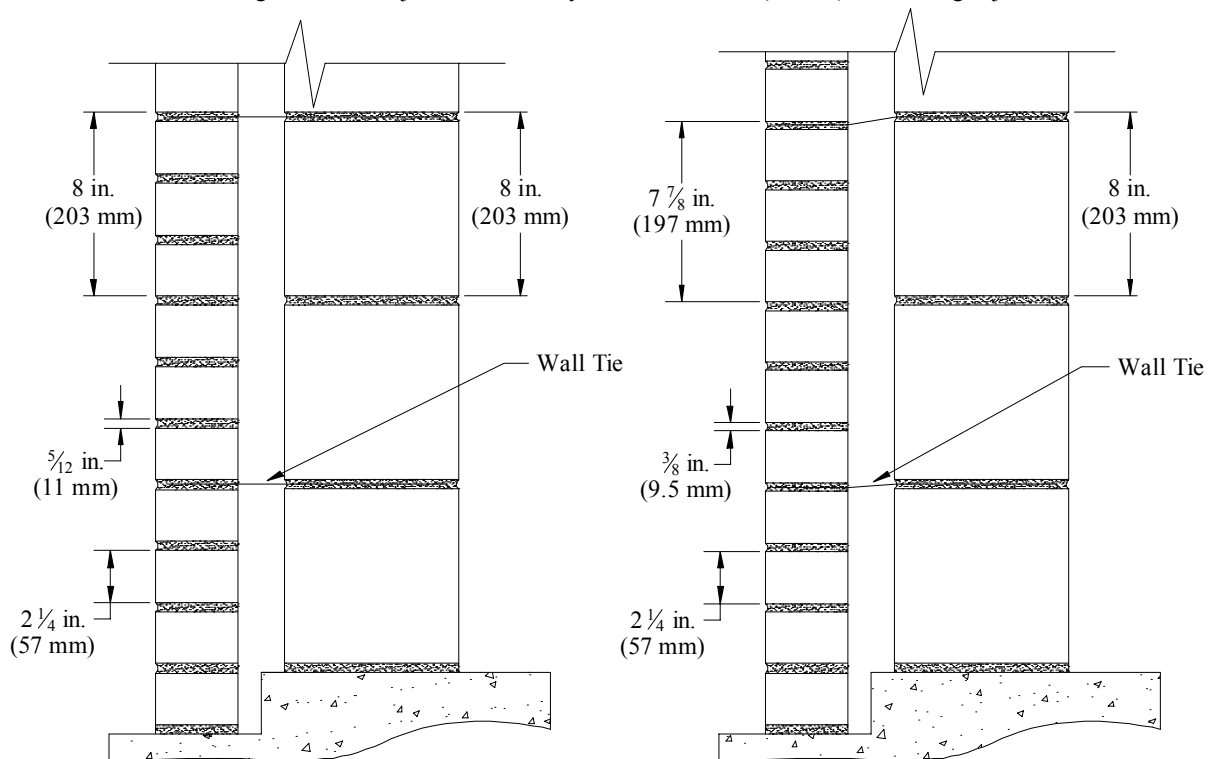
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Modular Wall Sections

Incorporating brick into a project, either as a structural component or as a veneer, can present unique modular coordination considerations in addition to those present with single wythe construction. Concrete brick most commonly have nominal widths of 4 inches (102 mm), lengths varying from 8 to 16 inches (203 to 406 mm), and heights from 2 1/2 to 6 inches (64 to 152 mm). The specified dimensions of a common concrete brick are typically 3 5/8 by 2 1/4 by 7 5/8 inches (92 by 57 by 194 mm), but may be available in a wide range of dimensions.

Because of their unique dimensions, brick are usually laid with bed joints that are slightly larger (or sometimes smaller depending upon the actual size of the brick) than the standard 3/8 inch (9.5 mm) mortar joint thickness. For common concrete brick, bed joint thicknesses are increased slightly to 5/12 inches (11 mm), thereby providing a constructed height of 2 3/4 inches (68 mm) for one brick and one mortar joint. (Note that a 5/12 inch (11 mm) thick bed joint is still within the allowable tolerances prescribed by the Specification (Ref. 1.9).) The result is such that three courses of brick (including the mortar joints) equals one 8-inch (203 mm) high module, thereby maintaining the modular coordination of the project.

Using nonstandard mortar joint thicknesses becomes apparently necessary in multiwythe veneer construction, where discrete bed joints of adjacent wythes must align to accommodate the anchors tying the walls together. In the details shown here, if standard 3/8 inch (9.5 mm) bed joints were used (instead of the 5/12 inch (11 mm) joint as shown in the bottom left detail), successive courses would result in significant misalignment of the bed joints of the two wythes. In these cases, the use of adjustable wall ties is recommended. However, it should be noted that building codes (Ref. 1.8 and 1.9) limit the maximum misalignment of bed joints between wythes to 1 1/4 inches (32 mm) when using adjustable ties.



Recommended Construction:

- Vertical coursing of bed joints of each wythe align.
- Appropriate joint thickness selected.

Not Recommended Construction:

- Misalignment of bed joints makes installation of wall ties difficult and reduces their effectiveness in transferring loads.
- Inappropriate joint thickness selected.
- May be partially compensated by the use of adjustable wall ties.

Horizontal Coursing

Although virtually any building dimension can be constructed using concrete masonry, considering modular dimensioning during the initial layout phase can facilitate reducing both cost and construction time.

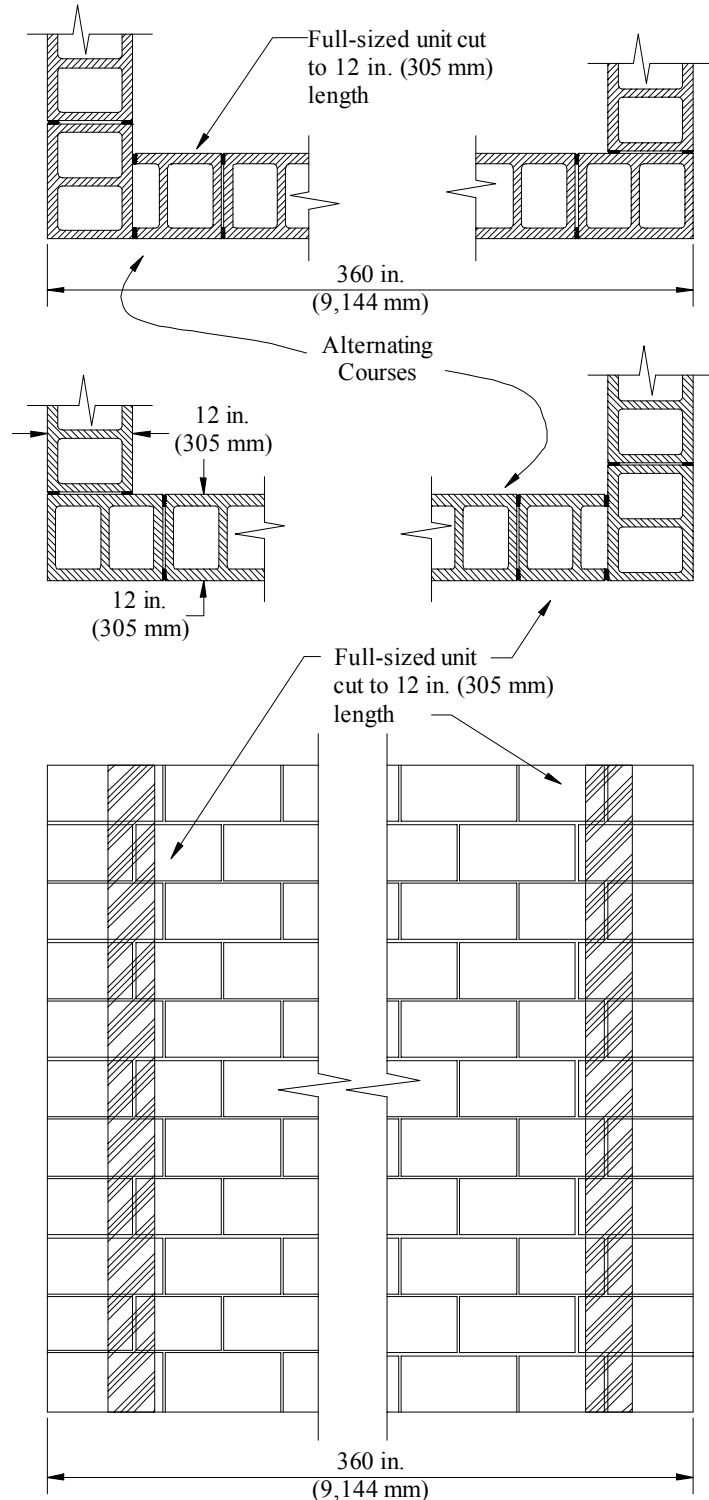
Ideally, the nominal plan dimensions of masonry structures should be evenly divisible by 8 inches (203 mm). This allows constructing each course of a wall using only full-length or half-length units, which in turn reduces labor and material costs. In addition, maintaining an 8-inch (203 mm) module over the length of a wall facilitates the turning of corners, whereby half of the units from one wall interlock with half of the units from the intersecting wall.

However, when using units with thicknesses other than 8 inches (203 mm), additional considerations need to be addressed. In the detail shown here, although the outside dimension of the structure is a modular 360 inches (9,144 mm), because the construction consists of 12-inch (305 mm) thick units, cutting of the units may become necessary to accommodate the increase in wall thickness.

The obvious impact of cutting units is an interruption in bond pattern as illustrated in the elevation. If vertical reinforcement will be placed within the cut cells, considerable difficulty could arise in placing the steel and consolidating the grout in the shaded portion of the wall. Section 2E provides some alternatives to cutting units when turning corners.

An attempt should also be made to create plan dimensions that are evenly divisible by 8 inches (203 mm) plus the nominal thickness of the units used in the construction. In the example illustrated here, slightly changing the overall dimensions of the building to 364 inches (9,271 mm) allows construction using only full-size units. The drawback to this concept is that it requires the designer to consider the layout of the entire building to ensure that bond is maintained on adjacent and opposite walls.

As an alternative to cutting units or changing building dimensions, corner block can be used if available. These units are specifically manufactured to turn corners without interrupting bond patterns.



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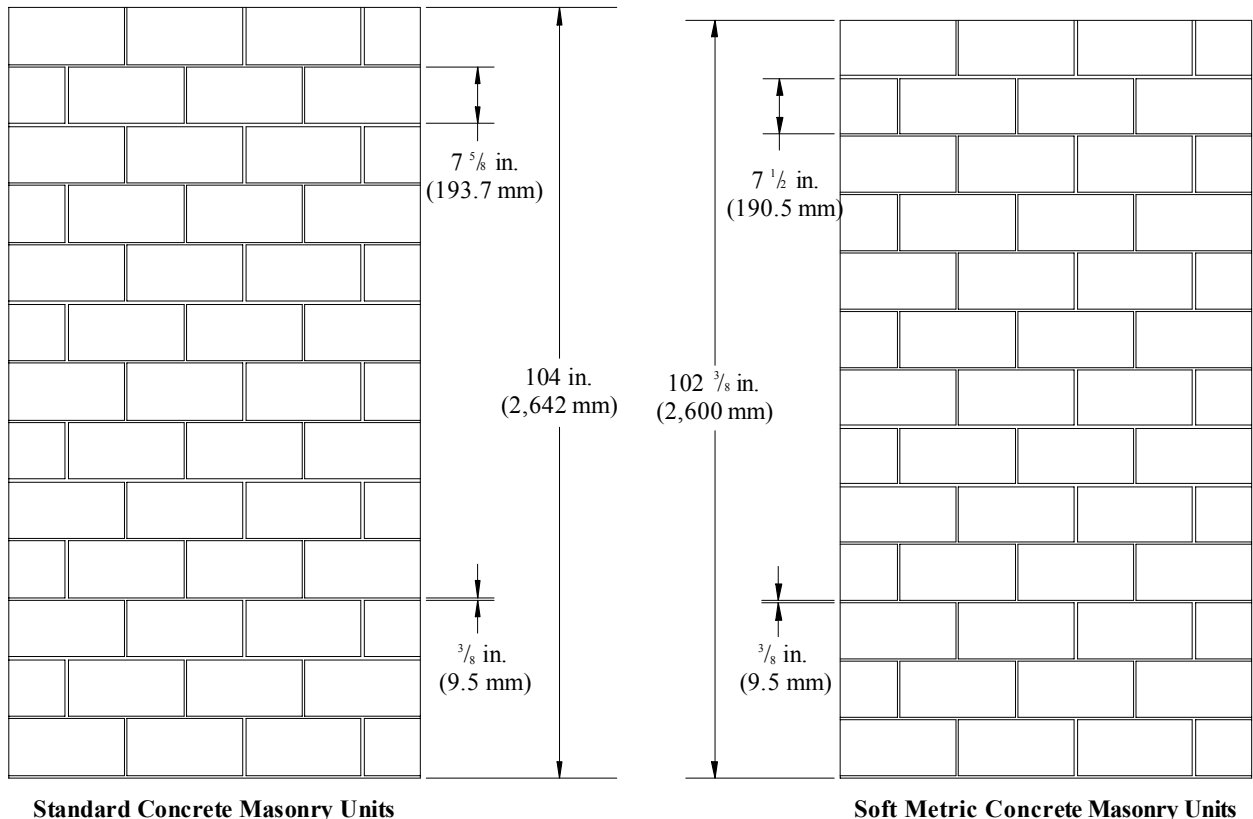
Vertical Metric Coursing

In recent years, the United States Government has been taking steps to encourage a change in the system of measurement used in the US from the inch-pound system to the metric system. In the construction industry, the most common effect of the conversion effort has been a simple re-labeling of products with equivalent metric dimensions without a change in the actual physical dimensions, a process commonly referred to as soft metric conversion. Conversely, hard metric conversion requires resizing products to conform to convenient rounded metric dimensions, a process difficult to accomplish with masonry units.

The hard metric equivalent of a 4 inch (102 mm) module is the 100 mm (3.9 inch) module. Since 4 inches equals 101.6 mm, the inch-pound module is 1.6 percent larger than the 100 mm metric module. This seemingly small difference (about $\frac{1}{6}$ of an inch) is cumulative, becoming $\frac{1}{8}$ inch in 8 inches (3.2 mm in 203 mm), $\frac{1}{4}$ inch in 16 inches (6 mm in 406 mm), and so on, making the two modules incompatible. This incompatibility is evident with both vertical and horizontal coursing of masonry units.

Control of vertical coursing can generally be achieved by either of two methods. The first method is to use standard soft metric units with a $\frac{3}{8}$ inch (9.5 mm) mortar joint and allow each story to be slightly taller than that specified. For example, consider a specified metric story height of 2,600 mm (102 $\frac{3}{8}$ inches) consisting of 13 courses of masonry units. Using soft metric units and maintaining $\frac{3}{8}$ inch (9.5 mm) bed mortar joints, the constructed story height would increase to 2,642 mm (104 inches), an increase of 1 $\frac{5}{8}$ inches (41 mm) in story height.

The second method is to specify the use of customized, soft metric, concrete masonry units manufactured to an actual height of 7 $\frac{1}{2}$ inches (190.5 mm) rather than the standard 7 $\frac{5}{8}$ inch (193.7 mm) specified height. Slight adjustments in the height of masonry units can be accomplished with relative ease during the manufacturing process - an option not available for the length or width of units. With 7 $\frac{1}{2}$ inch (190.5 mm) high units and the standard $\frac{3}{8}$ inch (9.5 mm) mortar joint, metric dimensioning is maintained over the 13 courses of masonry in the example cited above.



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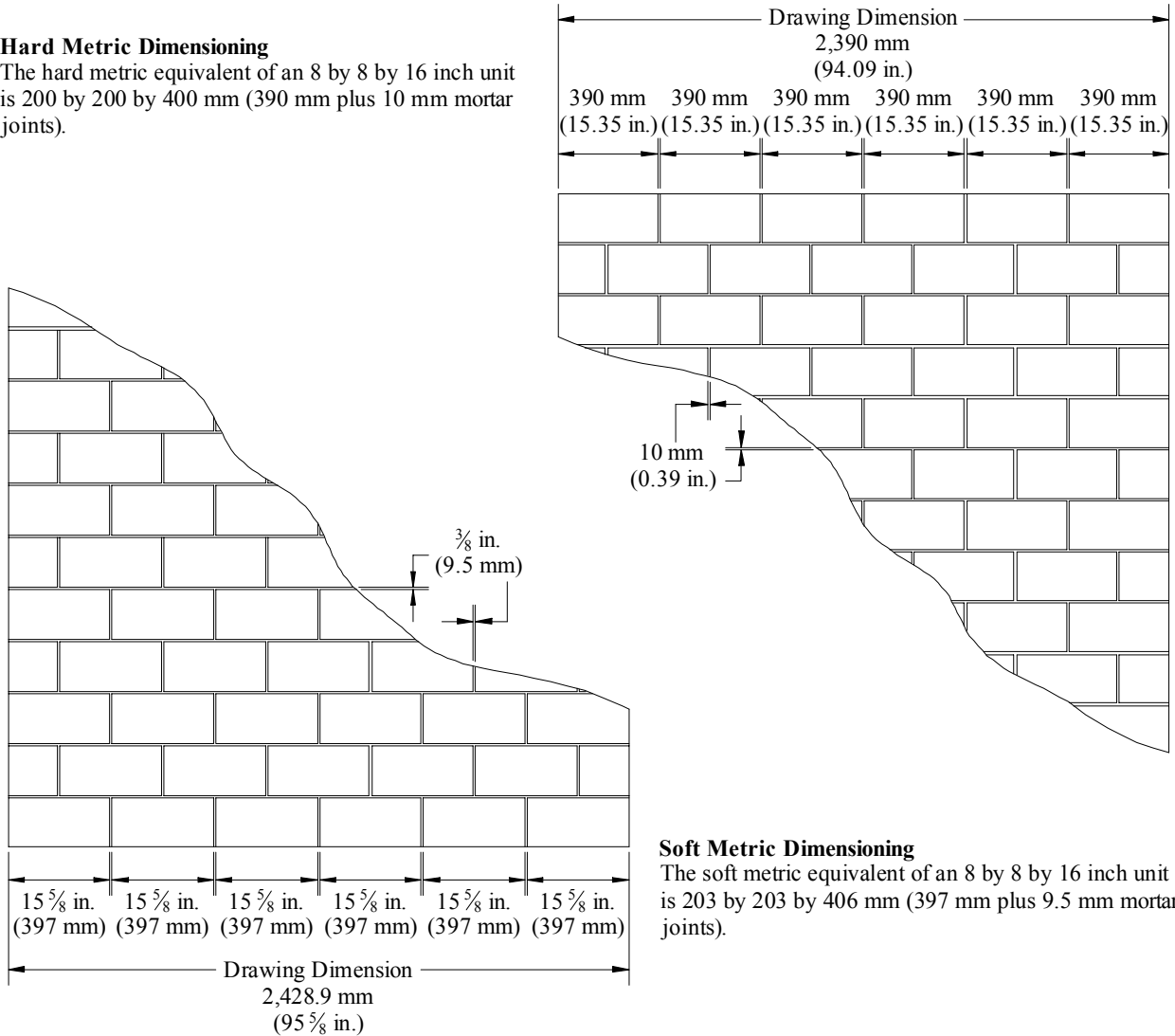
Horizontal Metric Coursing

As discussed in Figure 1A.5, when inch-pound dimensioned components are incorporated into a hard metric design, the modular concept no longer exists. Compared to vertical coursing, the control of horizontal coursing is more difficult to achieve when using soft metric units in a hard metric project. The designer should be cognizant that cutting around openings may be required. Sufficient distance between openings and intersecting walls or piers should be provided in the design to allow for field adjustments in lateral placement. Utilizing inch-pound doors and windows can minimize cutting and fitting around doors and window openings. Cutting and fitting around hard metric door and window openings can also be minimized by moving one side of the opening to the nearest inch-pound modular dimension. This will eliminate the need for cutting units on both sides of the opening.

It is possible to comply with the Federal mandate of designing and constructing all Federal structures using the metric system by a direct conversion of inch-pound units to metric dimensions, known as soft metric conversion. Thus, a nominal 8 by 8 by 16 inch unit is designated as 203 by 203 by 406 mm. The practical implications of soft metric conversion are not difficult to manage when they are incorporated into the design at the beginning of the project and a module of 101.6 mm, rather than 100 mm, is used.

Hard Metric Dimensioning

The hard metric equivalent of an 8 by 8 by 16 inch unit is 200 by 200 by 400 mm (390 mm plus 10 mm mortar joints).



Soft Metric Dimensioning

The soft metric equivalent of an 8 by 8 by 16 inch unit is 203 by 203 by 406 mm (397 mm plus 9.5 mm mortar joints).

SECTION 1B - UNIT PROPERTIES AND SPECIFICATIONS

The most widely used standards for specifying concrete masonry units are published by the American Society for Testing and Materials (ASTM). ASTM standards for manufactured masonry units specify minimum requirements, which in turn help to ensure quality performance when such units are incorporated into construction. Some of the more commonly used ASTM standards covering the minimum requirements for concrete masonry units include:

- C 55 - Concrete Brick (Ref. 1.2)
- C 73 - Calcium Silicate Brick (Ref. 1.3)
- C 90 - Loadbearing Concrete Masonry Units (Ref. 1.4)
- C 129 - Nonloadbearing Concrete Masonry Units (Ref. 1.5)
- C 936 - Interlocking Paving Units (Ref. 1.6)
- C 1372 - Segmental Retaining Wall Units (Ref. 1.7)

Requirements include, but may not be limited to, conformance to:

Specified constituent materials: The materials used to manufacture concrete masonry units, which include portland cement, water and aggregates, must comply with the minimum requirements of their respective specifications (other materials such as admixtures and colors are not covered by these minimum requirements and must be specified separately). The use of quality materials in the production of concrete masonry units helps to ensure a quality product.

Minimum compressive strength: The minimum compressive strength of concrete masonry units varies depending upon the type and anticipated use of the unit. For hollow and solid loadbearing concrete masonry units, ASTM C 90 specifies a minimum average compressive strength, based on net cross-sectional area, of at least 1,900 psi (13.1 MPa).

Maximum water absorption: The water absorption is a measure of the total water-fillable void content of the concrete, expressed in terms of pounds of water per cubic foot of concrete or as a percentage of the dry weight of the concrete, depending upon the type of unit and the specification being followed. In accordance with ASTM C 90, the maximum permissible water absorption ranges from 13 to 18 lb/ft³ (208 to 288 kg/m³), depending upon the density of the concrete.

Minimum face shell thickness, web thickness and equivalent web thickness: The minimum face shell, web thickness and equivalent web thickness requirements for hollow loadbearing units are specified in ASTM C 90 to obtain satisfactory structural performance. When the construction is to be grouted, these requirements are waived or decreased.

Permissible variations in dimensions: To ensure that the coursing of units falls within a modular dimension, tolerances are placed on the overall dimensions of concrete masonry units. ASTM C 90 limits the permissible variations in overall dimensions to $\pm \frac{1}{8}$ inch (3.2 mm) from the specified dimensions. Figures 1B.1 through 1B.5 detail common configurations for 4, 6, 8, 10, and 12 inch (102, 152, 203, 254, and 305 mm) units, respectively. These figures only list a small percentage of available unit configurations. Ref. 1.19 *Concrete Masonry Shapes and Sizes Manual* includes numerous other unit configurations that may be available regionally.

Specified finish and appearance: To limit the extent of cracking and other such defects that may interfere with the proper placement or impair the strength of a concrete masonry element, as well as establish minimum aesthetic boundaries, the size and extent of chips and cracks are limited.

Additional information on the minimum material requirements for masonry construction can be found in the *Specification for Masonry Structures* (Ref. 1.9) and The Masonry Society's *Annotated Guide to Masonry Specifications* (Ref. 1.17).

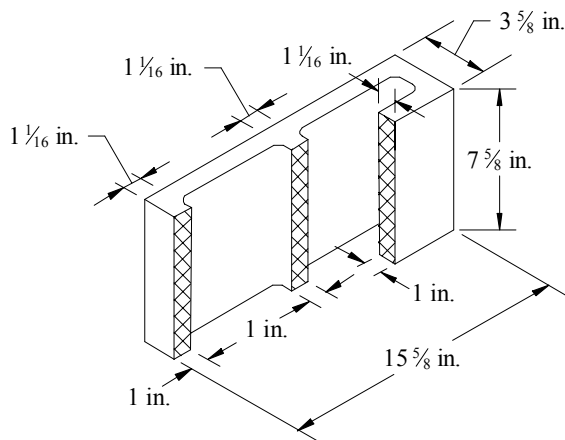
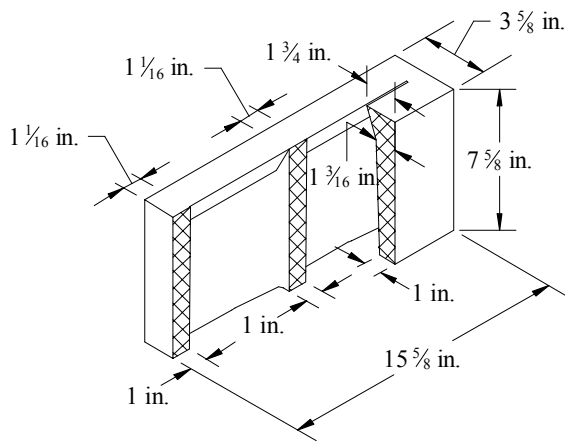
Specified Dimensions for 4 Inch (102 mm) Concrete Masonry Units

Typical dimensions for standard concrete masonry units of 4 inch (102 mm) nominal thickness are shown below. ASTM C 90 *Standard Specification for Loadbearing Concrete Masonry Units* (Ref. 1.4) includes requirements for minimum dimensions as follows:

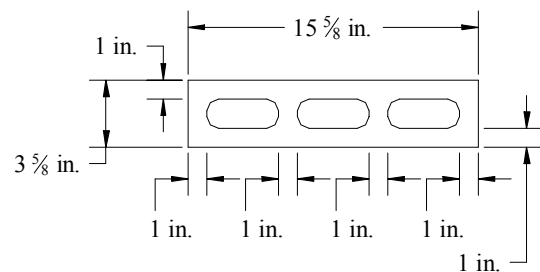
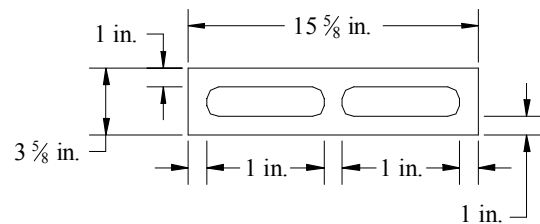
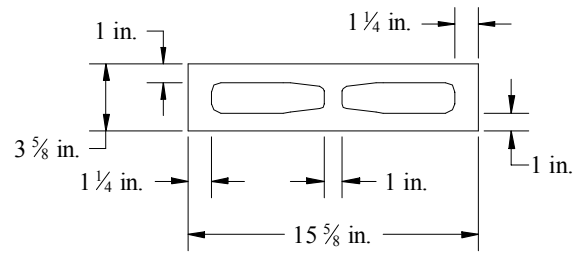
- Minimum face shell thickness = $\frac{3}{4}$ inch (19 mm)
- Minimum web thickness = $\frac{3}{4}$ inch (19 mm)
- Minimum equivalent web thickness = $1 \frac{5}{8}$ in./ft (136 mm/m)

These are minimum dimensions, and therefore may differ from the typical dimensions shown below. In addition, ASTM C 90 requires that no overall dimension (width, height or length) differ by more than $\pm \frac{1}{8}$ inch (3.2 mm) from the specified dimensions. This limitation on the variation in overall dimensions does not apply to the face shell or web thickness requirements.

Units shown below measure 4 x 8 x 16 inches (102 x 203 x 406 mm) nominally in width, height, and length, respectively. Other heights and lengths are available. While these figures show common sizes, unit configurations and dimensions may vary slightly by region and producer. Such variation is entirely suitable so long as the units conform to the dimensional limitations and tolerances specified by ASTM C 90.



Typical Drafts (Core Taper)



Typical Core Configurations

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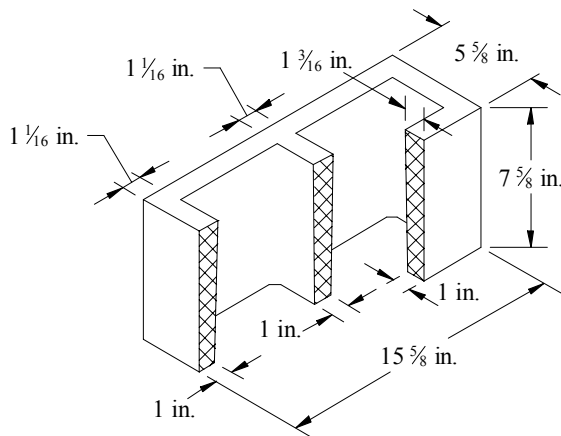
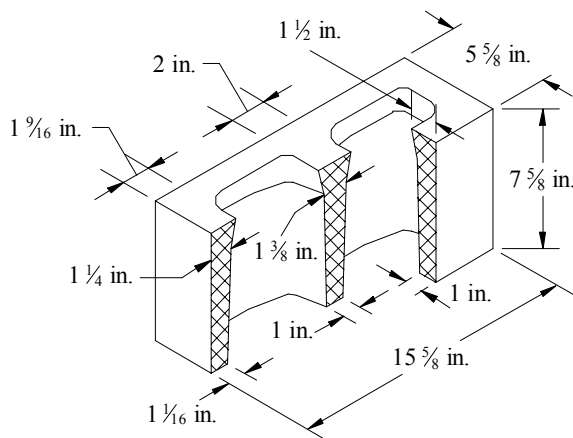
Specified Dimensions for 6 Inch (152 mm) Concrete Masonry Units

Typical dimensions for standard concrete masonry units of 6 inch (152 mm) nominal thickness are shown below. ASTM C 90 *Standard Specification for Loadbearing Concrete Masonry Units* (Ref. 1.4) includes requirements for minimum dimensions as follows:

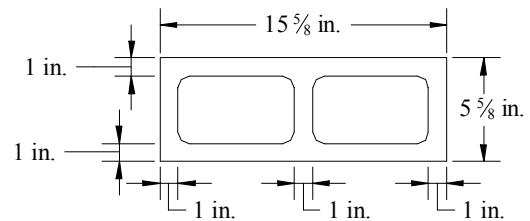
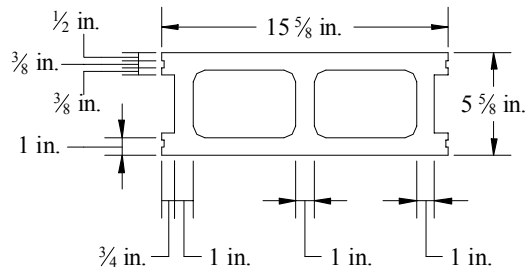
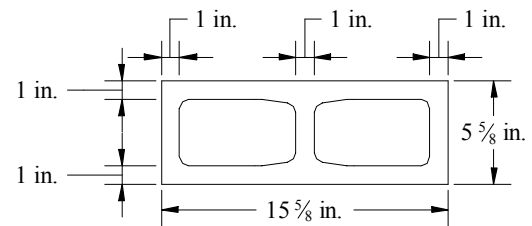
- Minimum face shell thickness = 1 inch (25 mm)
- Minimum web thickness = 1 inch (25 mm)
- Minimum equivalent web thickness = $2\frac{1}{4}$ in./ft (188 mm/m)

These are minimum dimensions, and therefore may differ from the typical dimensions shown below. In addition, ASTM C 90 requires that no overall dimension (width, height or length) differ by more than $\pm\frac{1}{8}$ inch (3.2 mm) from the specified dimensions. This limitation on the variation in overall dimensions does not apply to the face shell or web thickness requirements.

Units shown below measure 6 x 8 x 16 inches (152 x 203 x 406 mm) nominally in width, height, and length, respectively. Other heights and lengths are available. While these figures show common sizes, unit configurations and dimensions may vary slightly by region and producer. Such variation is entirely suitable so long as the units conform to the dimensional limitations and tolerances specified by ASTM C 90.



Typical Drafts (Core Taper)



Typical Core Configurations

Last Modified: October, 2002

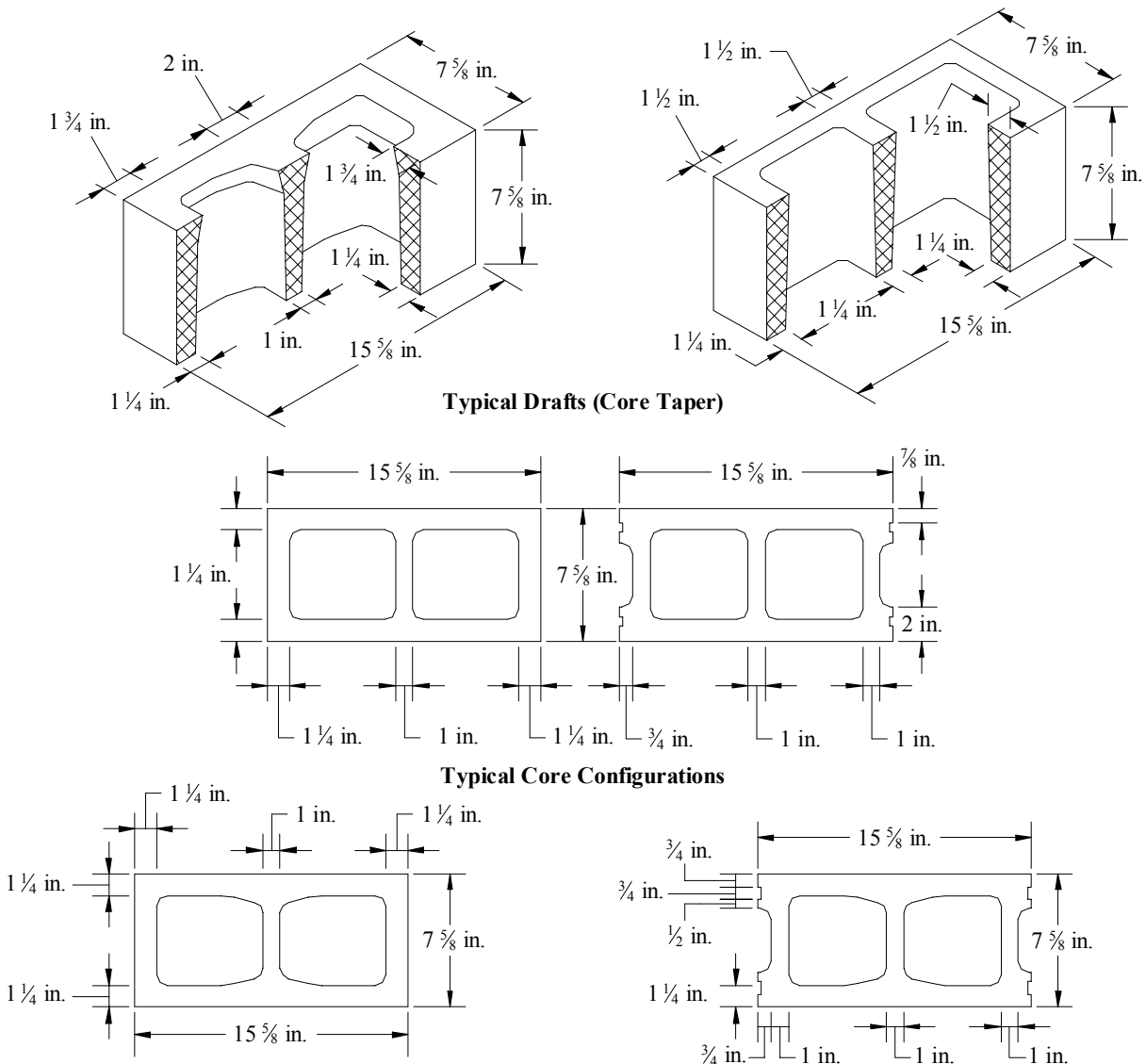
Specified Dimensions for 8 Inch (203 mm) Concrete Masonry Units

Typical dimensions for standard concrete masonry units of 8 inch (203 mm) nominal thickness are shown below. ASTM C 90 *Standard Specification for Loadbearing Concrete Masonry Units* (Ref. 1.4) includes requirements for minimum dimensions as follows:

- Minimum face shell thickness = 1 ¼ inch (32 mm)
- Minimum web thickness = 1 inch (25 mm)
- Minimum equivalent web thickness = 2 ¼ in./ft (188 mm/m)

These are minimum dimensions, and therefore may differ from the typical dimensions shown below. In addition, ASTM C 90 requires that no overall dimension (width, height or length) differ by more than ± ⅛ inch (3.2 mm) from the specified dimensions. This limitation on the variation in overall dimensions does not apply to the face shell or web thickness requirements.

Units shown below measure 8 x 8 x 16 inches (203 x 203 x 406 mm) nominally in width, height, and length, respectively. Other heights and lengths are available. While these figures show common sizes, unit configurations and dimensions may vary slightly by region and producer. Such variation is entirely suitable so long as the units conform to the dimensional limitations and tolerances specified by ASTM C 90.



Last Modified: October, 2002

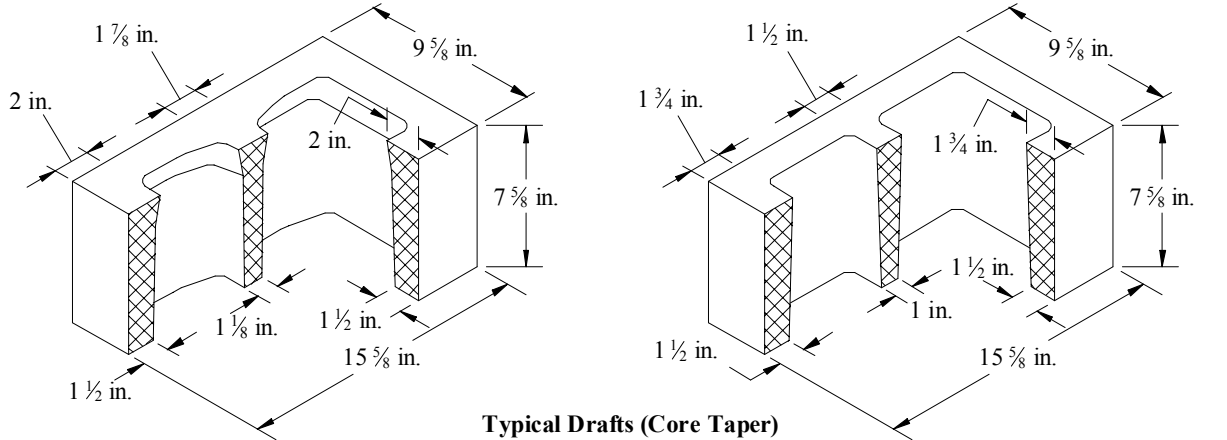
Specified Dimensions for 10 Inch (254 mm) Concrete Masonry Units

Typical dimensions for standard concrete masonry units of 10 inch (254 mm) nominal thickness are shown below. ASTM C 90 *Standard Specification for Loadbearing Concrete Masonry Units* (Ref. 1.4) includes requirements for minimum dimensions as follows:

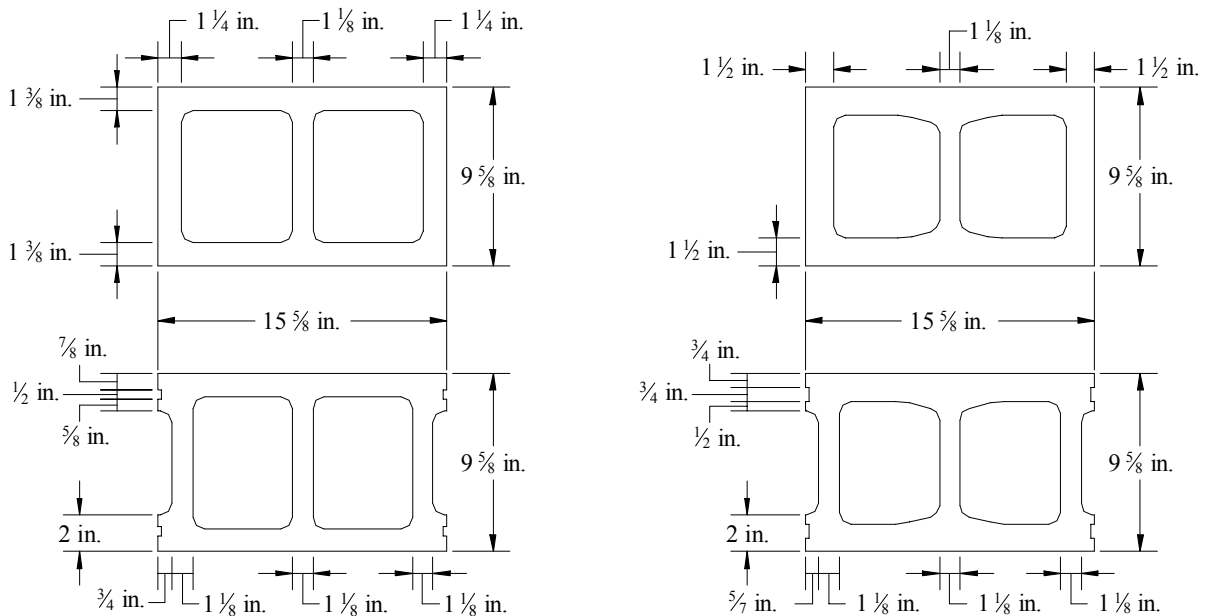
- Minimum face shell thickness = $1 \frac{3}{8}$ inch (35 mm) or $1 \frac{1}{4}$ inch (32 mm) if allowable loads are reduced
- Minimum web thickness = $1 \frac{1}{8}$ inch (29 mm)
- Minimum equivalent web thickness = $2 \frac{1}{2}$ in./ft (208 mm/m)

These are minimum dimensions, and therefore may differ from the typical dimensions shown below. In addition, ASTM C 90 requires that no overall dimension (width, height or length) differ by more than $\pm \frac{1}{8}$ inch (3.2 mm) from the specified dimensions. This limitation on the variation in overall dimensions does not apply to the face shell or web thickness requirements.

Units shown below measure 10 x 8 x 16 inches (254 x 203 x 406 mm) nominally in width, height, and length, respectively. Other heights and lengths are available. While these figures show common sizes, unit configurations and dimensions may vary slightly by region and producer. Such variation is entirely suitable so long as the units conform to the dimensional limitations and tolerances specified by ASTM C 90.



Typical Drafts (Core Taper)



Typical Core Configurations

Last Modified: October, 2002

Specified Dimensions for 12 Inch (305 mm) Concrete Masonry Units

Typical dimensions for standard concrete masonry units of 12 inch (305 mm) nominal thickness are shown below. ASTM C 90 *Standard Specification for Loadbearing Concrete Masonry Units* (Ref. 1.4) includes requirements for minimum dimensions as follows:

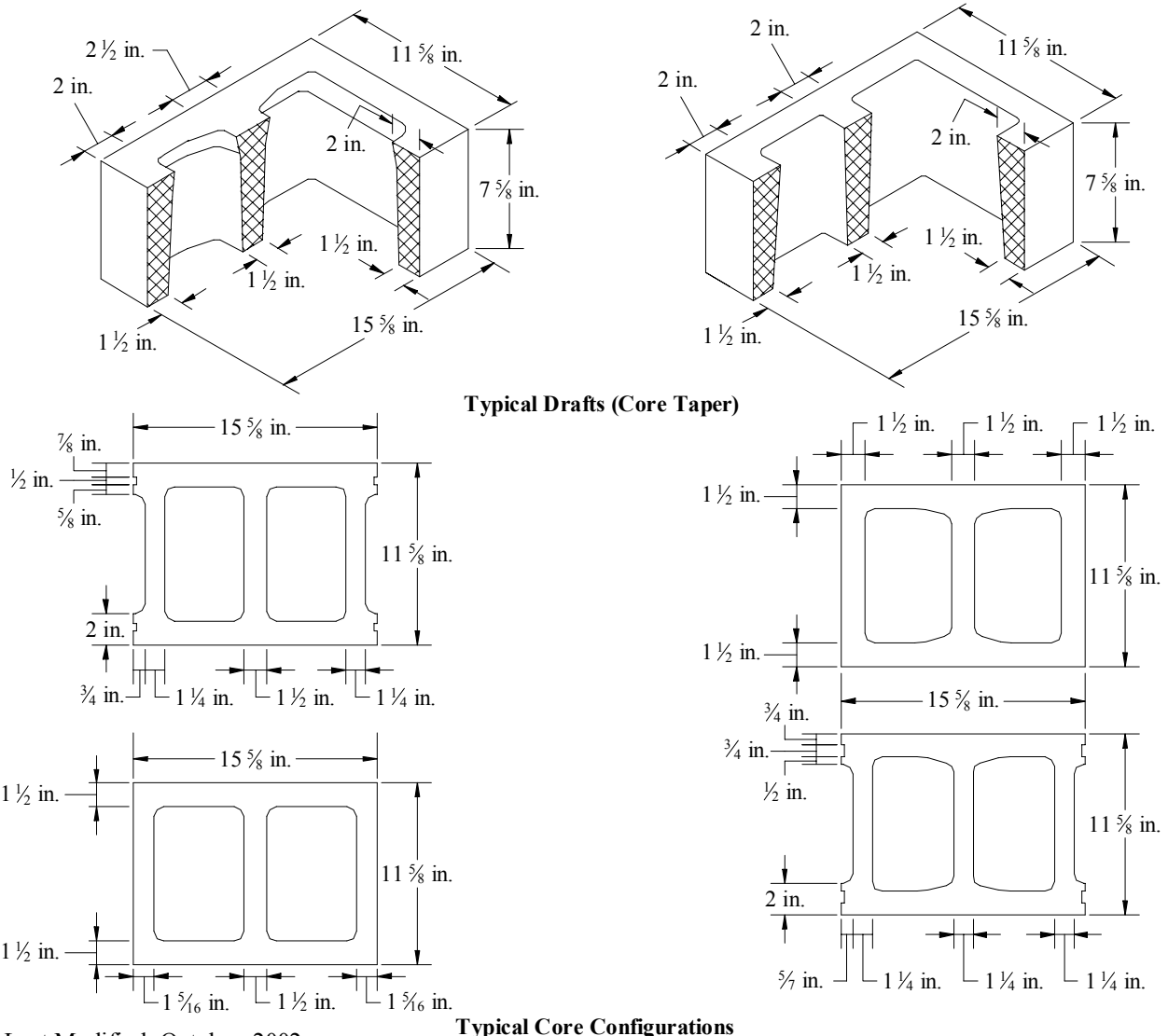
Minimum face shell thickness = 1 1/2 inch (38 mm) or 1 1/4 inch (32 mm) if allowable loads are reduced

Minimum web thickness = 1 1/8 inch (29 mm)

Minimum equivalent web thickness = 2 1/2 in./ft (208 mm/m)

These are minimum dimensions, and therefore may differ from the typical dimensions shown below. In addition, ASTM C 90 requires that no overall dimension (width, height or length) differ by more than ± 1/8 inch (3.2 mm) from the specified dimensions. This limitation on the variation in overall dimensions does not apply to the face shell or web thickness requirements.

Units shown below measure 12 x 8 x 16 inches (305 x 203 x 406 mm) nominally in width, height, and length, respectively. Other heights and lengths are available. While these figures show common sizes, unit configurations and dimensions may vary slightly by region and producer. Such variation is entirely suitable so long as the units conform to the dimensional limitations and tolerances specified by ASTM C 90.



Last Modified: October, 2002

Concrete Masonry Cross-Sectional Properties and Wall Weights

Many attributes of concrete masonry products are determined based on the weight of the actual construction or the cross-sectional properties of the element under consideration. Tables 1B.1 through 1B.10 list net and average cross-sectional properties for concrete masonry walls as well as wall weights for 4 through 12-inch (102 through 305 mm) single wythe walls. Assumptions used in determining these values include:

- Unit dimensions are based on the minimum requirements of ASTM C 90 (Ref. 1.4).
- Each unit is assumed to have square ends and two square cores.
- The nominal face dimensions of all units are 16 inches (406 mm) long and 8 inches (203 mm) high.
- The thickness of all mortar joints is assumed to be $\frac{3}{8}$ inch (9.5 mm).
- The depth of all mortar joints is assumed to be equal to the thickness of the face shell or web on which they are placed.
- Mortar density is taken equal to 125 lb/ft³ (2,000 kg/m³).
- Grout density is taken equal to 140 lb/ft³ (2,240 kg/m³).

The net cross-sectional properties are based on the minimum section within the element under consideration and are used for determining stress and strain resulting from load application. Average cross-sectional properties are calculated as the average cross-sectional properties of a given element throughout its height and are used for determining stiffness and deflection of an element.

Section properties and wall weights for grouted 4-inch (102 mm) concrete masonry walls are not provided. Because of the small core size and resulting difficulty in consolidating grout, these units are rarely grouted.

Table 1B.1 Horizontal Section Properties for 4 Inch (102 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Net Cross-Sectional Properties			Average Cross-Sectional Properties	
			A _n (in ² /ft)	I _n (in ⁴ /ft)	S _n (in ³ /ft)	I _{avg} (in ⁴ /ft)	r _{avg} (in.)
Hollow	None	Face shell	18.0	38.0	21.0	39.4	1.35
Hollow	None	Full	21.6	39.4	21.7	39.4	1.35
100% Solid	None	Full	43.5	47.6	26.3	47.6	1.05

Table 1B.2 Wall Weights for 4 Inch (102 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Wall Weight (lb/ft ²) for Concrete Unit Densities (lb/ft ³) of:					
			85	95	105	115	125	135
Hollow	None	Face shell	13	15	16	18	19	20
Hollow	None	Full	14	15	16	18	19	21
100% Solid	None	Full	27	30	33	35	38	41

Metric Conversions:

- Multiply in. by 25.4 to get mm
- Multiply in²/ft by 2,117 to get mm²/m
- Multiply in³/ft by 53,763 to get mm³/m
- Multiply in.⁴/ft by 1,365,588 to get mm⁴/m
- Multiply lb/ft² by 4.88 to get kg/m²
- Multiply lb/ft³ by 16.02 to get kg/m³

Table 1B.3 Horizontal Section Properties for 6 Inch (152 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Net Cross-Sectional Properties			Average Cross-Sectional Properties	
			A _n (in. ² /ft)	I _n (in. ⁴ /ft)	S _n (in. ³ /ft)	I _{avg} (in. ⁴ /ft)	r _{avg} (in.)
Hollow	None	Face shell	24.0	130.3	46.3	139.3	2.08
Hollow	None	Full	32.2	139.3	49.5	139.3	2.08
100% Solid	None	Full	67.5	178.0	63.3	178.0	1.62
Hollow	8 in.	Full	67.5	178.0	63.3	178.0	1.62
Hollow	16 in.	Face shell	46.6	155.1	55.1	158.1	1.79
Hollow	24 in.	Face shell	39.1	146.8	52.2	151.8	1.87
Hollow	32 in.	Face shell	35.3	142.7	50.7	148.7	1.91
Hollow	40 in.	Face shell	33.0	140.2	49.9	146.8	1.94
Hollow	48 in.	Face shell	31.5	138.6	49.3	145.5	1.96
Hollow	56 in.	Face shell	30.5	137.4	48.9	144.6	1.98
Hollow	64 in.	Face shell	29.7	136.5	48.5	144.0	1.99
Hollow	72 in.	Face shell	29.0	135.8	48.3	143.5	2.00
Hollow	80 in.	Face shell	28.5	135.3	48.1	143.0	2.00
Hollow	88 in.	Face shell	28.1	134.8	47.9	142.7	2.01
Hollow	96 in.	Face shell	27.8	134.5	47.8	142.4	2.02
Hollow	104 in.	Face shell	27.5	134.2	47.7	142.2	2.02
Hollow	112 in.	Face shell	27.2	133.9	47.6	142.0	2.03
Hollow	120 in.	Face shell	27.0	133.6	47.5	141.8	2.03

Table 1B.4 Wall Weights for 6 Inch (152 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Wall Weight (lb/ft ²) for Concrete Unit Densities (lb/ft ³) of:					
			85	95	105	115	125	135
Hollow	None	Face shell	20	22	24	26	28	30
Hollow	None	Full	20	22	24	26	28	31
100% Solid	None	Full	42	46	50	55	59	63
Hollow	8 in.	Full	53	56	58	60	62	64
Hollow	16 in.	Face shell	37	39	41	43	45	47
Hollow	24 in.	Face shell	31	33	35	37	39	41
Hollow	32 in.	Face shell	28	30	32	34	37	39
Hollow	40 in.	Face shell	26	29	31	33	35	37
Hollow	48 in.	Face shell	25	27	30	32	34	36
Hollow	56 in.	Face shell	25	27	29	31	33	35
Hollow	64 in.	Face shell	24	26	28	30	32	34
Hollow	72 in.	Face shell	23	26	28	30	32	34
Hollow	80 in.	Face shell	23	25	27	29	31	34
Hollow	88 in.	Face shell	23	25	27	29	31	33
Hollow	96 in.	Face shell	23	25	27	29	31	33
Hollow	104 in.	Face shell	22	24	27	29	31	33
Hollow	112 in.	Face shell	22	24	26	28	30	33
Hollow	120 in.	Face shell	22	24	26	28	30	32

Metric Conversions:

Multiply in. by 25.4 to get mm

Multiply in.²/ft by 2,117 to get mm²/m

Multiply in.³/ft by 53,763 to get mm³/m

Multiply in.⁴/ft by 1,365,588 to get mm⁴/m

Multiply lb/ft² by 4.88 to get kg/m²

Multiply lb/ft³ by 16.02 to get kg/m³

Last Modified: October, 2002

Table 1B.5 Horizontal Section Properties for 8 Inch (203 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Net Cross-Sectional Properties			Average Cross-Sectional Properties	
			A_n (in. ² /ft)	I_n (in. ⁴ /ft)	S_n (in. ³ /ft)	I_{avg} (in. ⁴ /ft)	r_{avg} (in.)
Hollow	None	Face shell	30.0	308.7	81.0	334.0	2.84
Hollow	None	Full	41.5	334.0	87.6	334.0	2.84
100% Solid	None	Full	91.5	443.3	116.3	443.3	2.20
Hollow	8 in.	Full	91.5	443.3	116.3	443.3	2.20
Hollow	16 in.	Face shell	62.0	378.6	99.3	387.1	2.43
Hollow	24 in.	Face shell	51.3	355.3	93.2	369.4	2.53
Hollow	32 in.	Face shell	46.0	343.7	90.1	360.5	2.59
Hollow	40 in.	Face shell	42.8	336.7	88.3	355.2	2.63
Hollow	48 in.	Face shell	40.7	332.0	87.1	351.7	2.66
Hollow	56 in.	Face shell	39.1	328.7	86.2	349.1	2.68
Hollow	64 in.	Face shell	38.0	326.2	85.6	347.2	2.70
Hollow	72 in.	Face shell	37.1	324.3	85.0	345.8	2.71
Hollow	80 in.	Face shell	36.4	322.7	84.6	344.6	2.73
Hollow	88 in.	Face shell	35.8	321.4	84.3	343.6	2.73
Hollow	96 in.	Face shell	35.3	320.4	84.0	342.8	2.74
Hollow	104 in.	Face shell	34.9	319.5	83.8	342.1	2.75
Hollow	112 in.	Face shell	34.6	318.7	83.6	341.5	2.76
Hollow	120 in.	Face shell	34.3	318.0	83.4	341.0	2.76

Table 1B.6 Wall Weights for 8 Inch (203 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Wall Weight (lb/ft ²) for Concrete Unit Densities (lb/ft ³) of:					
			85	95	105	115	125	135
Hollow	None	Face shell	25	28	31	33	36	39
Hollow	None	Full	26	28	31	34	37	39
100% Solid	None	Full	56	62	68	74	80	86
Hollow	8 in.	Full	73	76	78	81	84	86
Hollow	16 in.	Face shell	49	52	55	57	60	63
Hollow	24 in.	Face shell	41	44	47	49	52	55
Hollow	32 in.	Face shell	37	40	43	45	48	51
Hollow	40 in.	Face shell	35	38	40	43	46	48
Hollow	48 in.	Face shell	33	36	39	41	44	47
Hollow	56 in.	Face shell	32	35	38	40	43	46
Hollow	64 in.	Face shell	31	34	37	39	42	45
Hollow	72 in.	Face shell	31	33	36	39	41	44
Hollow	80 in.	Face shell	30	33	35	38	41	44
Hollow	88 in.	Face shell	30	32	35	38	40	43
Hollow	96 in.	Face shell	29	32	35	37	40	43
Hollow	104 in.	Face shell	29	32	34	37	40	42
Hollow	112 in.	Face shell	29	31	34	37	39	42
Hollow	120 in.	Face shell	28	31	34	37	39	42

Metric Conversions:

Multiply in. by 25.4 to get mm

Multiply in.²/ft by 2,117 to get mm²/m

Multiply in.³/ft by 53,763 to get mm³/m

Multiply in.⁴/ft by 1,365,588 to get mm⁴/m

Multiply lb/ft² by 4.88 to get kg/m²

Multiply lb/ft³ by 16.02 to get kg/m³

Last Modified: October, 2002

Table 1B.7 Horizontal Section Properties for 10 Inch (254 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Net Cross-Sectional Properties			Average Cross-Sectional Properties	
			A_n (in. ² /ft)	I_n (in. ⁴ /ft)	S_n (in. ³ /ft)	I_{avg} (in. ⁴ /ft)	r_{avg} (in.)
Hollow	None	Face shell	33.0	566.7	117.8	635.3	3.55
Hollow	None	Full	50.4	635.3	132.0	635.3	3.55
100% Solid	None	Full	115.5	891.7	185.3	891.7	2.78
Hollow	8 in.	Full	115.5	891.7	185.3	891.7	2.78
Hollow	16 in.	Face shell	76.2	736.8	153.1	759.7	3.04
Hollow	24 in.	Face shell	61.8	680.1	141.3	718.2	3.17
Hollow	32 in.	Face shell	54.6	651.8	135.4	697.5	3.25
Hollow	40 in.	Face shell	50.3	634.8	131.9	685.0	3.30
Hollow	48 in.	Face shell	47.4	623.4	129.5	676.7	3.33
Hollow	56 in.	Face shell	45.3	615.3	127.9	670.8	3.36
Hollow	64 in.	Face shell	43.8	609.2	126.6	666.4	3.38
Hollow	72 in.	Face shell	42.6	604.5	125.6	662.9	3.40
Hollow	80 in.	Face shell	41.6	600.7	124.8	660.1	3.41
Hollow	88 in.	Face shell	40.9	597.6	124.2	657.9	3.42
Hollow	96 in.	Face shell	40.2	595.1	123.6	656.0	3.43
Hollow	104 in.	Face shell	39.6	592.9	123.2	654.4	3.44
Hollow	112 in.	Face shell	39.2	591.0	122.8	653.0	3.45
Hollow	120 in.	Face shell	38.8	589.4	122.5	651.8	3.45

Table 1B.8 Wall Weights for 10 Inch (254 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Wall Weight (lb/ft ²) for Concrete Unit Densities (lb/ft ³) of:					
			85	95	105	115	125	135
Hollow	None	Face shell	30	34	37	40	44	47
Hollow	None	Full	31	34	38	41	44	48
100% Solid	None	Full	71	78	86	93	101	108
Hollow	8 in.	Full	93	96	99	102	106	109
Hollow	16 in.	Face shell	62	65	68	71	75	78
Hollow	24 in.	Face shell	51	54	58	61	64	68
Hollow	32 in.	Face shell	46	49	53	56	59	62
Hollow	40 in.	Face shell	43	46	49	53	56	59
Hollow	48 in.	Face shell	41	44	47	51	54	57
Hollow	56 in.	Face shell	39	43	46	49	52	56
Hollow	64 in.	Face shell	38	41	45	48	51	55
Hollow	72 in.	Face shell	37	41	44	47	50	54
Hollow	80 in.	Face shell	37	40	43	46	50	53
Hollow	88 in.	Face shell	36	39	43	46	49	52
Hollow	96 in.	Face shell	36	39	42	45	49	52
Hollow	104 in.	Face shell	35	38	42	45	48	52
Hollow	112 in.	Face shell	35	38	41	45	48	51
Hollow	120 in.	Face shell	35	38	41	44	48	51

Metric Conversions:

Multiply in. by 25.4 to get mm

Multiply in.²/ft by 2,117 to get mm²/m

Multiply in.³/ft by 53,763 to get mm³/m

Multiply in.⁴/ft by 1,365,588 to get mm⁴/m

Multiply lb/ft² by 4.88 to get kg/m²

Multiply lb/ft³ by 16.02 to get kg/m³

Last Modified: October, 2002

Table 1B.9 Horizontal Section Properties for 12 Inch (305 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Net Cross-Sectional Properties			Average Cross-Sectional Properties	
			A_n (in ² /ft)	I_n (in ⁴ /ft)	S_n (in ³ /ft)	I_{avg} (in ⁴ /ft)	r_{avg} (in.)
Hollow	None	Face shell	36.0	929.4	159.9	1,064.7	4.29
Hollow	None	Full	57.8	1,064.7	183.2	1,064.7	4.29
100% Solid	None	Full	139.5	1,571.0	270.3	1,571.0	3.36
Hollow	8 in.	Full	139.5	1,571.0	270.3	1,571.0	3.36
Hollow	16 in.	Face shell	90.2	1,265.2	217.7	1,310.4	3.67
Hollow	24 in.	Face shell	72.1	1,153.3	198.4	1,228.5	3.82
Hollow	32 in.	Face shell	63.1	1,097.3	188.8	1,187.5	3.91
Hollow	40 in.	Face shell	57.7	1,063.7	183.0	1,163.0	3.97
Hollow	48 in.	Face shell	54.1	1,041.3	179.2	1,146.6	4.02
Hollow	56 in.	Face shell	51.5	1,025.3	176.4	1,134.9	4.05
Hollow	64 in.	Face shell	49.5	1,013.4	174.3	1,126.1	4.08
Hollow	72 in.	Face shell	48.0	1,004.0	172.7	1,119.3	4.10
Hollow	80 in.	Face shell	46.8	996.6	171.5	1,113.9	4.12
Hollow	88 in.	Face shell	45.9	990.5	170.4	1,109.4	4.13
Hollow	96 in.	Face shell	45.0	985.4	169.5	1,105.7	4.14
Hollow	104 in.	Face shell	44.3	981.1	168.8	1,102.5	4.15
Hollow	112 in.	Face shell	43.7	977.4	168.1	1,099.8	4.16
Hollow	120 in.	Face shell	43.2	974.2	167.6	1,097.5	4.17

Table 1B.10 Wall Weights for 12 Inch (305 mm) Single Wythe Walls

Wall Construction	Grout Spacing	Mortar Bedding	Wall Weight (lb/ft ²) for Concrete Unit Densities (lb/ft ³) of:					
			85	95	105	115	125	135
Hollow	None	Face shell	35	38	42	46	50	54
Hollow	None	Full	36	39	43	47	51	54
100% Solid	None	Full	86	95	104	113	122	131
Hollow	8 in.	Full	113	116	120	124	128	132
Hollow	16 in.	Face shell	74	78	81	85	89	93
Hollow	24 in.	Face shell	61	65	68	72	76	80
Hollow	32 in.	Face shell	54	58	62	66	69	73
Hollow	40 in.	Face shell	50	54	58	62	65	69
Hollow	48 in.	Face shell	48	52	55	59	63	67
Hollow	56 in.	Face shell	46	50	53	57	61	65
Hollow	64 in.	Face shell	45	48	52	56	60	63
Hollow	72 in.	Face shell	43	47	51	55	59	62
Hollow	80 in.	Face shell	43	46	50	54	58	61
Hollow	88 in.	Face shell	42	46	49	53	57	61
Hollow	96 in.	Face shell	41	45	49	53	56	60
Hollow	104 in.	Face shell	41	45	48	52	56	60
Hollow	112 in.	Face shell	40	44	48	52	55	59
Hollow	120 in.	Face shell	40	44	47	51	55	59

Metric Conversions:

Multiply in. by 25.4 to get mm

Multiply in²/ft by 2,117 to get mm²/m

Multiply in³/ft by 53,763 to get mm³/m

Multiply in⁴/ft by 1,365,588 to get mm⁴/m

Multiply lb/ft² by 4.88 to get kg/m²

Multiply lb/ft³ by 16.02 to get kg/m³

Last Modified: October, 2002

SECTION 1C - QUALITY ASSURANCE TESTING

The following provides a brief overview of the aspects that should be considered in the development of a quality assurance plan. For further information, *Inspection of Concrete Masonry Construction* (Ref. 1.16) contains a detailed review of building code requirements as related to pre-construction evaluation, on-site inspection, material properties, construction tolerances, grouting and quality assurance checklists.

The Quality Assurance Plan

The success of a construction project depends in part on strict adherence to contract documents, plans and specifications, which is facilitated by establishing a comprehensive quality assurance program at the onset of a project. A quality assurance plan is the administrative and procedural requirements set up by the architect or engineer to assure the owner that the project complies with the contract documents. It includes the owner's policy statement and describes the scope of work, organizational relationships and the quality objectives for the project.

Provisions for quality construction include structural details, water penetration resistance, energy efficiency, the desired aesthetics and possibly other areas as well. Because building codes are typically limited to life safety concerns, published quality assurance requirements, such as those summarized below, focus on ensuring minimal structural performance. Hence, the designer should add other provisions as necessary for the specific project.

Building Code Requirements for Masonry Structures (ACI 530/ASCE 5/TMS 402) (Ref. 1.8) and *Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602) (Ref. 1.9) includes three levels of quality assurance and inspection as outlined below:

Level 1: Level 1 quality assurance, the least stringent program, requires a verification that masonry materials comply with the approved submittals. This quality assurance program applies to empirically designed masonry, glass unit masonry and masonry veneer used in nonessential facilities.

Level 2: Level 2 quality assurance requires periodic inspection and certification of material properties prior to construction. It applies to masonry used in non-essential facilities requiring engineering design and to empirically designed masonry, glass unit masonry and masonry veneer used in essential facilities. Essential facilities are those that must be operational at all times, such as hospitals, fire stations and police stations. Key inspection items include verifying that required reinforcing steel, anchors, ties and connectors are in place and that appropriate grouting procedures are used.

Level 3: Level 3 quality assurance is the most stringent program, requiring continuous inspection and material evaluation. This quality assurance program applies to masonry used in essential facilities that is required to be designed by engineered methods.

Materials Testing and Evaluation

The strength of units, mortar, grout and reinforcement independently and compositely have a significant influence on the resulting strength of the masonry assemblage. Material testing may be necessary before, during, or after construction to verify compliance with the contract documents. When testing is required, the following test methods are used to evaluate given properties of masonry materials.

Concrete masonry units: *Standard Test Methods of Sampling and Testing Concrete Masonry Units and Related Units*, ASTM C 140 (Ref. 1.10) is used to ensure compliance with the applicable unit specification. ASTM C 140 contains procedures for sampling and testing to determine compressive strength, absorption, density, dimensions, cross-sectional area, moisture content and equivalent thickness, among other properties.

Mortar: *Standard Specification for Mortar for Unit Masonry*, ASTM C 270 (Ref. 1.11) covers requirements for selection, quantity and use of specified ingredients in masonry mortar. Compliance is demonstrated by either of two alternative methods; proportion or property specification. When neither proportion nor property specification is specified, the proportion specification governs. The proportion specification prescribes a range of proportions by volume of cementitious materials and aggregates for each of the different mortar types. Physical testing of the mortar is not required to demonstrate compliance with the proportion specifications. The property specification requires testing of laboratory prepared mortar to demonstrate compliance with a specified minimum compressive strength, minimum water retention and maximum air content. With either method, *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry*, ASTM C 780 (Ref. 1.12) may be used as a quality control measure to ensure a consistent product throughout construction. ASTM C 780 contains test methods for determining consistency (as determined by cone penetration, retention test and modified concrete penetrometer), aggregate ratio, water content, air content, compressive strength and splitting tensile strength. Probably the most frequently used test of ASTM C 780 is the evaluation of compressive strength of field prepared mortar. However, when such testing is conducted, the results should not be compared to the minimum compressive strength of laboratory prepared mortar of ASTM C 270. The appendixes of ASTM C 270 and the annexes of ASTM C 780 provide a detailed discussion covering the use and evaluation of mortar materials.

Grout: *Standard Specification for Grout for Masonry*, ASTM C 476 (Ref. 1.13) allows grout (as with mortar) to be specified by either a proportion specification or by strength requirements. When the proportion specification is specified, grout testing is not required. However, when a minimum compressive strength is specified, the procedures outlined in *Standard Test Method for Sampling and Testing Grout*, ASTM C 1019 (Ref. 1.14) are used for the sampling and compression testing of grout.

Prisms: Compliance with the specified compressive strength of masonry, f'_m , is determined using one of two methods, the unit strength method or the prism test method. When the prism test method is used, *Standard Test Method for Compressive Strength of Masonry Prisms*, ASTM C 1314 (Ref. 1.15) covers prism construction, transporting, curing and testing. The unit strength method correlates the compressive strength of the masonry to the compressive strength of the units and the type of mortar used in construction as outlined in Ref. 1.9. The unit strength option alleviates the need and expense of constructing and testing masonry prisms.

SECTION 1D - CONSTRUCTION TOLERANCES

Virtually all construction materials are manufactured to a specified tolerance. Likewise, nearly all structures incorporating such building components are required to be constructed to a specified tolerance. Masonry structures and the materials used in their construction are no different. While Section 1B details the manufacturing tolerances for masonry units, this section outlines the permissible tolerances for masonry structures. Because masonry is often used as an exposed construction material, it is subjected to tighter tolerances than typically associated with other structural systems that are normally hidden when construction is complete.

Unless otherwise specified in the contract documents, the tolerances for the placement of masonry elements are outlined in *Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602) (Ref. 1.9). While the intent of the construction and placement tolerances contained within *Specification for Masonry Structures* is to safeguard structural performance and not achieve any aesthetic criterion, the stipulated values are often regarded as more than adequate for aesthetic purposes.

Tighter tolerances may be required in the project documents to ensure the final overall appearance of the masonry is acceptable. However, it should be cautioned that using more stringent construction tolerances could significantly complicate the job and increase the cost of construction. While maintaining tight construction tolerances may be aesthetically desirable, it must be recognized that factors such as the condition of previous construction and modular coordination of the project may require the mason to vary the masonry construction slightly from the intended plans or specifications.

The details of this section outline the tolerance requirements contained within ACI 530.1/ASCE 6/TMS 602 (Ref. 1.9) for mortar joints, alignment, location of elements and placement of reinforcement. Further information on construction tolerances can be found in *Inspection of Concrete Masonry Construction* (Ref. 1.16).

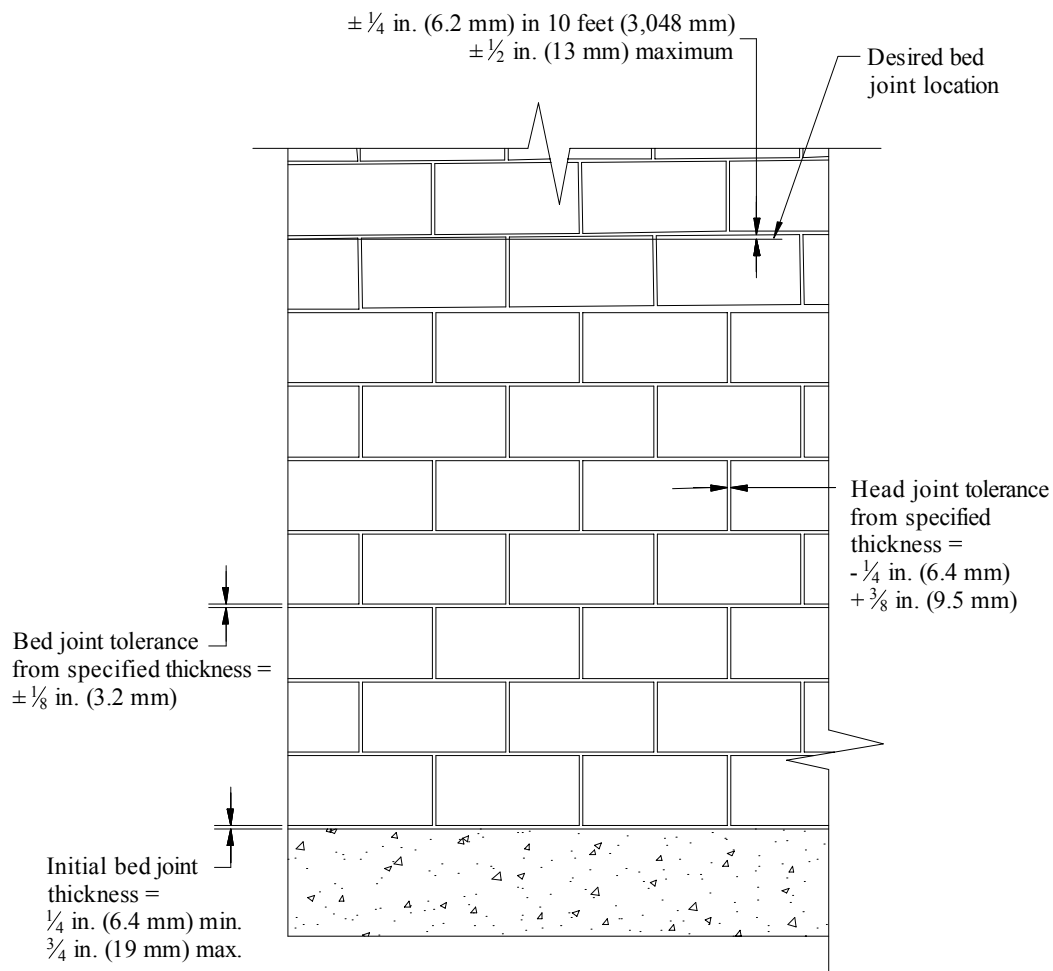
ACI 530.1/ASCE 6/TMS 602 Mortar Joint Tolerances

Although primarily aesthetic, significant variations in mortar joint thicknesses can result in poor structural performance. The following tolerances imposed by the *Specification for Masonry Structures* (Ref. 1.9) are intended, in part, to ensure structural performance is not compromised.

Mortar bed joints, typically $\frac{3}{8}$ inch (9.5 mm) thick for concrete masonry construction, are permitted to vary by $\pm \frac{1}{8}$ inch (3.2 mm) in thickness. The exception to this is with the initial bed joint between the top of the footing and the first course of masonry, which may vary in thickness from $\frac{1}{4}$ to $\frac{3}{4}$ inch (6.4 to 19 mm) to accommodate variations in the top of the footing.

Head joint thickness may vary by $-\frac{1}{4}$ inch (6.4 mm) to $+\frac{3}{8}$ inch (9.5 mm). Thus, for a specified joint thickness of $\frac{3}{8}$ inch (9.5 mm), the head joint thickness may vary from a minimum thickness of $\frac{1}{8}$ inch (3.2 mm) to a maximum thickness of $\frac{3}{4}$ inch (19 mm).

Although bed joints should be constructed level, they are permitted to vary by $\pm \frac{1}{2}$ inch (13 mm) maximum from level provided the joint does not slope more than $\pm \frac{1}{4}$ inch (6.4 mm) in 10 feet (3,048 mm). This requirement also applies to the top surface of bearing walls.



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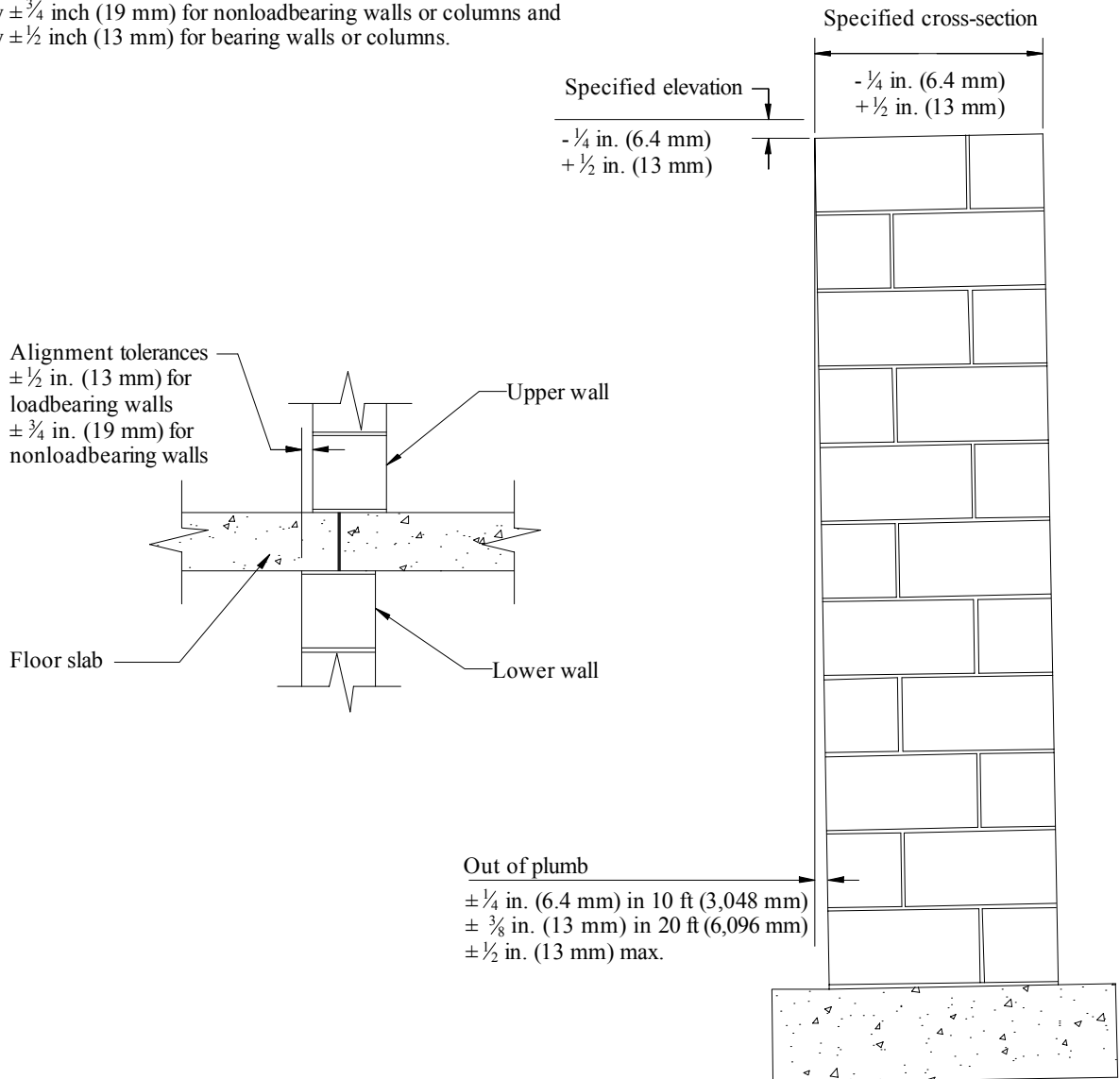
ACI 530.1/ASCE 6/TMS 602 Alignment Tolerance

The *Specification for Masonry Structures* (Ref. 1.9) establishes alignment and out-of-plumb tolerances primarily to ensure structural performance. In these cases, the intention is to limit the eccentricity of applied loads, and thereby not reduce the load carrying capacity of a given element.

Walls, columns, and other masonry building elements are required to be constructed to within $-\frac{1}{4}$ inch (6.4 mm) or $+\frac{1}{2}$ inch (13 mm) from the specified dimensions in cross-section and elevation.

Masonry walls, columns and other building elements may not vary from plumb by more than $\pm\frac{1}{2}$ inch (13 mm) maximum, while maintaining a slope of less than $\pm\frac{1}{4}$ inch (6.4 mm) in 10 feet (3,048 mm) and $\pm\frac{3}{8}$ inch (9.5 mm) in 20 feet (6,096 mm). Masonry building elements should also maintain true to a line within these same tolerances.

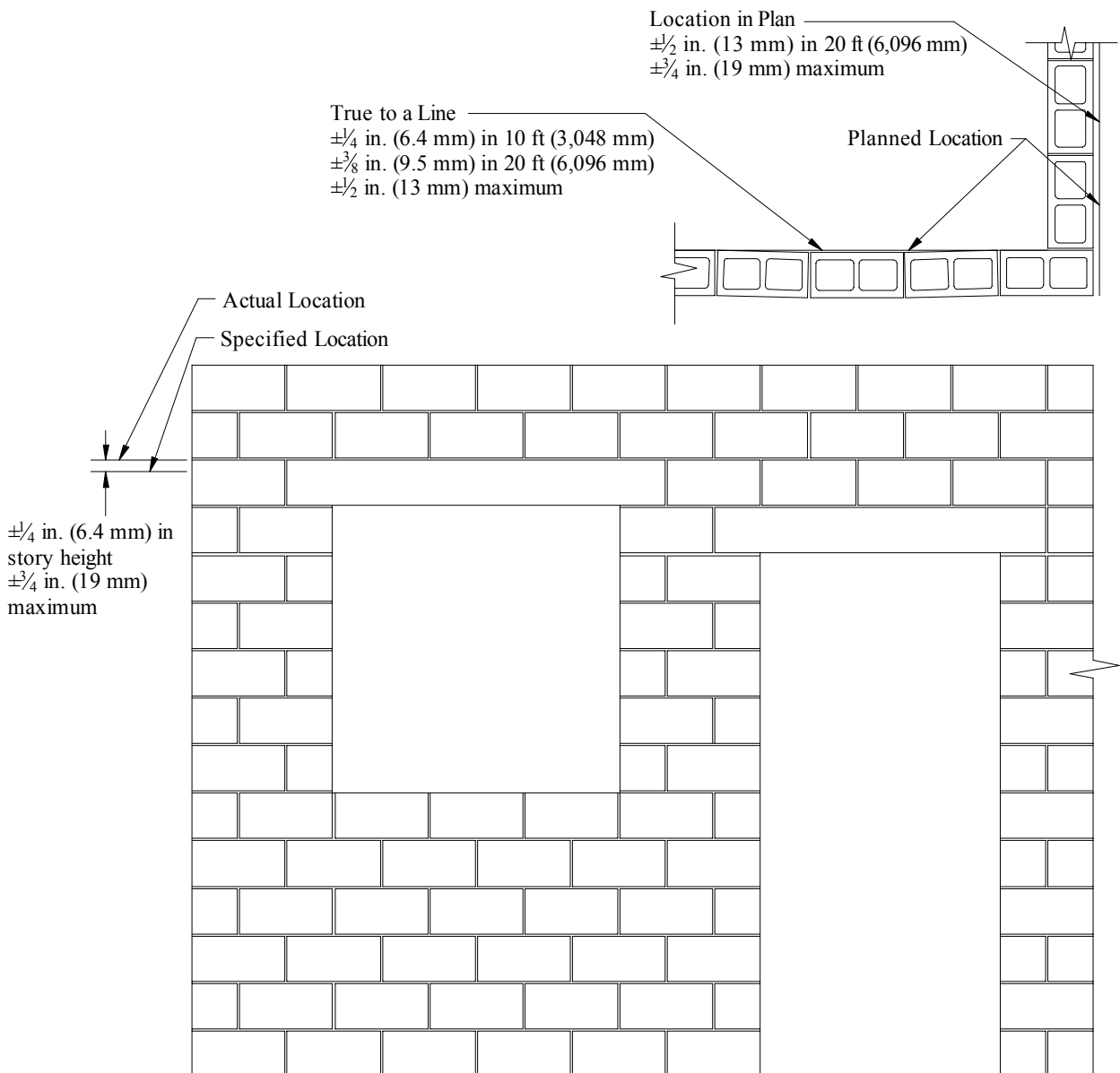
Columns and walls continuing from one story to another may vary in alignment by $\pm\frac{3}{4}$ inch (19 mm) for nonloadbearing walls or columns and by $\pm\frac{1}{2}$ inch (13 mm) for bearing walls or columns.



ACI 530.1/ASCE 6/TMS 602 Tolerances for Locating Elements

For continuity of construction and to facilitate the connection of discrete elements, the *Specification for Masonry Structures* (Ref. 1.9) requires masonry members to be located within a maximum distance of $\pm 3/4$ inch (19 mm), not exceeding $\pm 1/2$ inch (13 mm) in 20 feet (6,096 mm), from their intended location in plan. Such tolerances also minimize unanticipated eccentricity of axial loads.

Masonry building elements must also be located within $\pm 1/4$ inch (6.4 mm) per story height without exceeding $\pm 3/4$ inch (19 mm) maximum. This requirement would apply not only to the top of walls or other vertical assemblies, but also to discrete elements within an assembly such as lintels and bond beams.



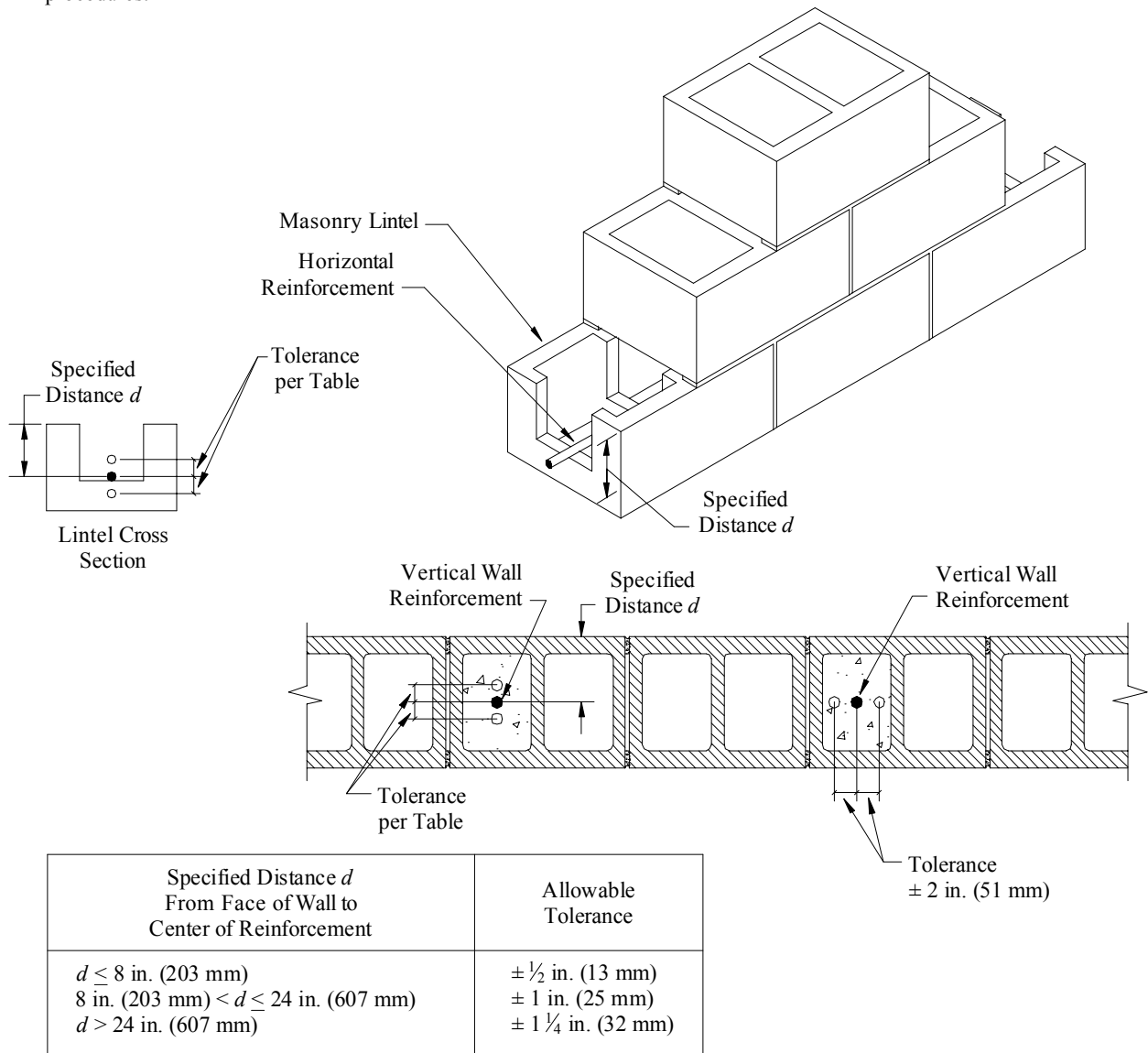
Last Modified: October, 2002

ACI 530.1/ASCE 6/TSM 602 Placement Tolerances for Reinforcement

In accordance with the *Specification for Masonry Structures* (Ref. 1.9), the tolerance for the placement of reinforcement in walls and other flexural elements is $\pm \frac{1}{2}$ inch (13 mm) when the specified distance (d), measured from the centerline of the reinforcement to the opposite compression face of the masonry, is 8 inches (203 mm) or less. The tolerance increases to ± 1 inch (25 mm) for d equal to 24 inches (610 mm) or less but greater than 8 inches (203 mm). For d greater than 24 inches (610 mm), the tolerance for the placement of reinforcement is $\pm 1 \frac{1}{4}$ inches (32 mm).

Vertical bars must be placed within 2 inches (51 mm) of their specified location measured parallel to the length of the wall for all applications. The placement tolerances for such reinforcement are larger because slight deviations from specified locations have a negligible impact on the structural performance of an assemblage.

To facilitate the placement of reinforcement and achieve the required placement tolerances, reinforcing bar positioners may be used for both horizontal and vertical reinforcement, although bar positioners may hinder high lift grouting procedures.

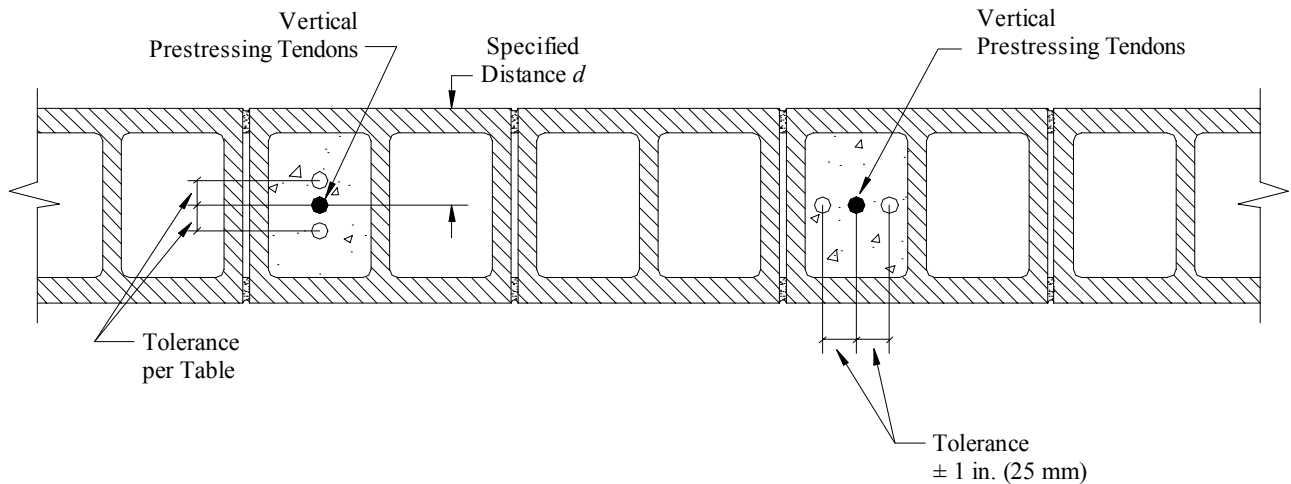


Last Modified: October, 2002

ACI 530.1/ASCE 6/TSM 602 Placement Tolerances for Prestressing Tendons

In accordance with the *Specification for Masonry Structures* (Ref. 1.9), the tolerance for the placement of prestressing tendons in walls and other flexural elements is $\pm \frac{1}{4}$ inch (6.4 mm) when the specified distance (d), measured from the centerline of the reinforcement to the opposite compression face of the masonry, is less than 8 inches (203 mm). The tolerance increases to $\pm \frac{3}{8}$ inch (9.5 mm) for d greater than or equal to 8 inches (203 mm).

Vertical tendons must be placed within 1 inch (25 mm) of their specified location measured parallel to the length of the wall for all applications. The placement tolerances for such prestressing tendons are larger because slight deviations from specified locations have a negligible impact on the structural performance of an assemblage.



Specified Distance d From Face of Wall to Center of Prestressing Tendons	Allowable Tolerance
$d < 8$ in. (203 mm)	$\pm \frac{1}{4}$ in. (6.4 mm)
$d \geq 8$ in. (203 mm)	$\pm \frac{3}{8}$ in. (9.5 mm)

SECTION 1E - CODE DETAILING REQUIREMENTS

The *Building Code Requirements for Masonry Structures* (Ref. 1.8) contains several prescriptive detailing requirements for masonry assemblages and structures pertaining to a wide range of design applications and configurations. While each requirement differs in function, their purpose is consistent; to secure a desired level of anticipated performance.

To facilitate interpretation of the prescriptive Code requirements, several figures have been generated based on the requirements of the 2002 edition of the ACI 530/ASCE 5/TMS 402. The figure number, a short description, and the pertinent Code (Ref. 1.8) section number follows:

- Figure 1E.1 - Intersecting Walls (Section 1.9.4)
- Figure 1E.2 - Size of Reinforcement (Section 1.12.2)
- Figure 1E.3 - Strength Design Size of Reinforcement (Section 3.2.3)
- Figure 1E.4 - Placement of Reinforcement (Section 1.12.3)
- Figure 1E.5 - Protection of Reinforcement (Section 1.12.4)
- Figure 1E.6 - Standard Hooks and Bends (Section 1.12.5)
- Figure 1E.7 - Detailed Plain Shear Walls (Section 1.13.2.2.2)
- Figure 1E.8 - Ordinary Reinforced Shear Walls (Section 1.13.2.2.3)
- Figure 1E.9 - Intermediate Reinforced Shear Walls (Section 1.13.2.2.4)
- Figure 1E.10 - Special Reinforced Shear Walls (Section 1.13.2.2.5)
- Figure 1E.11 - Seismic Detailing of Partition Walls (Section 1.13.5.2)
- Figure 1E.12 - Masonry Columns (Sections 1.13.6 and 2.1.6)
- Figure 1E.13 - Anchored Veneer General Details (Section 6.1.5)
- Figure 1E.14 - Anchored Veneer Support (Section 6.2.2.3)
- Figure 1E.15 - Anchored Veneer Anchors (Section 6.2.2.5)
- Figure 1E.16 - Anchored Veneer Installation (Sections 6.2.2.6, 6.2.2.7, and 6.2.2.8)
- Figure 1E.17 - Anchored Veneer Seismic Detailing (Section 6.2.2.10)
- Figure 1E.18 - Adhered Veneer General Details (Section 6.3.2)
- Figure 1E.19 - Composite Masonry (Section 2.1.5.2)
- Figure 1E.20 - Noncomposite Masonry (Section 2.1.5.3)
- Figure 1E.21 - Stack Bond Construction Details (Section 1.11)

A detailed review of the provisions combined with design applications for both the *Building Code Requirements for Masonry Structures* (Ref. 1.8) and *Specification for Masonry Structures* (Ref. 1.9) is provided in the *Masonry Designers' Guide* (Ref. 1.20). The *Masonry Designers' Guide* provides a thorough review and interpretation of the national masonry design and construction provisions.

ACI 530/ASCE 5/TMS 402 Intersecting Wall Provisions

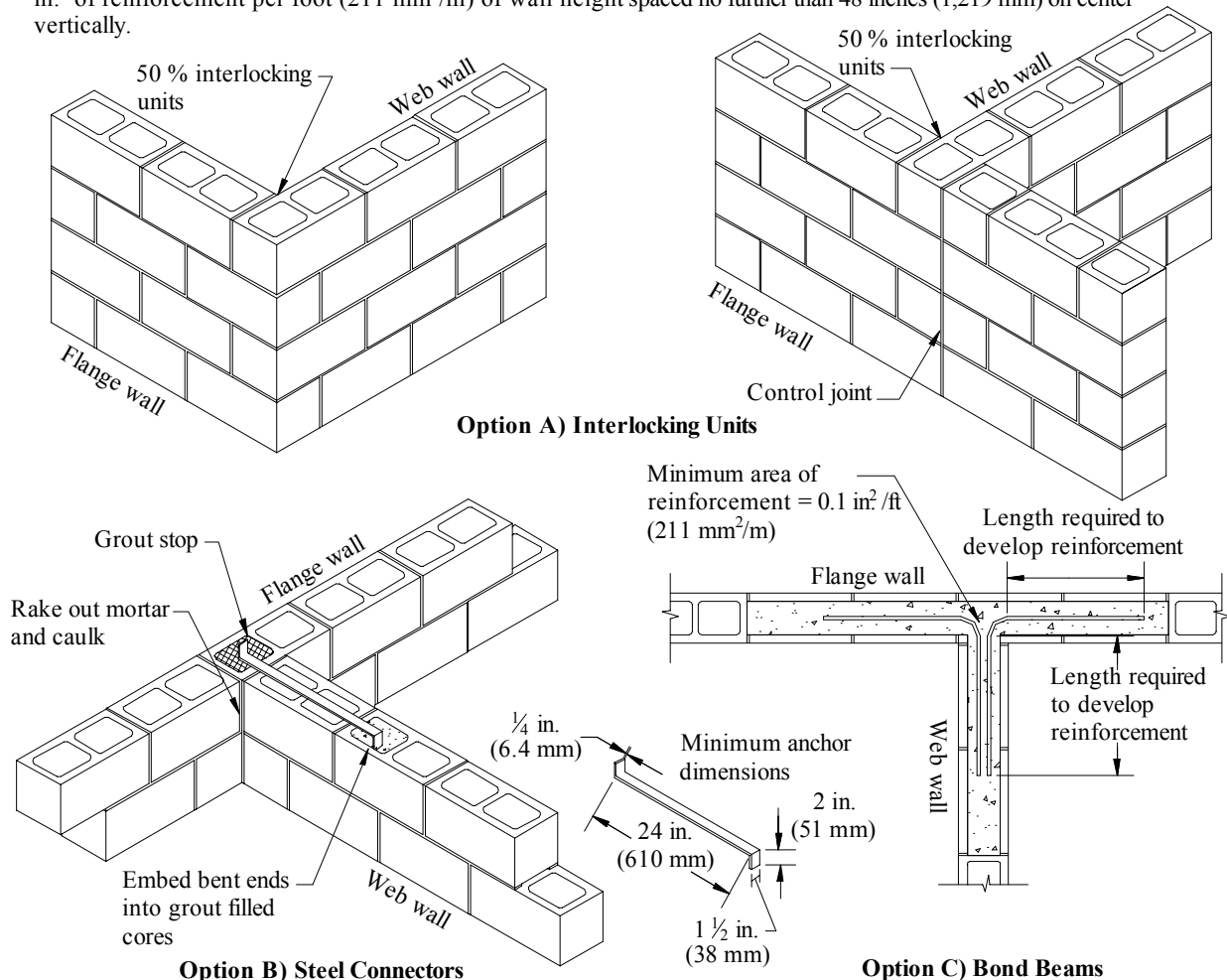
The design of wall intersections generally falls into one of two categories; those in which shear is designed to be transferred between two intersecting walls and those in which shear is prevented from being transferred from one wall to another. Detailing for flanged walls can substantially increase the flexural and axial load capacity of two intersecting walls.

When the design relies upon two intersecting walls to act compositely to resist applied loads, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) stipulates three options to transfer stresses from one wall to the other, each requiring the masonry to be laid in running bond. When any of these conditions are not met, the transfer of shear forces between walls is required to be prevented.

Option A: Walls are constructed such that 50 percent of the units interlock at the interface. This option, while easily accomplished at corners, results in bond interruption at 'T' intersections. As such, it is generally good practice to install a control joint in the flange wall to minimize cracking at this location unless horizontal reinforcement or other detailing is provided to eliminate the need for a control joint. If a control joint is constructed, the portion of the flange wall separated from the intersection by the control joint generally should not be considered effective in resisting applied loads from the web wall. See Section 2C for control joint details.

Option B: Walls are anchored together by steel connectors spaced at vertical intervals not exceeding 48 inches (1,219 mm) on center. While not required by Code, it is generally good practice to construct a control joint (to minimize cracking potential) at the intersection of two walls anchored in such a manner.

Option C: Bond beams are incorporated into the intersecting walls. The bond beams are required to contain at least 0.1 in.² of reinforcement per foot (211 mm²/m) of wall height spaced no further than 48 inches (1,219 mm) on center vertically.



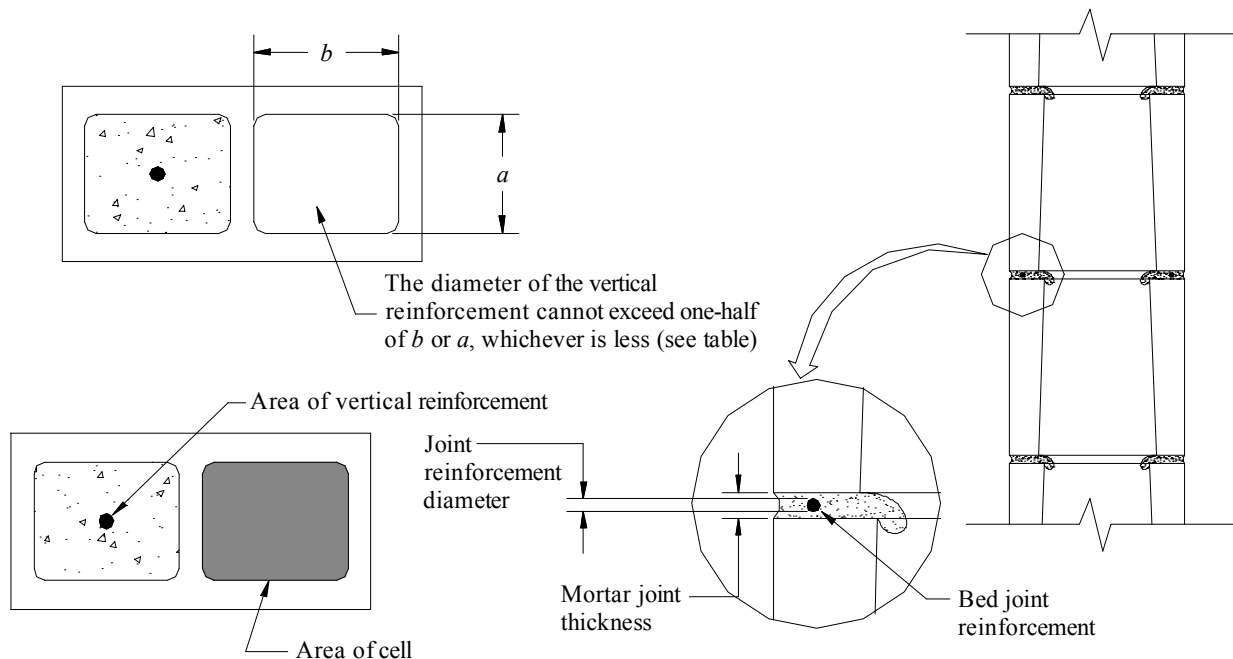
Last Modified: October, 2002

ACI 530/ASCE 5/TMS 402 Requirements for Size of Reinforcement

To help ensure masonry construction performs as anticipated, the code limits the size of reinforcement for masonry designed by the provisions of the *Building Code Requirements for Masonry Structures* (Ref. 1.8). The maximum reinforcement limitations facilitate adequate flow and good consolidation of mortar and grout around the reinforcement. These limits, which are primarily based on historically accepted practice, include the following for all masonry:

- A) Reinforcing bars shall not exceed No. 11 (M #36).
- B) Reinforcement diameter shall not exceed one-half the least clear dimension (which includes mortar protrusions, face shell or web taper and the presence of other reinforcing bars) of the cell, bond beam or collar joint in which it is placed.
- C) Longitudinal and cross wires of joint reinforcement shall have a minimum wire size of W1.1 (MW 7) and a maximum wire size of one-half the joint thickness.
- D) The area of vertical reinforcement shall not exceed 6 percent of the area of the grout space within which it is placed.

Note that different limits apply for masonry designed by the strength design procedures of Chapter 3 of the *Building Code Requirements for Masonry Structures* (Ref. 1.8). Refer to Figure 1E.3 for the reinforcement size limitations pertaining to masonry designed in accordance with the strength design provisions.



Maximum Size of Vertical Reinforcement Permitted For Typical Unit Configurations^A

Nominal Unit Width, in. (mm)	Cell Dimension a^B in. (mm)	Cell Dimension b^B in. (mm)	Maximum Diameter of Reinforcement, in. (mm)	Maximum Area of Vertical Steel, in. ² (mm ²)	Maximum Bar Size
4 (102)	0.63 (16)	6.19 (157)	----- ^C	----- ^C	----- ^C
6 (152)	2.13 (54)	5.81 (148)	1.06 (27)	0.74 (478)	No. 7 (M#22)
8 (203)	3.63 (92)	5.81 (148)	1.81 (46)	1.26 (815)	No. 9 (M#29)
10 (254)	5.38 (137)	5.63 (143)	2.68 (68)	1.81 (1,170)	No. 11 (M#36)
12 (305)	7.13 (181)	5.63 (143)	2.81 (71)	2.40 (1,550)	No. 11 (M#36)

^A Refer to Section 1B for typical unit configurations.

^B Dimensions are based on specified minimum dimensions for two-core, square core units and take into account a cell taper of 1/4 inch (6.4 mm) and mortar protrusions not exceeding 1/2 inch (13 mm).

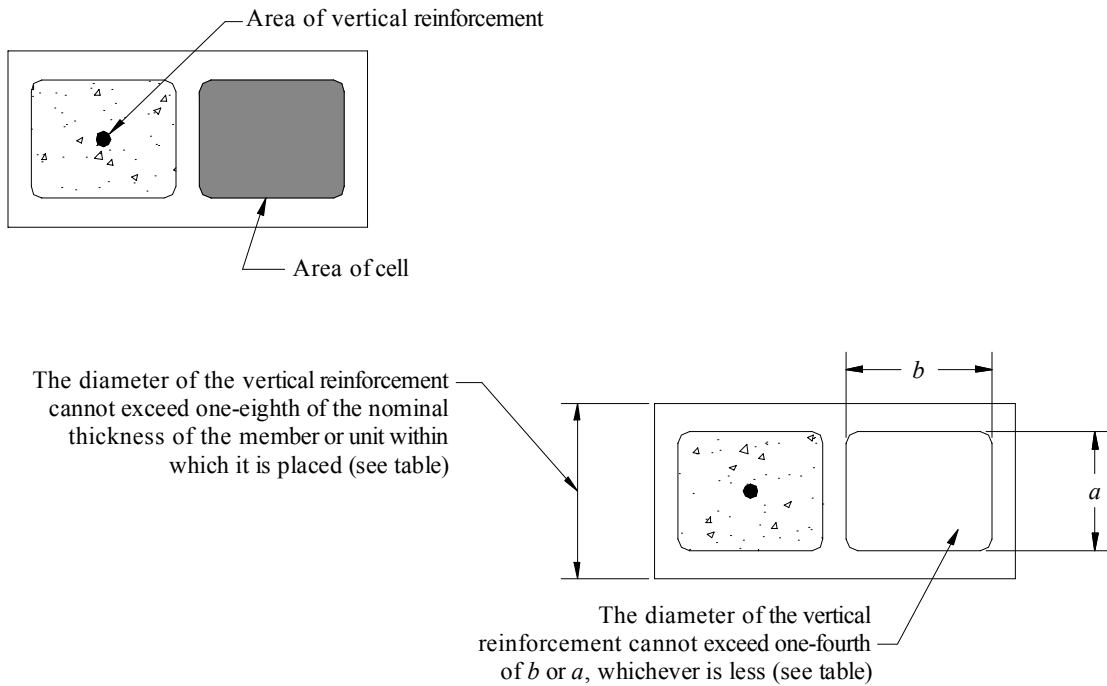
^C Although not limited by Code, grouting of 4 inch (102 mm) concrete masonry units can not be practically accomplished due to cell constraints and the resulting inability to adequately consolidate the grout.

ACI 530/ASCE 5/TMS 402 Requirements for Size of Reinforcement

In addition to the limitations summarized in Figure 1E.2, masonry designed in accordance with the strength design provisions of Chapter 3 of the *Building Code Requirements for Masonry Structures* (Ref. 1.8) must also comply with the following reinforcement size limitations. These limitations, above those stipulated in Figure 1E.2, stem primarily from a lack of available research and not on historical precedence.

For masonry designed by strength design procedures, reinforcing steel must comply with the following:

- A) Reinforcing bars shall not exceed No. 9 (M #29).
- B) The nominal bar diameter shall not exceed one-eighth of the nominal member thickness nor one-fourth of the least clear dimension of the grout space within which it is placed.
- C) The area of vertical reinforcement shall not exceed 4 percent of the area of the grout space within which it is placed.



Maximum Size of Vertical Reinforcement Permitted For Typical Unit Configurations^A

Nominal Unit Width, in. (mm)	Cell Dimension a^B in. (mm)	Cell Dimension b^B in. (mm)	Maximum Diameter of Reinforcement, in. (mm)	Maximum Area of Vertical Steel, in. ² (mm ²)	Maximum Bar Size
4 (102)	0.63 (16)	6.19 (157)	----- ^C	----- ^C	----- ^C
6 (152)	2.13 (54)	5.81 (148)	0.53 (14)	0.50 (319)	No. 4 (M#13)
8 (203)	3.63 (92)	5.81 (148)	0.91 (23)	0.84 (545)	No. 7 (M#22)
10 (254)	5.38 (137)	5.63 (143)	1.25 (32)	1.21 (781)	No. 9 (M#29)
12 (305)	7.13 (181)	5.63 (143)	1.41 (36)	1.61 (1,039)	No. 9 (M#29)

^A Refer to Section 1B for typical unit configurations.

^B Dimensions are based on specified minimum dimensions for two-core, square core units and take into account a cell taper of ¼ inch (6.4 mm) and mortar protrusions not exceeding ½ inch (13 mm).

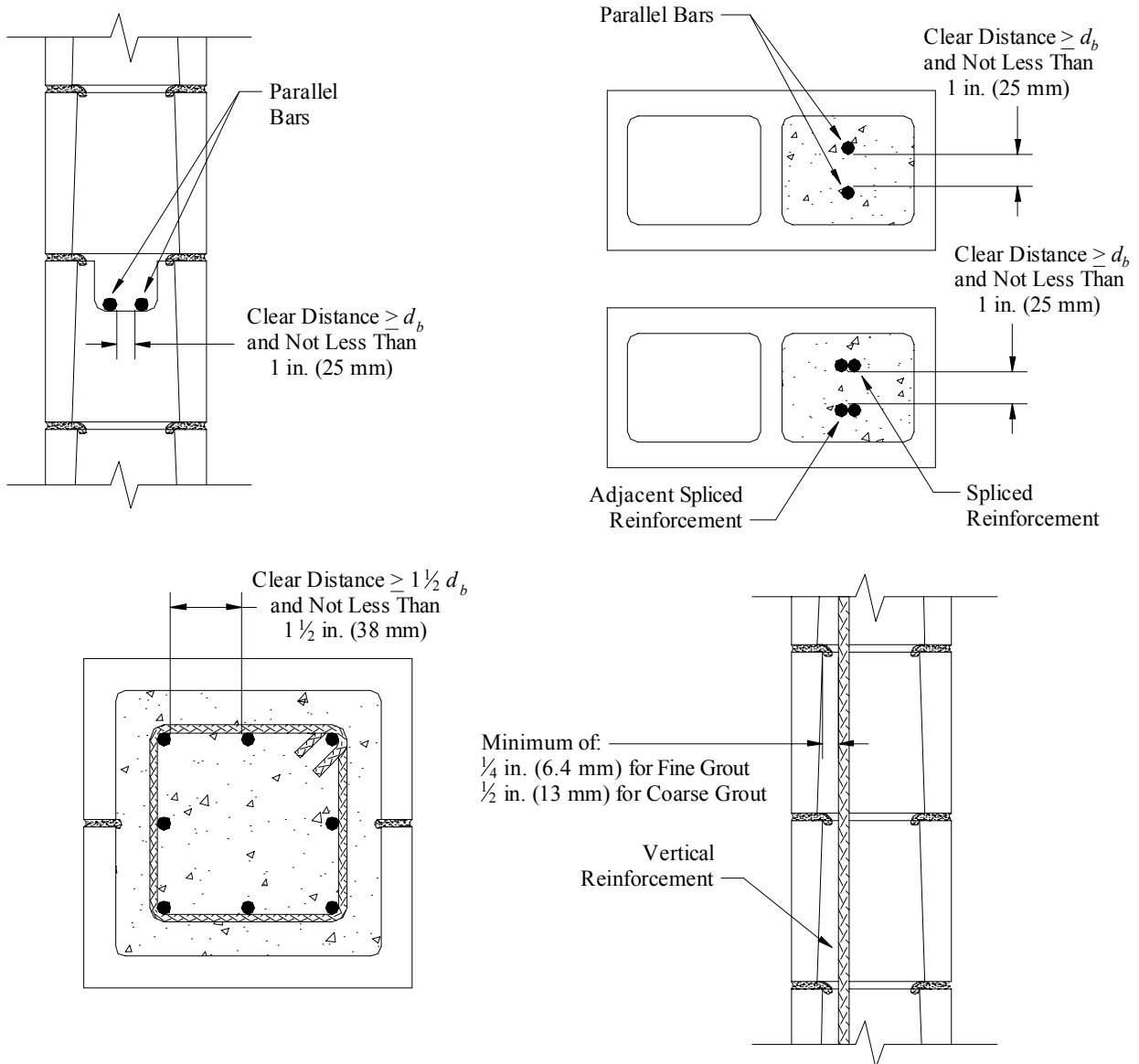
^C Although not limited by Code, grouting of 4 inch (102 mm) concrete masonry units can not be practically accomplished due to cell constraints and the resulting inability to adequately consolidate the grout.

ACI 530/ASCE 5/TMS 402 Placement Requirements for Reinforcement

To help ensure intended performance as well as structural reliability, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) has established placement and clearance requirements for reinforcement contained within masonry construction. These requirements, which pertain to all reinforced masonry construction, include:

- A) The thickness of grout between the reinforcement and masonry units shall not be less than $\frac{1}{4}$ inches (6.4 mm) for fine grout or $\frac{1}{2}$ inches (13 mm) for coarse grout. (Note, this requirement does not apply to the presence of mortar protrusions.)
- B) The clear distance between parallel bars shall not be less than the nominal diameter of the bars (d_b), nor less than 1 inch (25 mm).
- C) In columns and pilasters, the clear distance between vertical bars shall not be less than one and one-half times the nominal bar diameter (d_b), nor less than $1\frac{1}{2}$ inches (38 mm).

These requirements do not apply to the distance between contact splices of reinforcement. However, these clear distance limitations do apply to the clear distance between a contact lap splice and adjacent splices or bars.



Last Modified: October, 2002

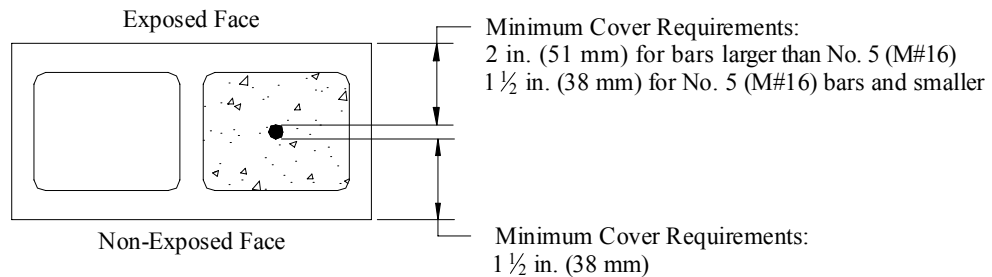
ACI 530/ASCE 5/TMS 402 Corrosion Protection Requirements

To help preclude corrosion of structural reinforcement embedded in masonry the *Building Code Requirements for Masonry Structures* (Ref. 1.8) stipulates minimum cover requirements. Reinforcement cover is measured from the exposed face of the masonry to the nearest surface of the reinforcement. In accordance with the Code requirements, reinforcing bars shall have a masonry cover distance (which includes the unit, grout, and mortar) of not less than:

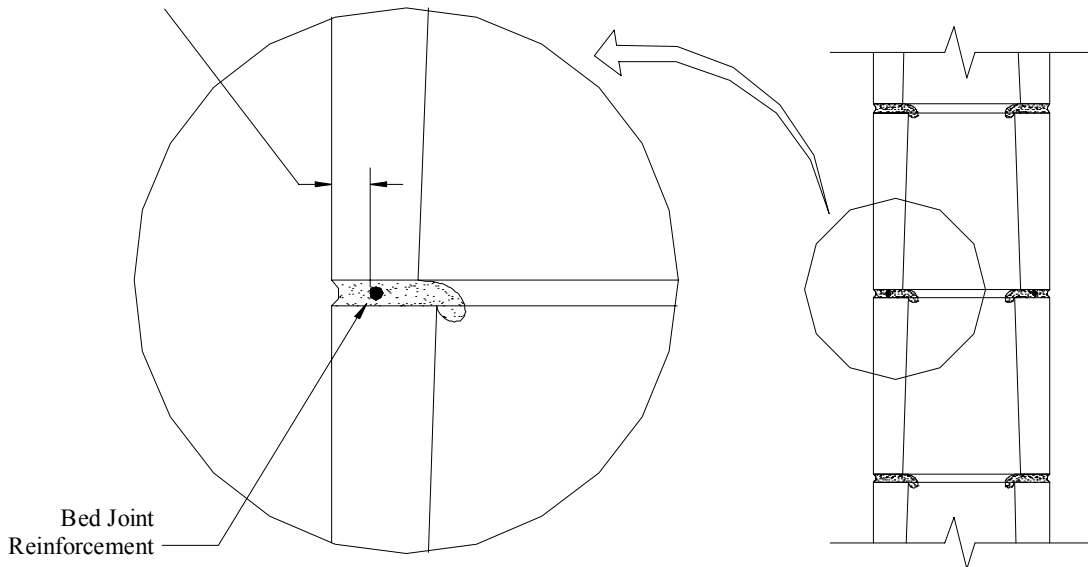
A) For masonry exposed to earth or weather: 2 inches (51 mm) for bars larger than No. 5 (M#16) and 1½ inches (38 mm) for No. 5 (M#16) bars or smaller.

B) For masonry not exposed to earth or weather: 1½ inches (38 mm).

Joint reinforcement shall be fully embedded in mortar or grout with a minimum cover of 5/8 in. (16 mm) when exposed to earth or weather or when the average ambient relative humidity exceeds 75%. For all other cases, the minimum cover distance is required to be 1/2 in. (13 mm).



5/8 in. (16 mm) when
 exposed to earth, weather, or high humidity
 1/2 in. (13 mm) when
 not exposed to earth, weather, or high humidity

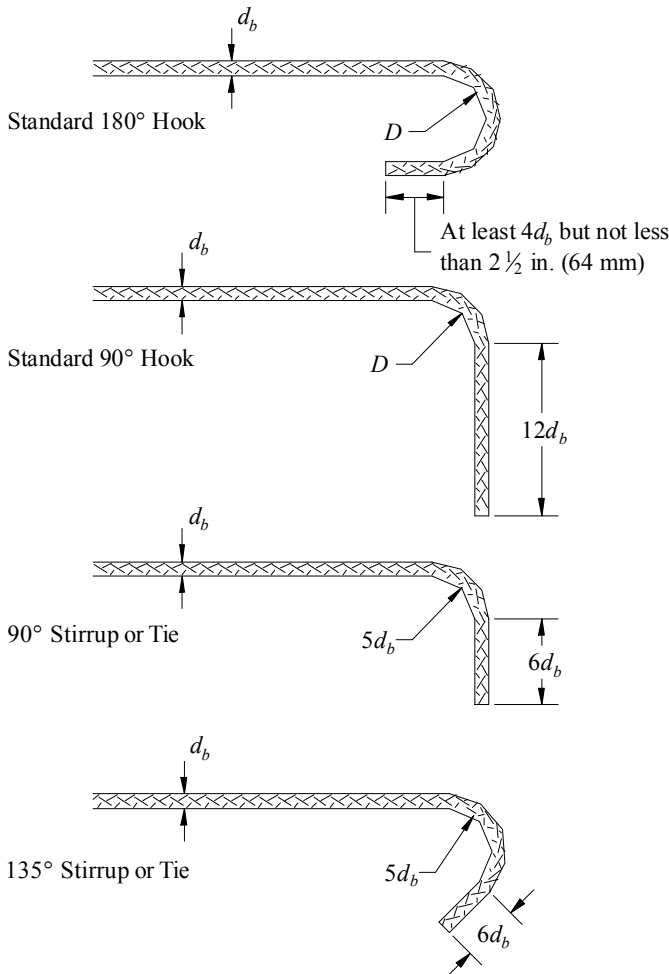


ACI 530/ASCE 5/TMS 402 Standard Hooks and Bend Requirements

The *Building Code Requirements for Masonry Structures* (Ref. 1.8) and *Specification for Masonry Structures* (Ref. 1.9) contains three options for reinforcing bar hooks that are typically used to terminate reinforcing bars in masonry; 180°, 90°, and 135°. In accordance with the Code, the 135° hooks are only to be used for anchoring stirrups or ties. When 90° hooks are used with stirrups or ties, the minimum length of the leg extension need only be six times the bar diameter instead of twelve bar diameters required for standard hooks. All extension distances are measured from the point of tangency of the bend to the end of the bar.

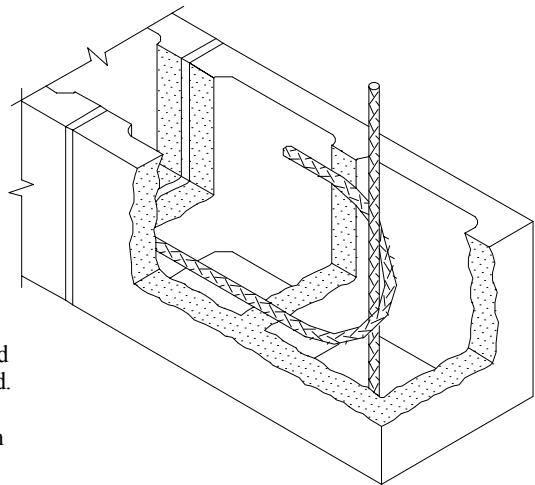
While hooks are not considered effective when the reinforcement is in compression, a standard hook in tension is considered to develop an equivalent embedment length of $11.25 d_b$.

In addition, minimum bend diameters for reinforcing bars are stipulated by the Code. These prescribed bends help to ensure the reinforcement maintains its structural integrity without breakage and minimizes potential grout crushing associated with using a smaller bend radius.



Bar Size and Type	Minimum Diameter of Bend, D^A
No. 3 (M #10) through No. 7 (M #22) Grade 40 (Grade 300)	5 bar diameters
No. 3 (M #10) through No. 8 (M #25) Grade 50 (Grade 300) or Grade 60 (Grade 420)	6 bar diameters
No. 9 (M #29), No. 10 (M #32), and No. 11 (M #36) Grade 50 (Grade 300) or Grade 60 (Grade 420)	8 bar diameters

^A Does not apply to stirrups or ties.



The termination of horizontal shear reinforcement should be anchored around vertical reinforcement with a standard 180° hook as illustrated. Space to accommodate the hook is limited (especially in smaller wythes); therefore the hook may need to be placed on an angle within the bond beam as shown.

Last Modified: October, 2002

**ACI 530/ASCE 5/TMS 402 Prescriptive Seismic Detailing Requirements
Detailed Plain (Unreinforced) Masonry Shear Walls**

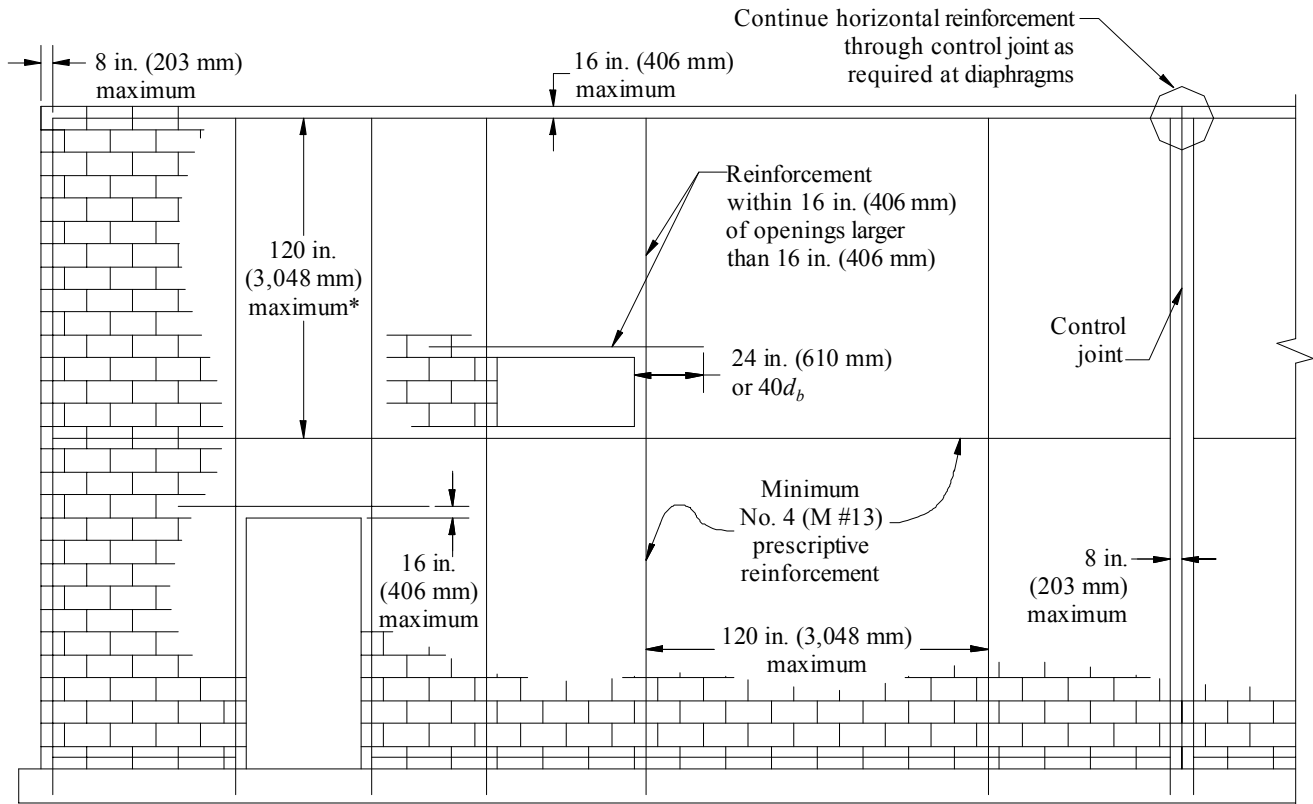
Plain masonry shear walls, which are designed as unreinforced elements of a structure, rely entirely upon the masonry to carry and distribute anticipated loads. However, to ensure a minimum level of performance during a design level earthquake, some prescriptive reinforcement is mandated by the *Building Code Requirements for Masonry Structures* (Ref. 1.8) for detailed plain masonry shear walls (note that ordinary plain (unreinforced) masonry shear walls do not require any prescriptive reinforcement and are permitted to be used in Seismic Design Categories A and B). This minimum prescriptive reinforcement for detailed plain masonry shear walls entails:

Detailed Plain Masonry Shear Walls
Permitted in:
Seismic Design Category A and B

Vertical Reinforcement: The prescriptive vertical reinforcement is required to consist of at least one No. 4 bar (M #13) at each corner, within 16 inches (406 mm) of each side of openings, within 8 inches (203 mm) of each side of control joints, within 8 inches (203 mm) of the ends of walls, and at a maximum spacing of 120 inches (3,048 mm).

Horizontal Reinforcement: The minimum prescriptive horizontal reinforcement consists of at least two wires of wire size W1.7 (MW 11) joint reinforcement spaced not more than 16 inches (406 mm) on center *or* bond beams containing no less than one No. 4 (M #13) bar spaced not more than 120 inches (3,048 mm) apart. Horizontal reinforcement is also required at the bottom and top of wall openings. Such reinforcement shall extend at least 24 inches (610 mm) or 40 bar diameters, whichever is greater, past the opening. Structural reinforcement located at roof and floor levels is required to be continuous. The horizontal reinforcing bar located closest to the top of the wall shall be placed within 16 inches (406 mm) of the top of the wall.

Neither horizontal nor vertical prescriptive reinforcement is required for openings smaller than 16 inches (406 mm) in either the horizontal or vertical direction, unless the required prescriptive reinforcement is interrupted by such openings.



*In lieu of bond beams with No. 4 bars (M #13) at 120 inches (3,048 mm) on center, provide two wires of wire size W1.7 (MW 11) joint reinforcement at 16 inches (406 mm) on center.

Last Modified: October, 2002

ACI 530/ASCE 5/TMS 402 Prescriptive Seismic Detailing Requirements
Ordinary Reinforced Masonry Shear Walls

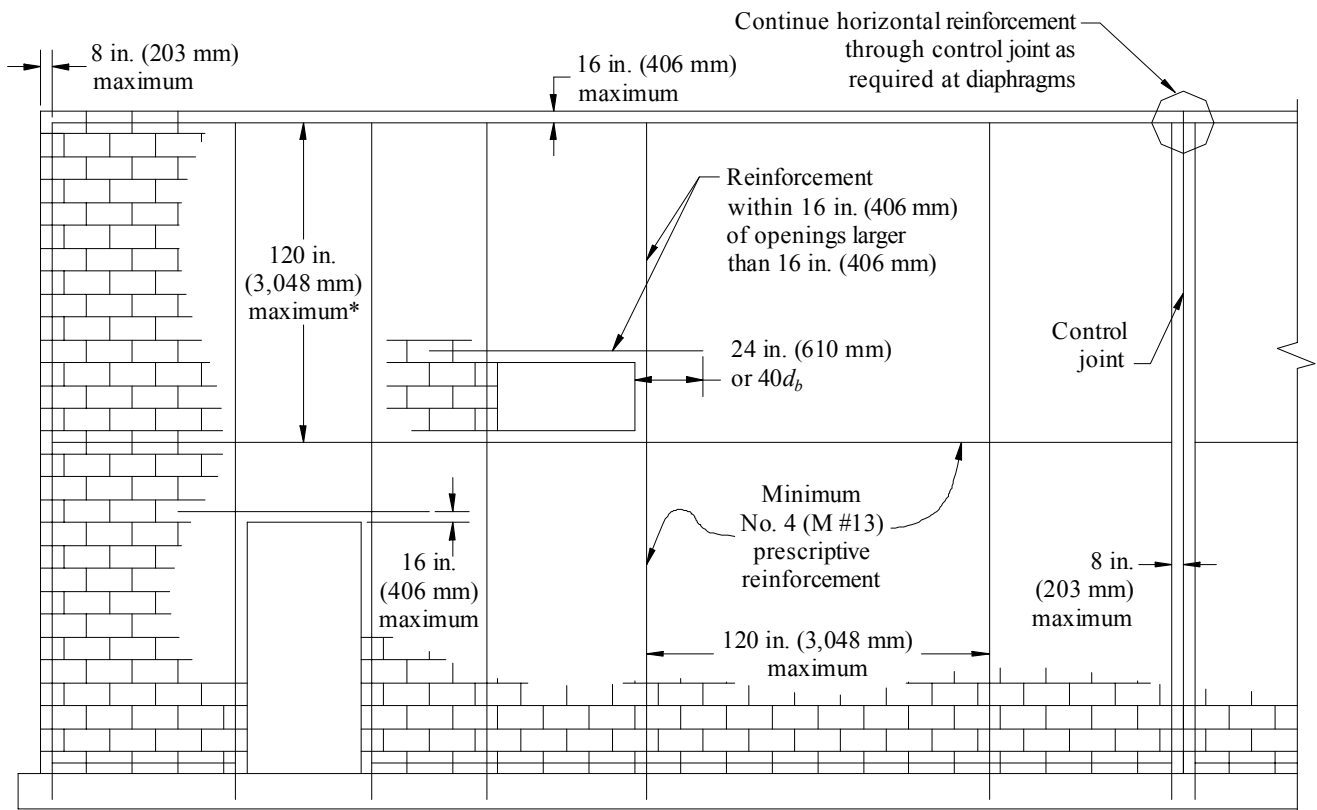
Ordinary reinforced masonry shear walls, which are designed in accordance with reinforced masonry procedures, rely upon the reinforcement to carry and distribute anticipated tensile stresses, while the masonry carries the compressive stresses. Although such walls contain some reinforcement, to ensure a minimum level of performance during a design level earthquake, a minimum amount of prescriptive reinforcement is also mandated by the *Building Code Requirements for Masonry Structures* (Ref. 1.8). The reinforcement required by design may also serve as the minimum prescriptive reinforcement, which entails:

Ordinary Reinforced Masonry Shear Walls
Permitted in:
Seismic Design Category A, B, and C

Vertical Reinforcement: The prescriptive vertical reinforcement is required to consist of at least one No. 4 bar (M #13) at each corner, within 16 inches (406 mm) of each side of openings, within 8 inches (203 mm) of each side of control joints, within 8 inches (203 mm) of the ends of walls, and at a maximum spacing of 120 inches (3,048 mm).

Horizontal Reinforcement: The minimum prescriptive horizontal reinforcement consists of at least two wires of wire size W1.7 (MW 11) joint reinforcement spaced not more than 16 inches (406 mm) on center *or* bond beams containing no less than one No. 4 (M #13) bar spaced not more than 120 inches (3,048 mm) apart. Horizontal reinforcement is also required at the bottom and top of wall openings. Such reinforcement shall extend at least 24 inches (610 mm) or 40 bar diameters, whichever is greater, past the opening. Structural reinforcement located at roof and floor levels is required to be continuous. The horizontal reinforcing bar located closest to the top of the wall shall be placed within 16 inches (406 mm) of the top of the wall.

Neither horizontal nor vertical prescriptive reinforcement is required for openings smaller than 16 inches (406 mm) in either the horizontal or vertical direction, unless the required prescriptive reinforcement is interrupted by such openings.



*In lieu of bond beams with No. 4 bars (M #13) at 120 inches (3,048 mm) on center, provide two wires of wire size W1.7 (MW 11) joint reinforcement at 16 inches (406 mm) on center.

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**ACI 530/ASCE 5/TMS 402 Prescriptive Seismic Detailing
 Intermediate Reinforced Masonry Shear Walls**

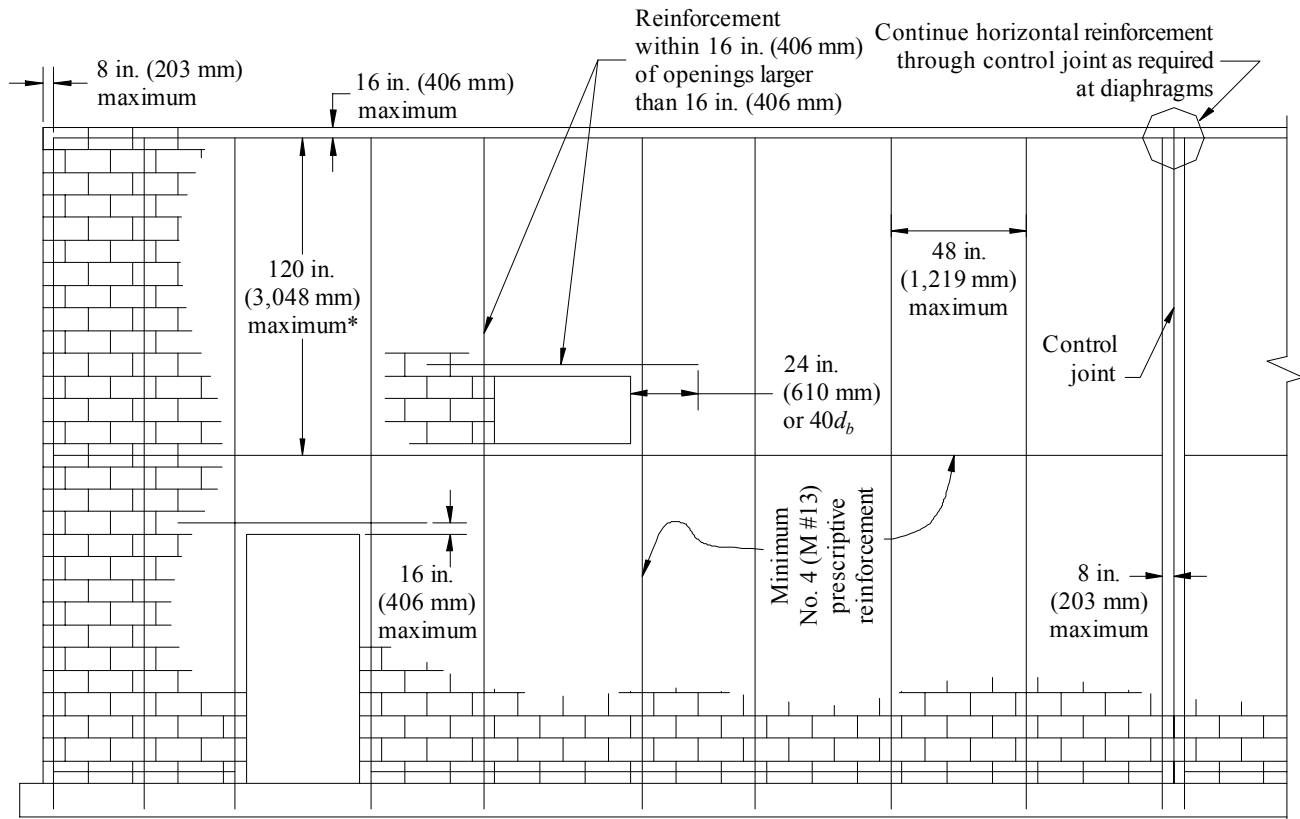
Intermediate reinforced masonry shear walls, which are designed in accordance with reinforced masonry procedures, rely upon the reinforcement to carry and distribute anticipated tensile stresses, while the masonry carries the compressive stresses. Although such walls contain some reinforcement, to ensure a minimum level of performance during a design level earthquake, a minimum amount of prescriptive reinforcement is also mandated by the *Building Code Requirements for Masonry Structures* (Ref. 1.8). The reinforcement required by design may also serve as the minimum prescriptive reinforcement, which entails:

Intermediate Reinforced Masonry Shear Walls Permitted in:
 Seismic Design Category A, B, and C

Vertical Reinforcement: The prescriptive vertical reinforcement is required to consist of at least one No. 4 bar (M #13) at each corner, within 16 inches (406 mm) of each side of openings, within 8 inches (203 mm) of each side of control joints, within 8 inches (203 mm) of the ends of walls, and at a maximum spacing of 48 inches (1,219 mm).

Horizontal Reinforcement: The minimum prescriptive horizontal reinforcement consists of at least two wires of wire size W1.7 (MW 11) joint reinforcement spaced not more than 16 inches (406 mm) on center *or* bond beams containing no less than one No. 4 (M #13) bar spaced not more than 120 inches (3,048 mm) apart. Horizontal reinforcement shall also be provided at the bottom and top of wall openings. Such reinforcement shall extend at least 24 inches (610 mm) or 40 bar diameters, whichever is greater, past the opening. Structural reinforcement located at roof and floor levels is required to be continuous. The horizontal reinforcing bar located closest to the top of the wall shall be placed within 16 inches (406 mm) of the top of the wall.

Neither horizontal nor vertical prescriptive reinforcement is required for openings smaller than 16 inches (406 mm) in either the horizontal or vertical direction, unless the required prescriptive reinforcement is interrupted by such openings.



*In lieu of bond beams with No. 4 bars (M #13) at 120 inches (3,048 mm) on center, provide two wires of wire size W1.7 (MW 11) joint reinforcement at 16 inches (406 mm) on center.

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**ACI 530/ASCE 5/TMS 402 Prescriptive Seismic Detailing Requirements
 Special Reinforced Masonry Shear Walls**

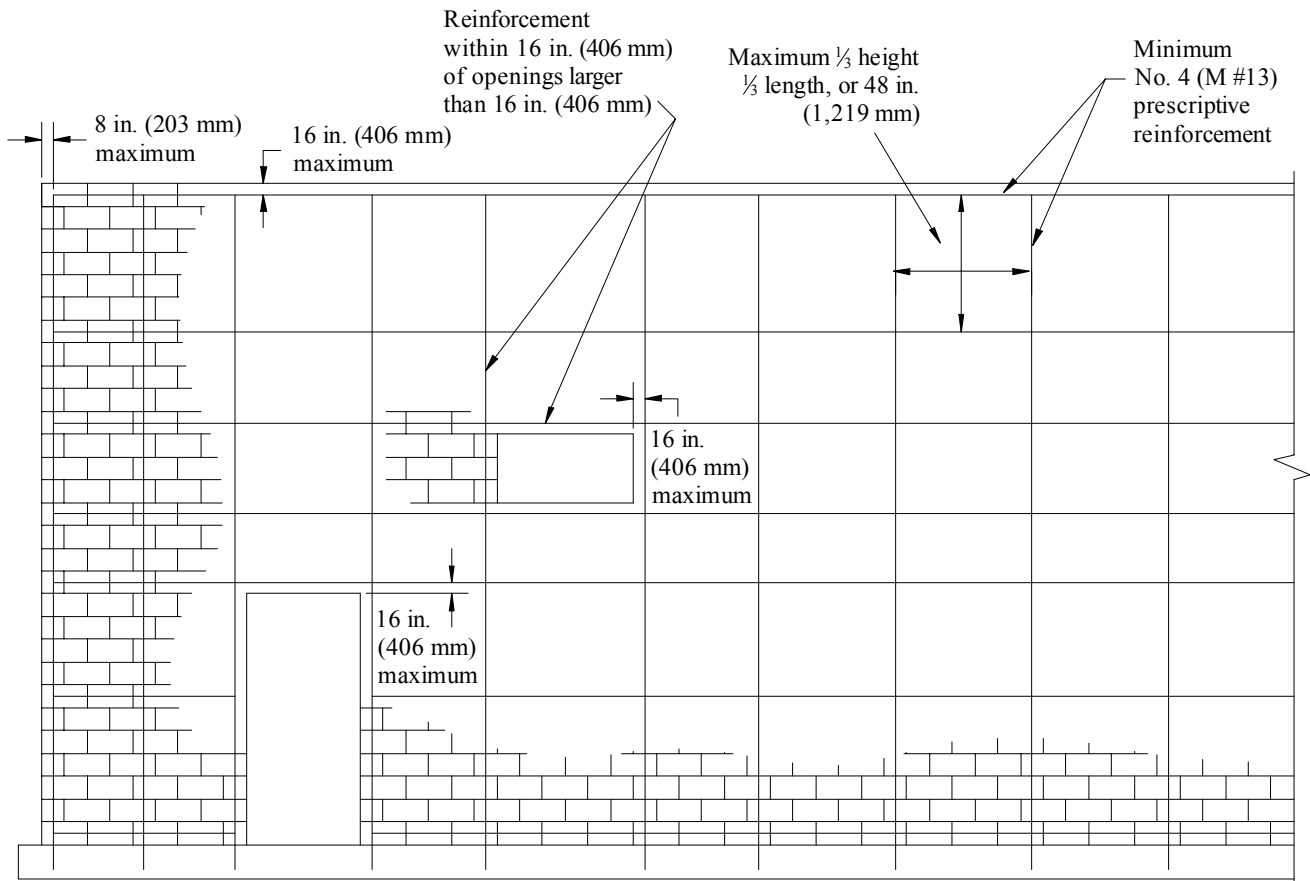
The prescriptive reinforcement for special reinforced masonry shear walls is required to comply with the requirements for intermediate reinforced masonry shear walls and the following:

Special Reinforced Masonry Shear Walls
 Permitted in:
 Seismic Design Category A, B, C, D, E, and F

The sum of the cross-sectional area of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum cross-sectional area in each direction shall be not less than 0.0007 times the gross cross-sectional area of the wall. The maximum spacing of vertical and horizontal reinforcement shall be the smaller of one-third the length of the shear wall, one-third the height of the shear wall or 48 inches (1,219 mm) and shall be uniformly distributed. The minimum cross-sectional area of vertical reinforcement shall be one-third of the required horizontal reinforcement. All horizontal reinforcement shall be anchored around the vertical reinforcement with a standard hook.

Due to the large quantities of prescriptive horizontal reinforcement, control joints are typically not necessary for special reinforced masonry shear walls.

Stack bond masonry shear walls assigned to Seismic Design Categories D, E, or F are required to be constructed of fully grouted open-end units, fully grouted hollow units laid with full head joints, or solid units. The maximum spacing of reinforcement for stack bond masonry shear walls assigned to Seismic Design Category D is 24 inches (610 mm). Stack bond masonry shear walls assigned to Seismic Design Categories E or F are required to have a horizontal cross-sectional area of reinforcement of at least 0.0025 times the gross cross-sectional area of the masonry at a maximum spacing of 16 inches (406 mm).



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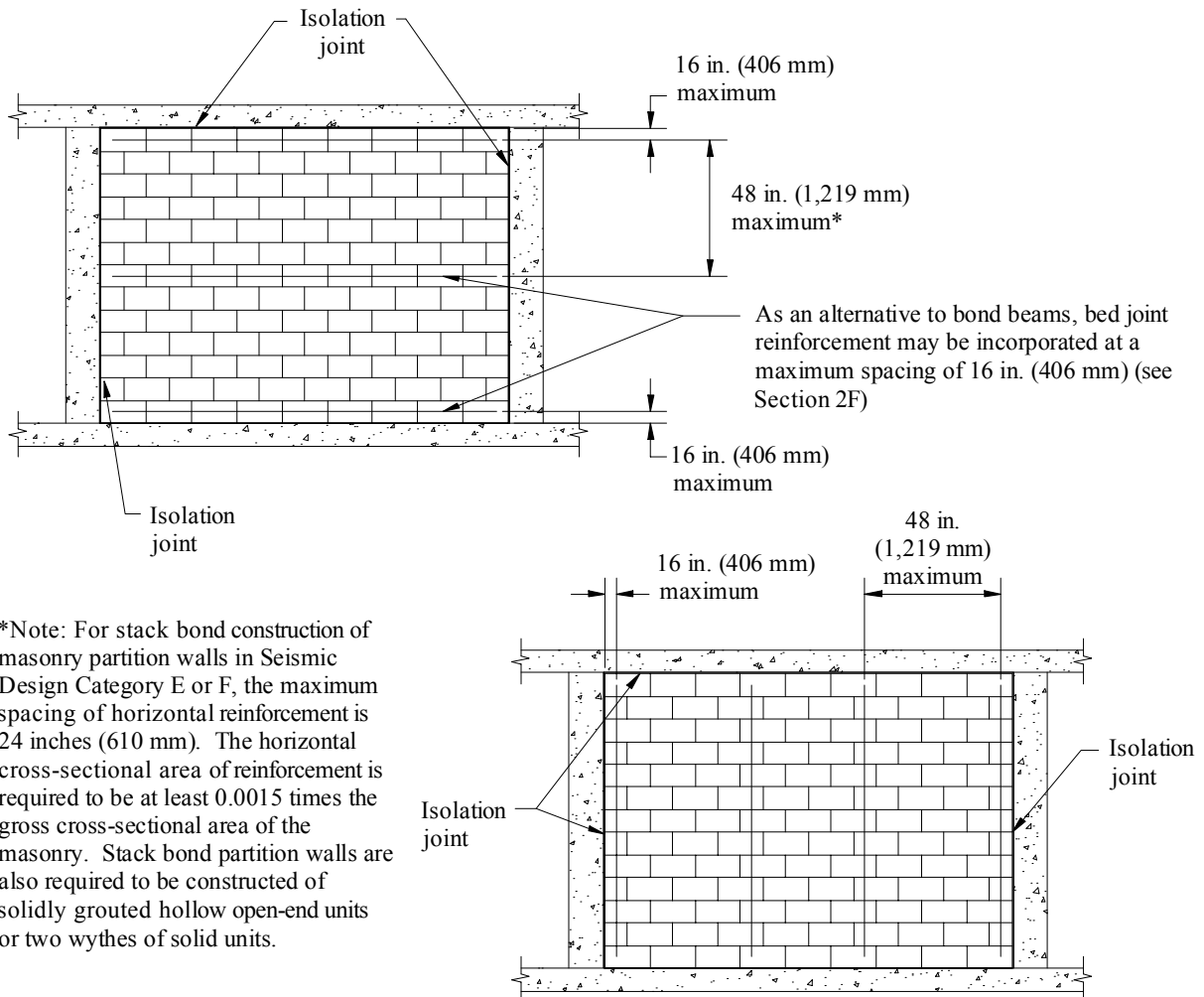
**ACI 530/ASCE 5/TMS 402 Prescriptive Seismic Detailing Requirements
Nonloadbearing Elements**

When incorporated into structures assigned to Seismic Design Category C, D, E or F, masonry partition walls and other nonloadbearing masonry elements that are not designed to resist loads (other than those induced by their own mass) are required to be isolated from the lateral-force resisting system. This helps to ensure that forces are not inadvertently transferred between the structural system and the non-structural system.

In addition, the non-structural elements such as partition walls assigned to Seismic Design Category C and above must be reinforced in *either* the horizontal or vertical direction in accordance with the following:

Horizontal Reinforcement: Horizontal joint reinforcement shall consist of at least two longitudinal W1.7 (MW 11) wires for walls having a thickness greater than 4 inches (102 mm). For walls of 4-inch (102 mm) thickness and less, only one W1.7 (MW 11) wire is required. The spacing of the joint reinforcement shall not exceed 16 inches (406 mm) for either case. Alternatively, bond beams incorporating at least one No. 4 bar (M #13) and spaced no further apart than 48 inches (1,219 mm) may be used instead of bed joint reinforcement. Horizontal reinforcement shall be provided within 16 inches (406 mm) of the top and bottom of these masonry walls.

Vertical Reinforcement: Vertical reinforcement shall consist of at least one No. 4 (M #13) bar spaced no more than 48 inches (1,219 mm) on center. Vertical reinforcement shall be located within 16 inches (406 mm) of the ends of the masonry wall.



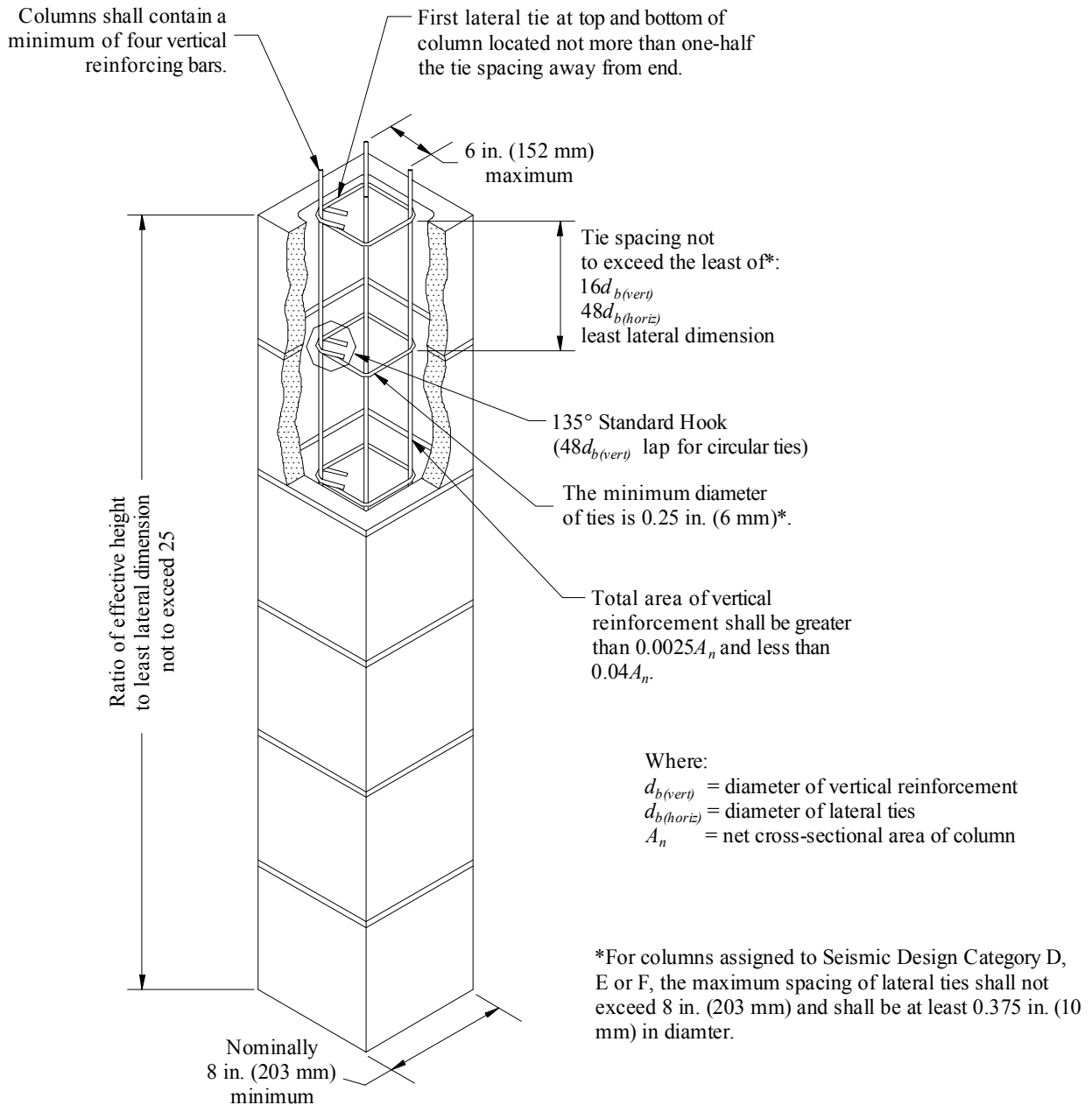
*Note: For stack bond construction of masonry partition walls in Seismic Design Category E or F, the maximum spacing of horizontal reinforcement is 24 inches (610 mm). The horizontal cross-sectional area of reinforcement is required to be at least 0.0015 times the gross cross-sectional area of the masonry. Stack bond partition walls are also required to be constructed of solidly grouted hollow open-end units or two wythes of solid units.

Last Modified: October, 2002

ACI 530/ASCE 5/TMS 402 Detailing Requirements Masonry Columns

Columns are isolated elements used primarily to support axial loads, but can also be subjected to flexure and shear stresses. Because columns are often used to support other structural elements, such as beams, floors or roofs, their performance is often critical to the overall performance of a structure. To ensure a minimum level of anticipated performance, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) includes prescriptive details covering size, height and minimum reinforcement requirements.

In Seismic Design Categories A, B and C, column ties can be located either within the grout or bed joint mortar. In Seismic Design Categories D, E and F, lateral ties are required to be embedded in grout as shown in the detail below.



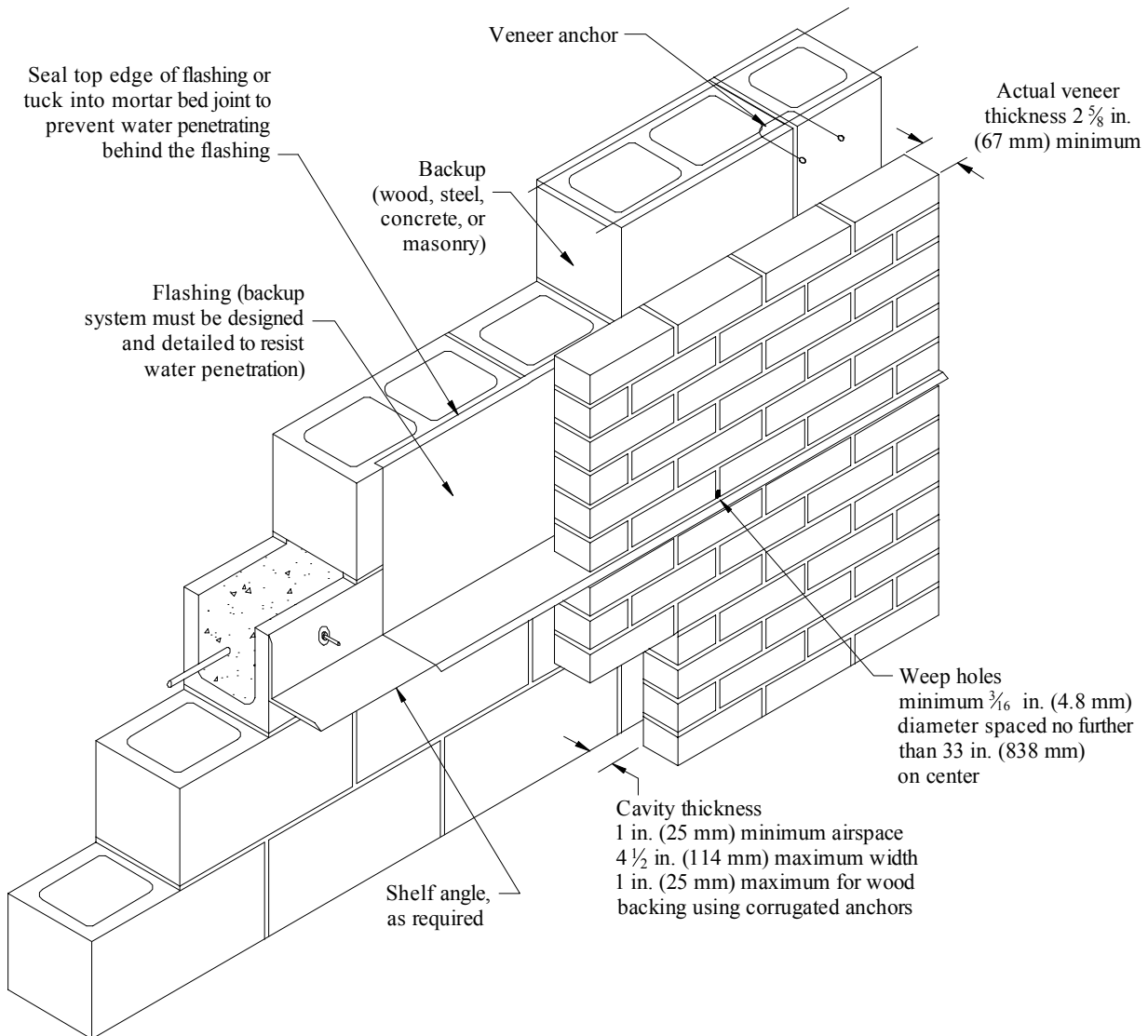
Last Modified: October, 2002

ACI 530/ASCE 5/TMS 402 General Requirements for Anchored Masonry Veneer

The *Building Code Requirements for Masonry Structures* (Ref. 1.8) includes provisions for the design of both anchored veneer and adhered veneer (refer to Figure 1E.18 for details on adhered veneer). Anchored veneer may be designed rationally in accordance with the provisions outlined in the Code and engineering judgment, or detailed prescriptively to meet the Code requirements. Figures 1E.13 through 1E.17 highlight the prescriptive requirements for anchored masonry veneer and may be used when the basic wind speed is less than or equal to 110 mph (145 kph). These provisions apply to veneer laid in running bond. When other than running bond construction is used, the veneer is required to contain joint reinforcement with at least one W1.7 (MW 11) wire spaced at a maximum distance of 18 inches (457 mm) on center vertically.

General design requirements for veneers include designing and detailing:

- The backing system of exterior veneer to resist water penetration;
- Flashing and weeps in exterior veneer to channel water out of cavity; and
- The veneer to accommodate differential movement.



Last Modified: October, 2002

ACI 530/ASCE 5/TMS 402 Support Requirements for Anchored Masonry Veneer

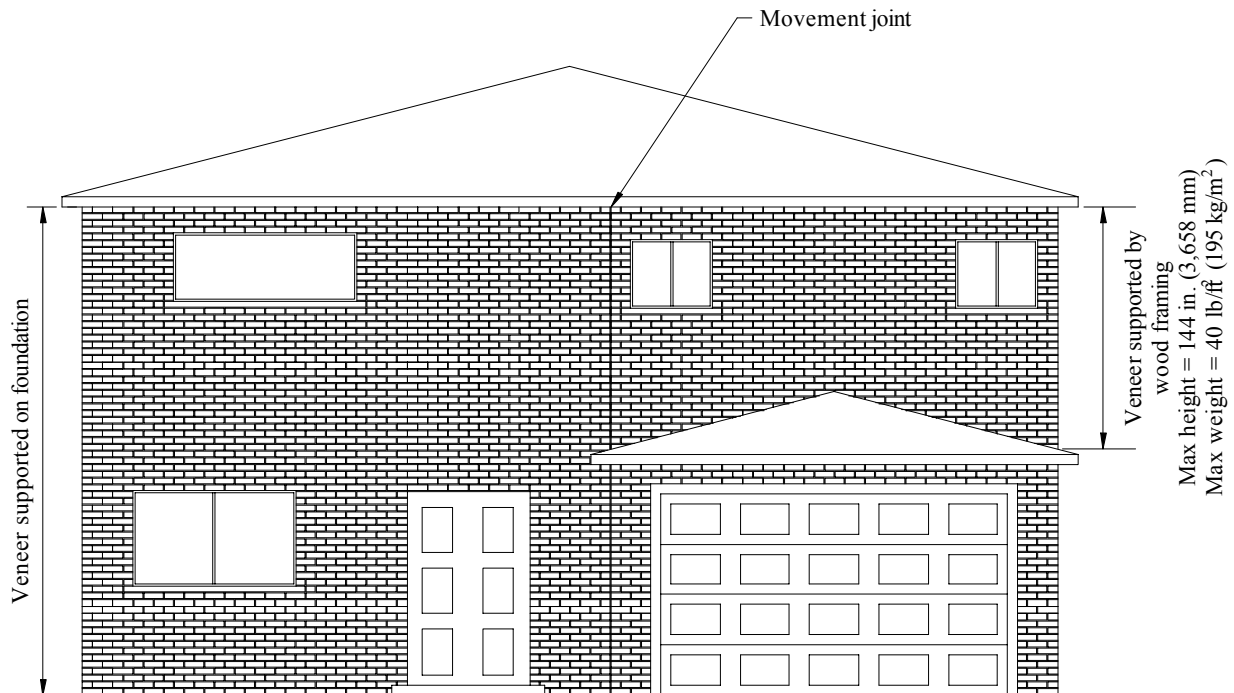
In accordance with the prescriptive detailing requirements of the *Building Code Requirements for Masonry Structures* (Ref. 1.8), the weight of anchored veneer is to be vertically supported by noncombustible structural supports. When combustible supports are used, the following limitations are to apply:

- Anchored veneer supported vertically by preservative treated wood foundations is not to exceed a height of 18 feet (5,486 mm) above the support.
- Interior anchored veneer may be supported on wood construction when the installed weight is not more than 40 lb/ft² (195 kg/m²).
- Exterior anchored veneer may be supported on wood construction if the installed weight is 40 lb/ft² (195 kg/m²) or less and the height is not more than 12 feet (3,658 mm). (Note that concrete masonry veneer 4 inches (102 mm) or less in nominal thickness and 130 lb/ft³ (2110 kg/m³) or less in density has an installed weight of less than 40 lb/ft².)

Anchored veneer supported by lintels, floors, wood construction, or other spanning elements not continuously supported shall be designed such that the deflection is limited to $l/600$ or 0.3 inches (7.6 mm), whichever is less.

Anchored veneer with a backing of wood framing shall not exceed a height of 30 feet (9,144 mm) (38 feet (11,582 mm) at gables). Veneer with a backing of cold-formed steel framing may exceed these heights if the weight of the veneer is supported by noncombustible construction at each story above these height limits. There are no prescriptive height limitations for veneer with concrete or masonry backing.

Unless pressure treated wood suitable for contact with masonry is used, veneer must be designed and detailed so that it is not in direct contact with wood or other similar material susceptible to moisture damage. When different sections of a veneer assemblage are supported by wood construction and by the foundation, respectively, a movement joint must be placed between each section to isolate the differential movement that may occur between each region.



ACI 530/ASCE 5/TMS 402 Anchor Requirements for Anchored Masonry Veneer

The following types of anchors are permitted under the prescriptive requirements of the *Building Code Requirements for Masonry Structures* (Ref. 1.8) for anchored masonry veneer.

Corrugated Sheet Metal Anchors: Corrugated sheet metal anchors, used with wood backup, are required to be at least $\frac{7}{8}$ inches (22 mm) wide, have a base metal thickness of at least 0.03 inches (0.76 mm), and have corrugations with a wavelength of 0.3 to 0.5 inches (7.6 to 13 mm) and an amplitude of 0.06 to 0.10 inches (1.5 to 2.5 mm).

Sheet Metal Anchors: Sheet metal anchors, used with wood backup, shall be at least $\frac{7}{8}$ inches (22 mm) wide, have a base metal thickness of at least 0.06 inches (1.5 mm) and shall have corrugations as given above for corrugated sheet metal anchors or be bent, notched or punched to provide equivalent performance.

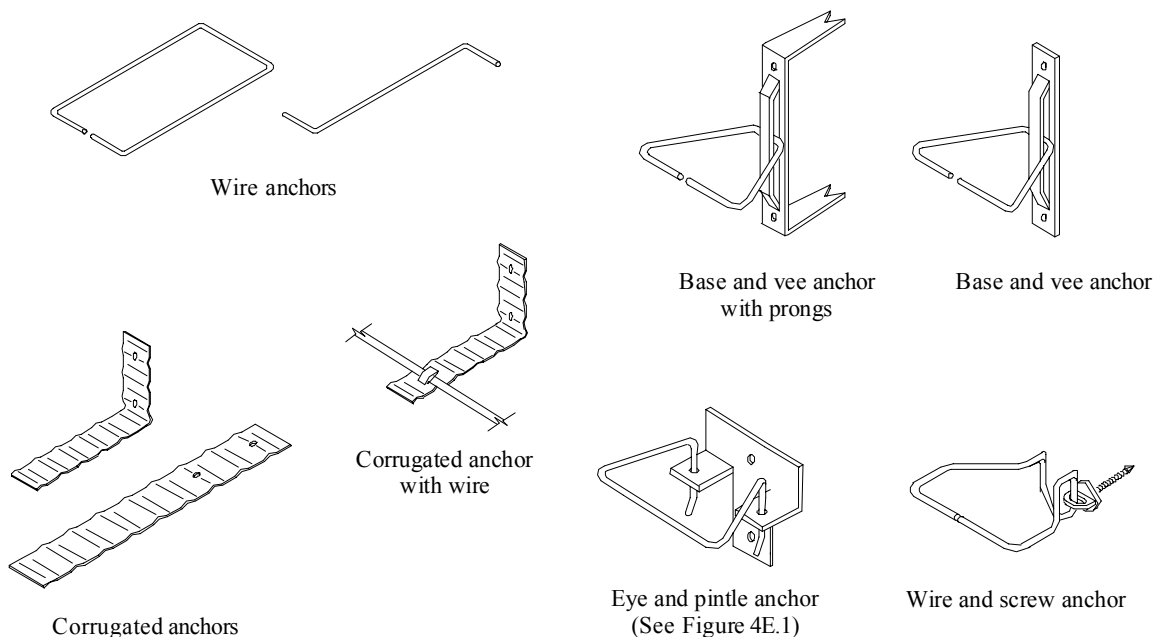
Wire Anchors: Wire anchors, used with wood or masonry backup, shall be at least W1.7 (MW 11) wire and have ends bent to form an extension from the bend at least 2 inches (51 mm) long. Note that for multiwythe walls designed for composite action, "Z" ties are not permitted for the use with hollow masonry units.

Joint Reinforcement Anchors: Ladder-type or tab-type joint reinforcement is permitted for use with masonry backup if the cross wires used to anchor the masonry veneer are at least W1.7 (MW 11) wire and the wires are spaced no further than 16 inches (406 mm) on center. Cross wires shall be welded to longitudinal wires, which shall be at least wire size W1.7 (MW 11).

Adjustable Anchors: Sheet metal and wire components of adjustable anchors shall conform to the requirements for corrugated sheet metal anchors, sheet metal anchors or wire anchors. Adjustable anchors with joint reinforcement shall also meet the requirements for joint reinforcement anchors. Adjustable anchors must also comply with the following requirements (refer to Figure 4A.1 for further guidance):

- The maximum clearance between connecting parts of the tie shall be $\frac{1}{16}$ inches (1.6 mm).
- Adjustable anchors shall be detailed to prevent disengagement.
- Pintle anchors shall have at least two pintle legs of wire size W 2.8 (MW 18) each and shall have an offset not exceeding $1\frac{1}{4}$ inches (32 mm).

Other veneer anchors are permitted when their performance is equivalent to the above.



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ACI 530/ASCE 5/TMS 402 Installation Requirements for Anchored Veneer

The *Building Code Requirements for Masonry Structures* (Ref. 1.8) contains the following requirements for installing anchors for masonry veneer:

Corrugated sheet metal, sheet metal and wire anchors shall be installed in accordance with the following:

Solid Units: Embed anchors in the mortar joint and extend into the veneer a minimum of 1½ inches (38 mm), with at least ⅝ inches (16 mm) mortar cover to the outside face.

Hollow Units: Embed anchors in mortar or grout and extend into the veneer a minimum of 1½ inches (38 mm), with at least ⅝ inches (16 mm) mortar or grout cover to the outside face.

Joint reinforcement anchors shall be installed such that the longitudinal wires are embedded in the mortar joint with at least ⅝ inches (16 mm) mortar cover on each side.

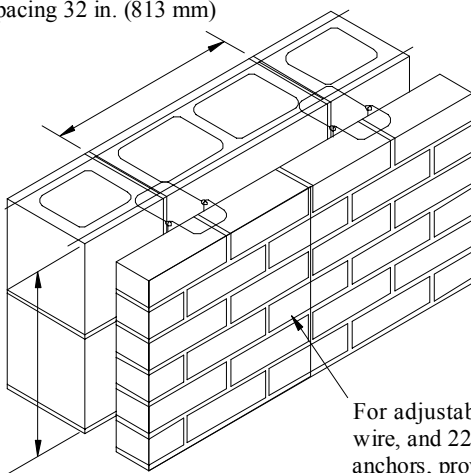
Depending upon the type of adjustable anchor to be used (sheet metal, wire etc.), these anchors shall be installed as described above for corrugated sheet metal, sheet metal, wire or joint reinforcement anchors.

For adjustable two-piece anchors, W1.7 (MW 11) wire anchors, and 22 gage (0.8 mm) corrugated sheet metal anchors, provide at least one anchor for each 2.67 ft² (0.25 m²) of wall area. For all other types of anchors, provide at least one anchor for each 3.5 ft² (0.33 m²) of wall area.

Anchors shall be spaced at a maximum of 32 inches (813 mm) horizontally and 18 inches (457 mm) vertically. Provide additional anchors around all openings larger than 16 inches (406 mm) in either dimension. Space anchors around perimeter of opening at a maximum of 36 inches (914 mm) on center. Place anchors within 12 inches (305 mm) of openings.

Mortar bed thickness shall be at least twice the thickness of the embedded anchor.

Maximum horizontal
spacing 32 in. (813 mm)



Maximum vertical
spacing 18 in. (457 mm)

For adjustable, W1.7 (MW 11) wire, and 22 gage (0.8 mm) anchors, provide one anchor for each 2.67 ft² (0.25 m²) of wall area. Provide one anchor for each 3.5 ft² (0.33 m²) of wall area for all other anchors.

⁶Anchor Types
A - Corrugated sheet metal
B - Sheet metal
C - Wire
D - Joint reinforcement
E - Adjustable

Table 1E.1 Veneer Anchor Installation

Backup Material	Anchors Permitted ⁶
Wood ¹	A ² , B, C, D, and E
Steel ³	E ⁴
Masonry ⁵	C, D, and E
Concrete	E

¹ Anchor shall be attached with corrosion-resistant 8d nails or equivalent fastener with equal or greater pullout strength.

² For corrugated sheet metal anchors, locate fastener within ½ inch (13 mm) of the 90° bend in the anchor.

³ Steel framing shall be corrosion resistant and have a base metal thickness of at least 0.043 inches (1.1 mm).

⁴ Attach with corrosion-resistant screws with a minimum shank diameter of 0.190 inches (4.8 mm).

⁵ The maximum misalignment of bed joints from one wythe to another is ¼ inches (32 mm).

ACI 530/ASCE 5/TMS 402 Seismic Requirements for Anchored Veneer

In addition to the other requirements for installing and constructing anchored masonry veneer outlined in Figures 1E.13 through 1E.16, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) contains the following requirements for veneer construction in areas of relatively moderate to high seismic risk.

Seismic Design Category A and B

Anchored masonry veneer that is part of a structure assigned to Seismic Design Category A or B is not subjected to any additional requirements.

Seismic Design Category C

Isolate the sides and top of anchored veneer from the structure so that vertical and lateral seismic forces resisted by the structure are not imparted to the veneer.

Seismic Design Category D

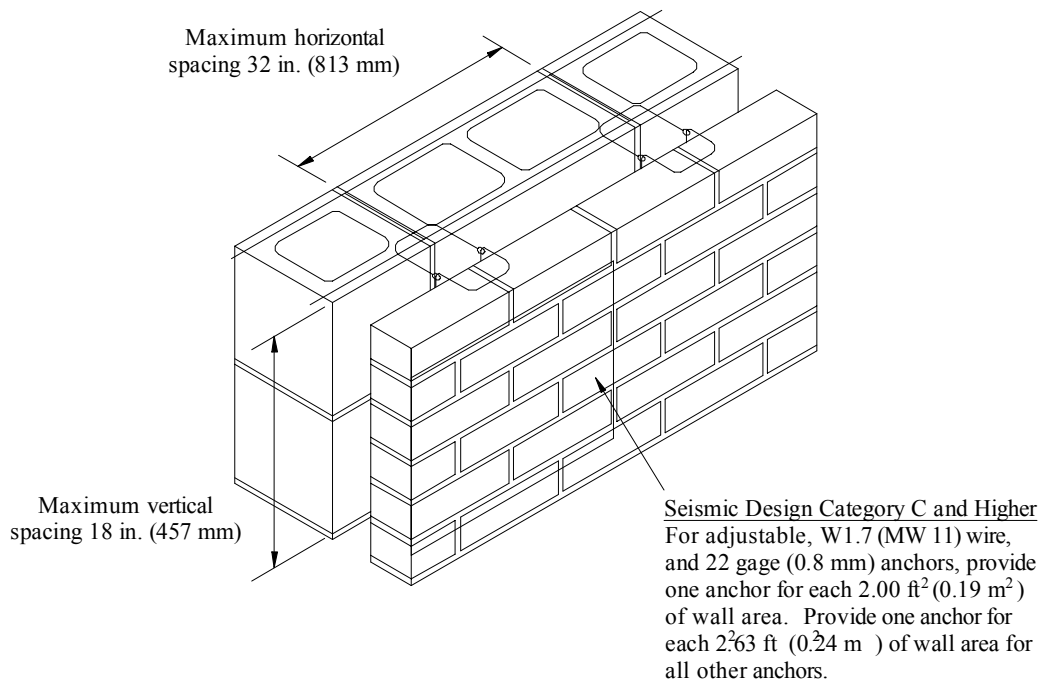
In addition to the general requirements and the requirements for Seismic Design Category C, the following requirements must be met for structures containing anchored veneer assigned to Seismic Design Category D.

- A) Support the weight of anchored veneer at each story level independently from other stories.
- B) The spacing of anchors shall be reduced as follows:
 - for adjustable two-piece anchors, W1.7 (MW 11) wire anchors, and 22 gage (0.8 mm) corrugated sheet metal anchors, provide at least one anchor for each 2.00 ft² (0.19 m²) of wall area, and
 - for all other types of anchors, provide at least one anchor for each 2.63 ft² (0.24 m²) of wall area.
- C) Provide continuous single-wire joint reinforcement of minimum size W1.7 (MW 11) at a maximum spacing of 18 inches (457 mm) on center vertically.

Seismic Design Category E and F

In addition to the general requirements and the requirements for Seismic Design Category D, the following requirements must be met for structures assigned to Seismic Design Category E or F and containing anchored veneer.

- A) Provide vertical expansion joints at all returns and corners for masonry veneer.
- B) Mechanically attach anchors (using clips or hooks) to the joint reinforcement required for Seismic Design Category D.



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ACI 530/ASCE 5/TMS 402 General Requirements for Adhered Masonry Veneer

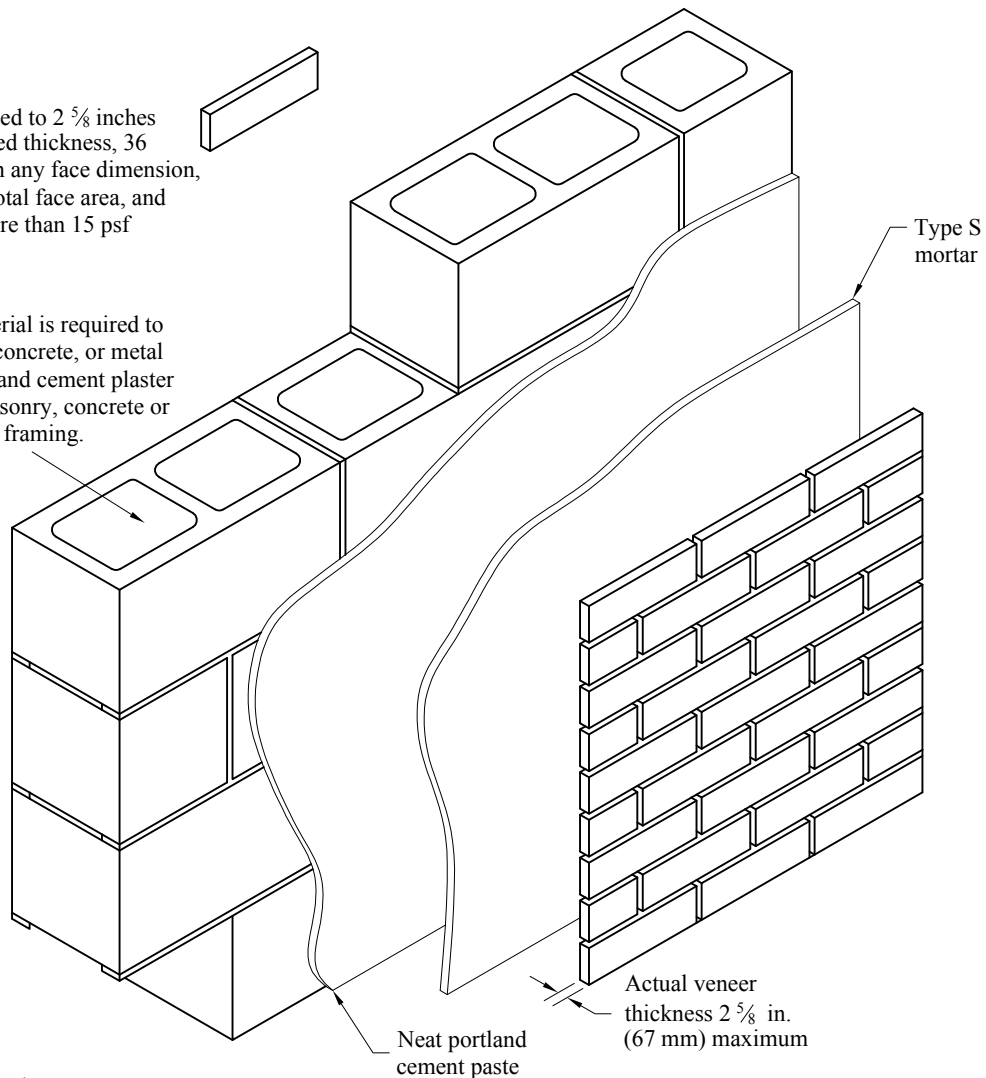
The Building Code Requirements for Masonry Structures (Ref. 1.8) includes provisions for the design of both anchored veneer and adhered veneer. (Refer to Figures 1E.13 through 1E.17 for details on anchored veneer.) Like anchored veneer, adhered veneer may be designed rationally in accordance with the provisions outlined in the Code and engineering judgment, or detailed prescriptively to meet the Code requirements. The following highlights the prescriptive requirements for adhered masonry veneer. Unlike anchored masonry veneer, there are no wind limitations imposed by the Code for adhered veneer. Further, the height, length and area of adhered veneer are not limited except as required to control restrained differential movement stresses between the veneer and the backing material.

Placing Adhered Veneer

- 1) Brush a paste of neat portland cement on the backing and on the back of the veneer unit.
- 2) Apply Type S mortar to the backing and to the veneer unit.
- 3) Tap the veneer unit into place, completely filling the space between the veneer unit and the backing. Sufficient mortar shall be used to create a slight excess to be forced out between the edges of the veneer units. The resulting thickness of the mortar in back of the veneer unit must be at least $\frac{3}{8}$ inches (9.5 mm) but not more than $1\frac{1}{4}$ inches (32 mm).
- 4) Tool the mortar joint with a round jointer when the mortar is thumbprint hard.

Unit sizes are limited to $2\frac{5}{8}$ inches (67 mm) in specified thickness, 36 inches (914 mm) in any face dimension, 5 ft² (0.46 m²) in total face area, and shall not weigh more than 15 psf (73 kg/m²).

Backing material is required to be masonry, concrete, or metal lath and portland cement plaster applied to masonry, concrete or steel or wood framing.



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ACI 530/ASCE 5/TMS 402 Composite Masonry Detailing Requirements

Multiwythe walls can take several forms: veneer, noncomposite, and composite. The primary differences between these types of walls systems is the method in which they are detailed for construction and how applied loads are assumed to be carried and distributed through the loadbearing system.

For veneer wall systems, the design assumes that all loads applied to the veneer are transferred through the ties to the structural back up. Therefore, for design purposes, the veneer is assumed to not contribute any load carrying capacity to the wall. Conversely, for composite and noncomposite wall systems, which must consist of two or more wythes of masonry units, each wythe is design as a structural component of the building. As such, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) contains different prescriptive detailing requirements for composite and noncomposite walls compared to veneered systems.

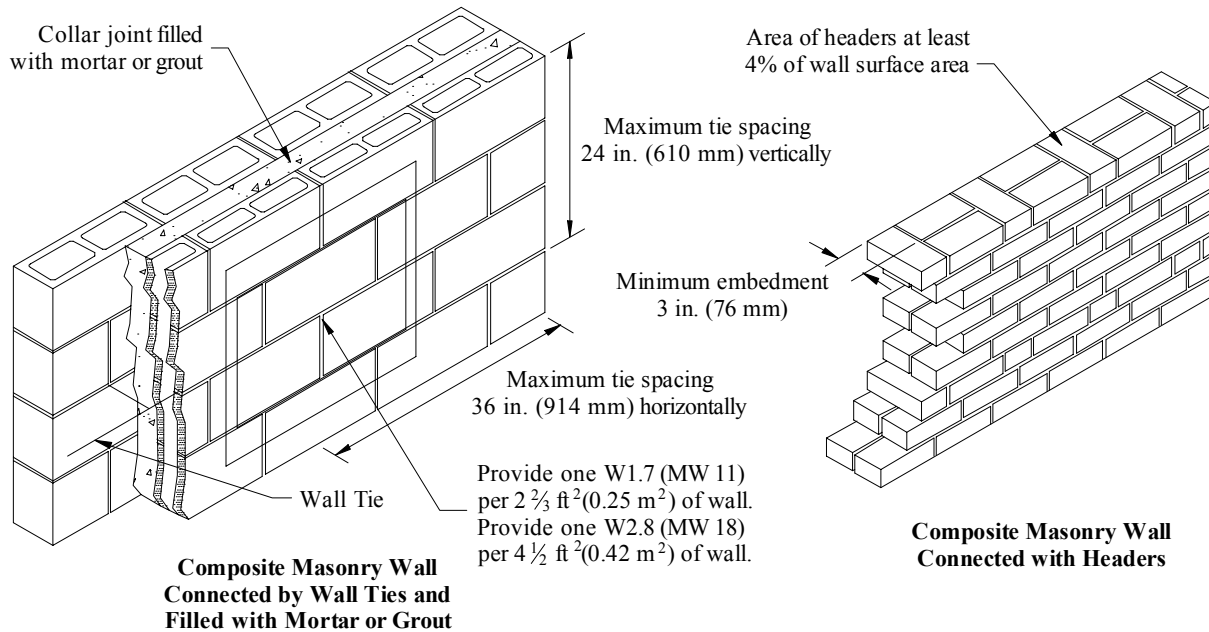
By definition, each wythe of a composite masonry wall is designed and detailed such that all components act together as a single element in resisting applied loads. Conversely, for noncomposite walls, each wythe is required to be designed to resist individually the loads imposed on it.

In addition to the design requirements stipulated by the Code to ensure sufficient structural capacity, multiwythe masonry walls designed for composite action are required to be connected by one of the following methods:

Headers The collar joints of composite masonry walls shall be crossed by uniformly distributed headers having a total cross-sectional area not less than 4 percent of the total wall surface. Headers connecting adjacent wythes are also required to be embedded at least 3 inches (76 mm) into each wythe. Although crossing the collar joint with headers was a common construction practice in the past, it is rarely used today due to increased labor costs and construction time. A more cost effective alternative for constructing composite masonry walls is the use of ties and grouted or mortared collar joints.

Wall Ties The collar joints of composite masonry walls connected by wall ties are required to be solidly filled with mortar or grout. When W1.7 (MW 11) wall ties are used, one tie shall be provided for each $2\frac{2}{3}$ ft² (0.25 m²) of wall area. When W2.8 (MW 18) wall ties are used, one tie shall be provided for each $4\frac{1}{2}$ ft² (0.42 m²) of wall area. Regardless of the size of wire, the maximum spacing between ties cannot exceed 36 inches (914 mm) horizontally and 24 inches (610 mm) vertically.

- Z wall ties are only permitted with solid masonry units.
- Cross wires of joint reinforcement may be used in lieu of wall ties.



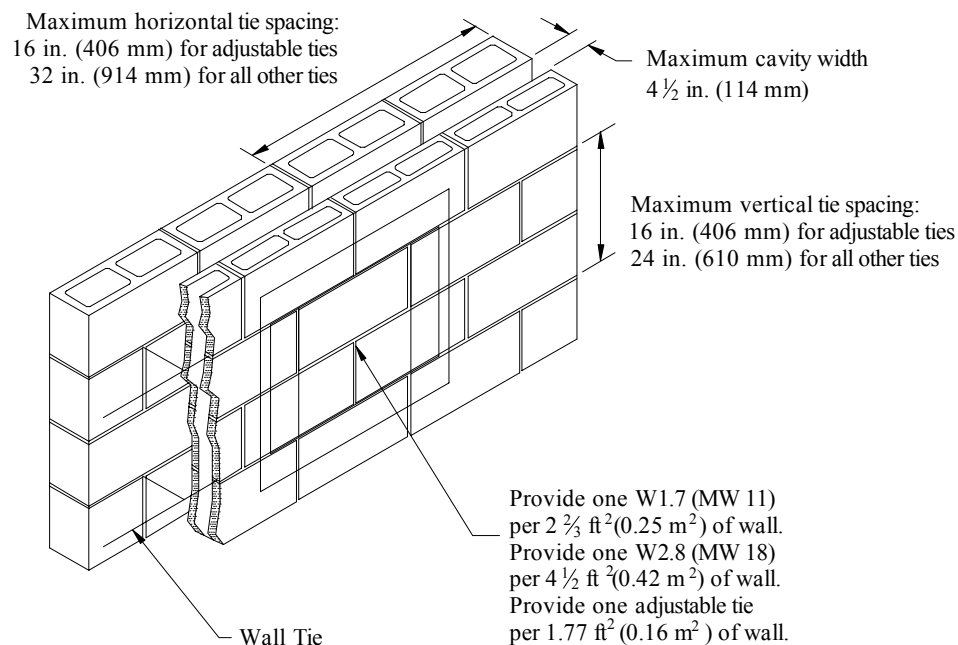
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ACI 530/ASCE 5/TMS 402 Noncomposite Masonry Detailing Requirements

As summarized in Figure 1E.19, each wythe of a noncomposite wall must be designed to resist individually the loads imposed on it. While practical applications for noncomposite walls are rare, prescriptive detailing requirements are provided in the *Building Code Requirements for Masonry Structures* (Ref. 1.8).

In addition to the design requirements stipulated by the Code to ensure sufficient structural capacity, multiwythe masonry walls designed for noncomposite action are required to be connected by wall ties without cavity drips. Unless a more detailed analysis is performed, the following prescriptive requirements apply:

- Collar joints shall not contain headers, grout, or mortar.
- The specified distance between wythes cannot exceed a width of 4½ inches (114 mm).
- When W1.7 (MW 11) wall ties are used, one tie shall be provided for each 2⅔ ft² (0.25 m²) of wall area.
- When W2.8 (MW 18) wall ties are used, one tie shall be provided for each 4½ ft² (0.42 m²) of wall area.
- When adjustable wall ties are used, one tie shall be provided for each 1.77 ft² (0.16 m²) of wall area.
- The maximum vertical spacing is 16 inches (406 mm) for adjustable wall ties and 24 inches (610 mm) for all other ties.
- The maximum horizontal spacing is 16 inches (406 mm) for adjustable wall ties and 32 inches (914 mm) for all other ties.
- Z wall ties are only permitted with solid masonry units.
- Where the cross wires of joint reinforcement are used as ties, the joint reinforcement is required to be ladder-type or tab-type.
- Adjustable ties shall not be used when the misalignment of bed joints from one wythe to another exceeds 1¼ inch (32 mm).
- Because the collar joints of noncomposite walls are free of mortar or grout that would act to confine the ties, adjustable ties are also required to comply with the clearance and engagement requirements of the *Specification for Masonry Structures* (Ref. 1.9). (Refer to Figure 1E.15.)



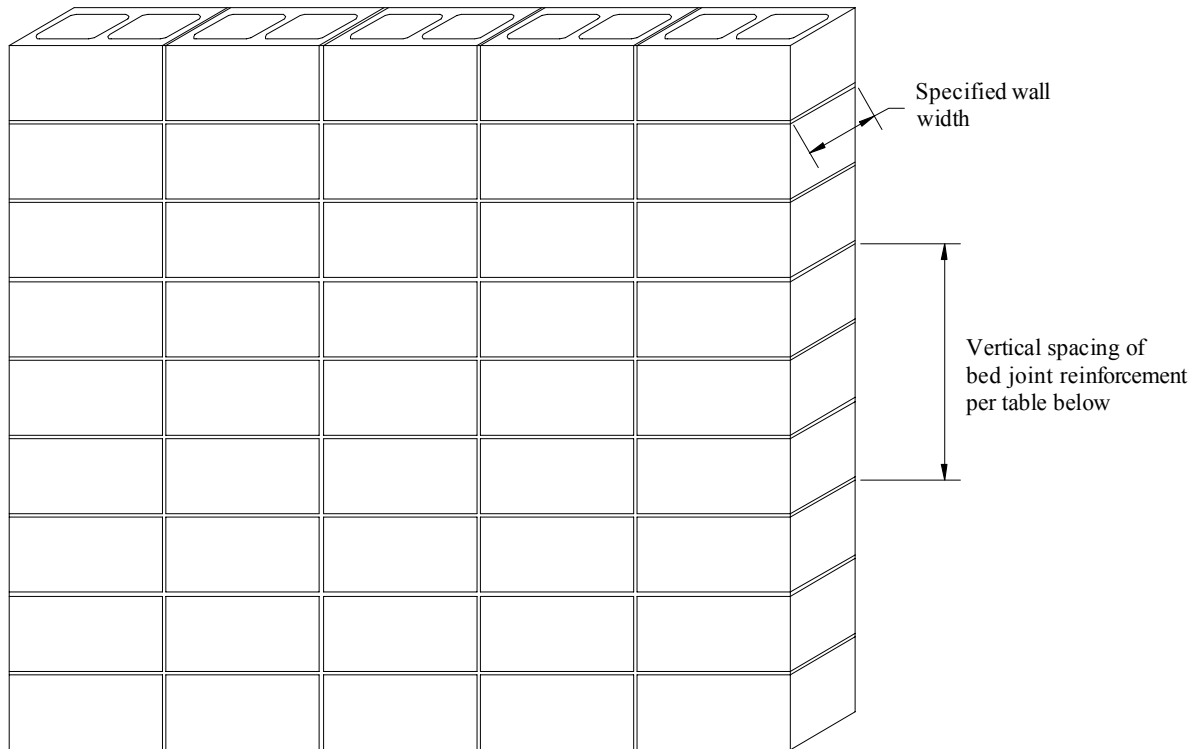
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ACI 530/ASCE 5/TMS 402 Stack Bond Masonry Detailing Requirements

For design purposes, the *Building Code Requirements for Masonry Structures* (Ref. 1.8) considers only two masonry bond patterns: running bond and other than running bond. Although there are numerous configurations and bond patterns achievable with masonry construction, the primary bond pattern "other than running bond" is stack bond. Generally, stack bond is defined as the placement of units such that the head joints of successive courses are vertically aligned.

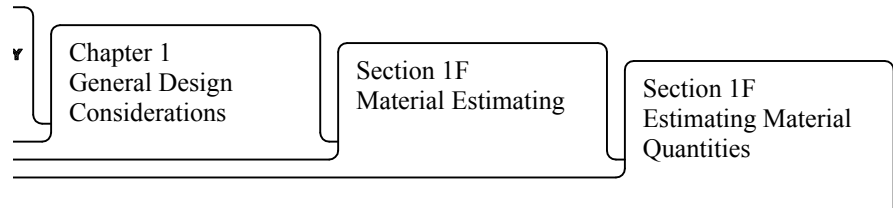
To provide structural continuity to a wall system constructed of stack bond masonry, the Code requires a minimum area of horizontal reinforcement equal to 0.00028 times the gross vertical cross-sectional area of the wall based on specified dimensions. This horizontal reinforcement can be in the form of bed joint steel placed in the mortar joints or bond beam steel spaced no further than 48 inches (1,219 mm) apart. The table below summarizes the maximum vertical spacing of bed joint reinforcement of various diameters to comply with this Code requirement.

Additional seismic detailing requirements may apply to stack bond shear walls assigned to Seismic Design Category D, E, or F. (Refer to Figure 1E.10.)



Specified Masonry Width	Maximum Spacing of W1.7 (MW 11) Bed Joint Reinforcement	Maximum Spacing of W2.8 (MW 17) Bed Joint Reinforcement
3 5/8 in. (92 mm)	32 in. (813 mm)	48 in. (1,219 mm)
5 5/8 in. (143 mm)	16 in. (406 mm)	32 in. (813 mm)
7 5/8 in. (194 mm)	16 in. (406 mm)	24 in. (610 mm)
9 5/8 in. (245 mm)	8 in. (203 mm)	16 in. (406 mm)
11 5/8 in. (295 mm)	8 in. (203 mm)	16 in. (406 mm)

Last Modified: October, 2002



SECTION 1F - ESTIMATING MATERIAL QUANTITIES

Estimating the quantity or volume of materials used in a typical masonry project can range from the relatively simple task associated with an unreinforced single wythe garden wall, to the comparatively difficult undertaking of a partially grouted multiwythe wall coliseum constructed of varying unit sizes, shapes, and configurations.

Large projects, due to their complexity in layout and detailing, often require detailed computer estimating programs or an intimate knowledge of the project to achieve a reasonable estimate of the materials required for construction. However, for smaller projects, or as a general means of obtaining ballpark estimates, the rule of thumb methods described in this section provide a practical means of determining the quantity of materials required for a specific masonry construction project.

It should be stressed that the information for estimating materials quantities in this section should be used with caution and checked against rational judgment. Design issues such as non-modular layouts or numerous returns and corners can significantly increase the number of units and the volume of mortar or grout required to construct a project. Often, material estimating is best left to the mason contractor who has developed a second hand disposition for estimating masonry material requirements.

Estimating Concrete Masonry Units

Probably the most straightforward material to estimate for most masonry construction projects is the units used in construction. The most direct means of determining the number of concrete masonry units needed for any project is to simply determine the total square footage of each wall and divide by the surface area provided by a single unit specified for the project.

For conventional units having nominal heights of 8 inches (203 mm) and nominal lengths of 16 inches (406 mm), the exposed surface area of a single unit in the wall is $\frac{5}{8}$ ft² (0.08 m²). Including a small allowance for waste and breakage, this translates to 119 units per 100 ft² (9.29 m²) of wall area. (Note, this value would double for half-length or half-height units.) Because this method of determining the necessary number of concrete masonry for a given project is independent of the unit width, it can be applied to estimating the number of units required regardless of their width.

When using this method of estimating the number of units required, the area of windows, doors, and other openings in the wall surface needs to be subtracted from the total wall area to yield the net masonry surface. Similarly, if varying unit configurations, such as pilaster units, corner units, or bond beam units are to be incorporated into the project, the number of units used in these applications need to be calculated separately and subtracted from the total number of units required.

Estimating Mortar Materials

Next to grout, mortar is probably the most commonly misestimated masonry construction material. Variables such as site batching versus pre-bagged mortar, mortar proportions, construction conditions, unit tolerances, work stoppages, combined with numerous other variables can lead to large deviations in the quantity of mortar required for comparable jobs.

As such, masons have developed general rules of thumb for estimating the quantity of mortar required to lay concrete masonry units. These general guidelines are as follows for various mortar types:

Masonry Cement Mortar

One 70 pound (31.8 kg) bag of masonry cement will generally lay approximately 30 hollow units if face shell bedding is used. For common batching proportions, 2,000 pounds (907 kg) of masonry sand is required for each 8 bags of masonry cement.

Pre-Bagged Mortar

The standard 40 pound (18.1 kg) bag of pre-blended mortar (which contains cement, lime, and sand) will lay approximately 16 hollow units if face shell bedding is used.

Portland Cement Lime Mortar

One 94 pound (42.6 kg) bag of portland cement, mixed in proportion with sand and lime to yield a lean Type S or rich Type N mortar, will lay approximately 60 hollow units if face shell bedding is used.

Estimating Grout

The quantity of grout required on a specific job can vary greatly depending upon the specific circumstances of the project. The properties and configuration of the units used in construction can have a huge impact alone. For example, units of low density tend to absorb more water from the mix than comparable units of higher density. Further, the method of delivering grout to a masonry wall (pumping versus bucketing) can introduce different amounts of waste. Although the absolute volume of grout waste seen on a large project may be larger than a comparable small project, smaller projects may experience a larger percentage of grout waste.

The following table provides guidance for the required volume of grout necessary to fill the vertical cells of walls of varying thickness. Additional grout may be necessary for grouting (horizontally) discrete courses of masonry. Walls constructed of 4-inch (102 mm) masonry units are not included in the table below. Due to the small cell size and difficulty in adequately placing and consolidating the grout, it is not recommended to grout conventional 4-inch (102 mm) units.

Table 1F.1 Grout Volume Estimation						
Wall Construction	Grout Spacing	Mortar Bedding	Volume of Grout (ft ³) per 100 ft ² of Wall (m ³ per 100 m ²)			
			6 inch (152 mm)	8 inch (203 mm)	10 inch (254 mm)	12 inch (305 mm)
Hollow	8 in.	Full	25.6 (7.8)	36.1 (11.0)	47.0 (14.3)	58.9 (18.0)
Hollow	16 in.	Face shell	12.8 (3.9)	18.1 (5.5)	23.5 (7.2)	29.5 (9.0)
Hollow	24 in.	Face shell	8.6 (2.6)	12.1 (3.7)	15.7 (4.8)	19.7 (6.0)
Hollow	32 in.	Face shell	6.4 (2.0)	9.1 (2.8)	11.8 (3.6)	14.8 (4.5)
Hollow	40 in.	Face shell	5.2 (1.6)	7.3 (2.2)	9.4 (2.9)	11.8 (3.6)
Hollow	48 in.	Face shell	4.3 (1.3)	6.1 (1.9)	7.9 (2.4)	9.9 (3.0)
Hollow	56 in.	Face shell	3.7 (1.1)	5.2 (1.6)	6.8 (2.1)	8.5 (2.6)
Hollow	64 in.	Face shell	3.2 (1.0)	4.6 (1.4)	5.9 (1.8)	7.4 (2.3)
Hollow	72 in.	Face shell	2.9 (0.9)	4.1 (1.2)	5.3 (1.6)	6.6 (2.0)
Hollow	80 in.	Face shell	2.6 (0.8)	3.7 (1.1)	4.7 (1.4)	5.9 (1.8)
Hollow	88 in.	Face shell	2.4 (0.7)	3.3 (1.0)	4.3 (1.3)	5.4 (1.6)
Hollow	96 in.	Face shell	2.2 (0.7)	3.1 (0.9)	4.0 (1.2)	5.0 (1.5)
Hollow	104 in.	Face shell	2.0 (0.6)	2.8 (0.9)	3.7 (1.1)	4.6 (1.4)
Hollow	112 in.	Face shell	1.9 (0.6)	2.6 (0.8)	3.4 (1.0)	4.3 (1.3)
Hollow	120 in.	Face shell	1.8 (0.5)	2.5 (0.8)	3.2 (1.0)	4.0 (1.2)

Last Modified: October, 2002

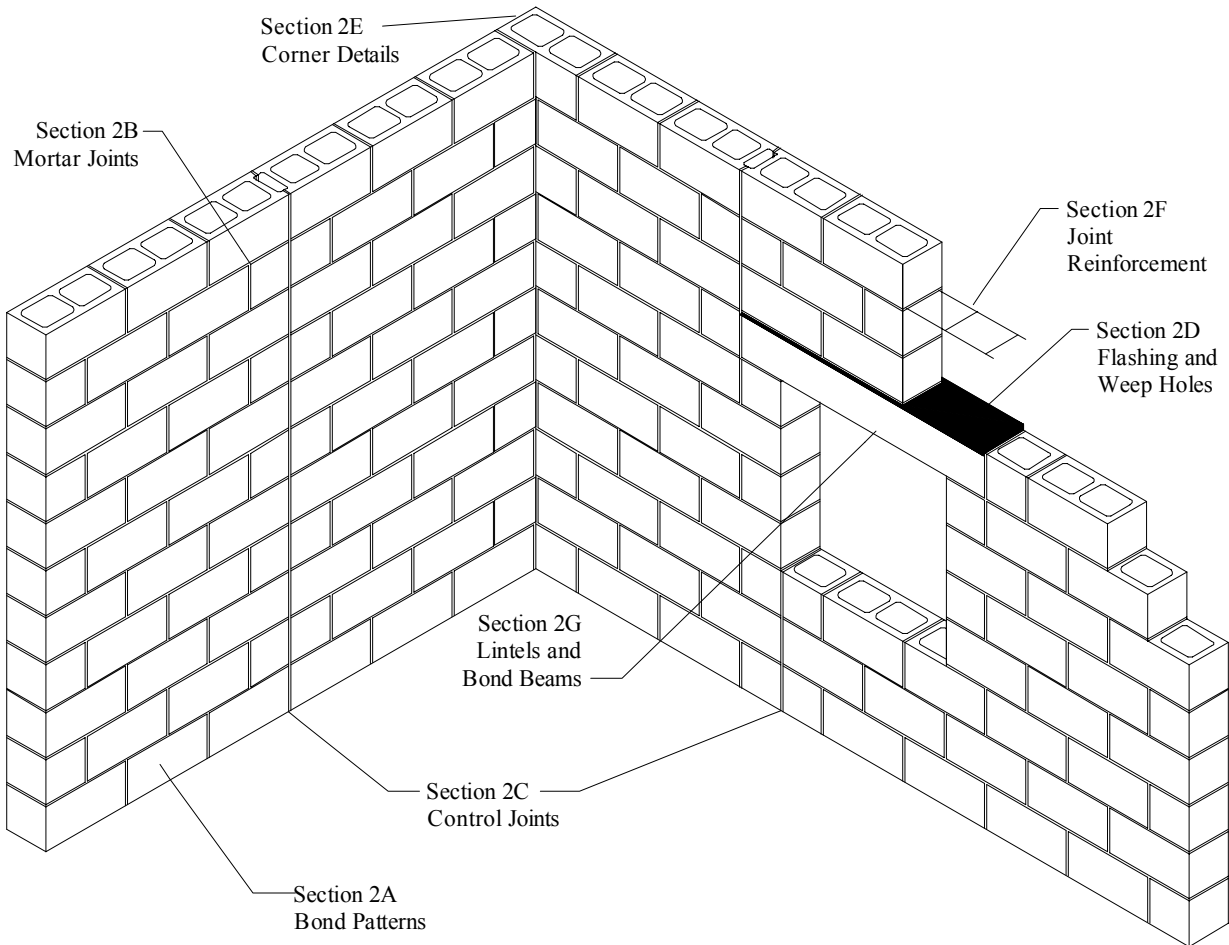
CHAPTER 1 REFERENCES

- 1.1 *Metric Design Guidelines for Concrete Masonry Construction*, TR-172, National Concrete Masonry Association, 2000.
- 1.2 *Standard Specification for Concrete Brick*, ASTM C 55-01a, American Society for Testing and Materials, 2001.
- 1.3 *Standard Specification for Calcium Silicate Face Brick (Sand-Lime Brick)*, ASTM C 73-99a, American Society for Testing and Materials 2001.
- 1.4 *Standard Specification for Loadbearing Concrete Masonry Units*, ASTM C 90-01a, American Society for Testing and Materials, 2001.
- 1.5 *Standard Specification for Nonloadbearing Concrete Masonry Units*, ASTM C 129-01a, American Society for Testing and Materials, 2001.
- 1.6 *Standard Specification for Solid Concrete Interlocking Paving Units*, ASTM C 936-01, American Society for Testing and Materials, 2001.
- 1.7 *Standard Specification for Segmental Retaining Wall Units*, ASTM C 1372-01a, American Society for Testing and Materials, 2001.
- 1.8 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02, Reported by the Masonry Standards Joint Committee, 2002.
- 1.9 *Specification for Masonry Structures*, ACI 530.1-02/ASCE 6-02/TMS 602-02, Reported by the Masonry Standards Joint Committee, 2002.
- 1.10 *Standard Test Methods of Sampling and Testing Concrete Masonry Units and Related Units*, ASTM C 140-01a , American Society for Testing and Materials, 2001.
- 1.11 *Standard Specification for Mortar for Unit Masonry*, ASTM C 270-01a, American Society for Testing and Materials, 2001.
- 1.12 *Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry*, ASTM C 780-00, American Society for Testing and Materials, 2000.
- 1.13 *Standard Specification for Grout for Masonry*, ASTM C 476-01, American Society for Testing and Materials, 2001.
- 1.14 *Standard Test Method for Sampling and Testing Grout*, ASTM C 1019-00b, American Society for Testing and Materials, 2001.
- 1.15 *Standard Test Method for Compressive Strength of Masonry Prisms*, ASTM C 1314-01a, American Society for Testing and Materials, 2001.
- 1.16 *Inspection of Concrete Masonry Construction*, TR-156, National Concrete Masonry Association, 2000.
- 1.17 *Annotated Guide to Masonry Specifications*, The Masonry Society.
- 1.18 *Crack Control for Concrete Masonry*, TEK 10-2A 1999, National Concrete Masonry Association, 2000.
- 1.19 *Concrete Masonry Shapes and Sizes Manual*, CM 260A, National Concrete Masonry Association, 1997.
- 1.20 *Masonry Designers' Guide*, Third Edition, Council for Masonry Research and The Masonry Society, Ed. Matthys, John, 2001.
- 1.21 *Standard Guide for Modular Coordination of Clay and Concrete Masonry Units*, ASTM E 835-93 (1999), American Society for Testing and Materials, 2001.

CHAPTER 2 - UNIVERSAL DETAILING REQUIREMENTS

This chapter contains details that apply to most, if not all, construction projects incorporating concrete masonry. As with other chapters in this manual, each detail is accompanied by commentary that highlights important design and construction considerations and their potential impact on the quality and performance of the masonry.

Section 2A covers bond patterns for masonry construction. While bond patterns are varied primarily for an aesthetic impact, their selection and use may have structural implications as well. Section 2B provides guidance for the selection of mortar types based on the exposure and intended application of the masonry system or element. Like bond patterns, the selected mortar joint profile can also influence the aesthetic appearance of the constructed element. However, unlike bond patterns, the selected mortar joint profile can have an impact on the long-term performance of a masonry assemblage. Section 2C reviews recommended control joint details. Control joints are primarily applicable to exposed concrete masonry construction, where the appearance of shrinkage cracks will detract from the wall's aesthetics. Section 2D illustrates proper flashing techniques to ensure water is directed to the exterior of a masonry wall before it can penetrate through to the interior. Section 2E contains methods of constructing corners while minimizing the need for cutting units. Such coordination can significantly impact the overall cost of masonry construction. Section 2F summarizes recommended applications for bed joint reinforcement. Bed joint reinforcement can be used both as primary structural steel and to help minimize the appearance of shrinkage cracks. Section 2G details lintels (both precast and masonry) and special units configurations for use in concrete masonry walls.



Last Modified: October, 2002

SECTION 2A - BOND PATTERNS

The term bond can generally refer to two different topics within masonry design and construction; the adhesive or mechanical interlock between mortar and units or the arrangement of units to achieve a desired pattern. This section addresses the latter of these subjects.

Concrete masonry bond patterns can be created by: varying the unit heights and/or lengths; varying the length the units overlap from one course to the next; varying the orientation of the units; as well as by using units of different configurations in the same wall. Implementing one or more of these alternatives can subtly or dramatically alter the appearance of a finished wall.

Bond patterns can be varied to create a near infinite number of appearances and styles. The aesthetic impact created by a specific bond pattern can be even more dramatic when combined with units of varying color or texture.

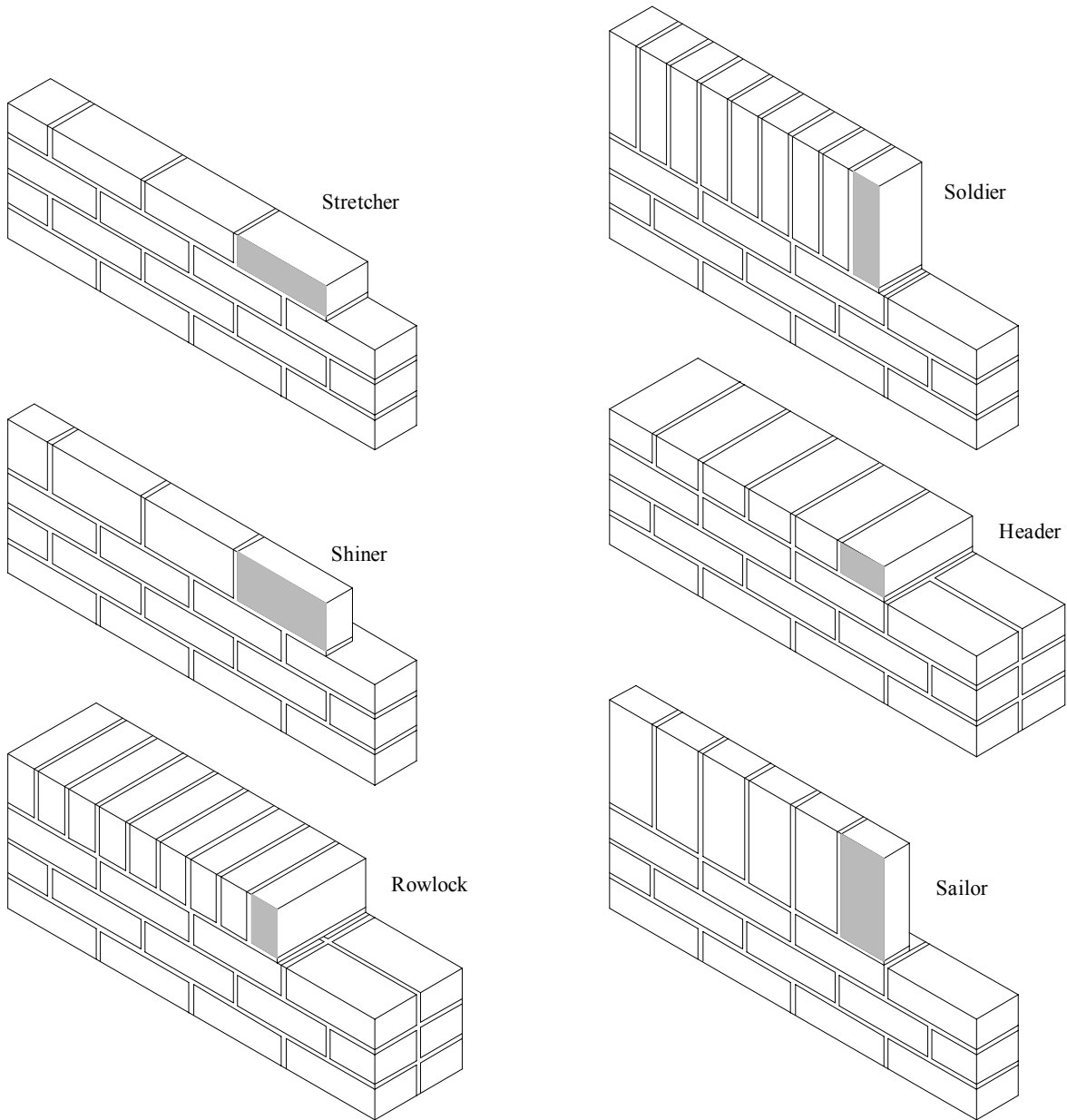
The evolution of various masonry bond patterns has continued for centuries. As such, regional differences in terminology or construction practices have developed. The designer should be cautioned against specifying unique or complex bond patterns without thoroughly communicating the intent to the mason contractor.

When specifying a unique bond pattern, elevation drawings for a particular project should clearly illustrate the intended final appearance of the structure. Also, when specifying a bond pattern that incorporates unique or nonstandard unit sizes, the availability of such units should first be verified with local manufacturers.

Unit Orientation

Chapter 10 of this manual provides a detailed listing of definitions for various masonry terms. Certain terms are used to describe the masonry unit orientation as it is laid in the wall (refer to figures below). Most concrete masonry is constructed with units laid as stretchers, that is, with the unit length horizontal in the wall and the unit height oriented vertically. Varying the unit orientation as detailed below is primarily applicable only to solid or brick concrete masonry units.

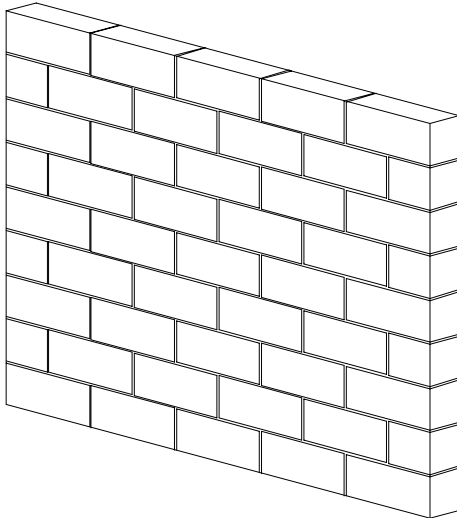
The nomenclature shown below applies to the orientation of a unit in a wall and not to any physical properties of the unit. Figure 2A.6 illustrates several bond patterns using brick size units in multiwythe construction.



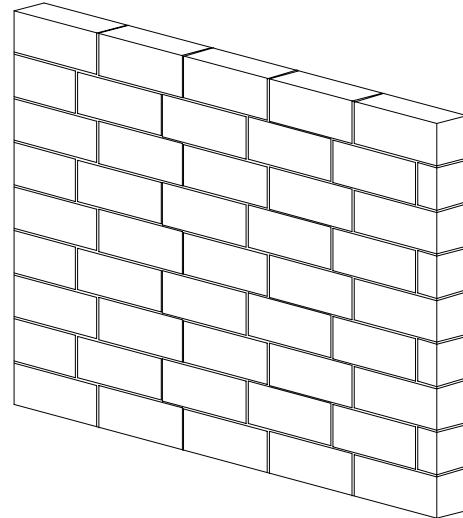
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Running Bond

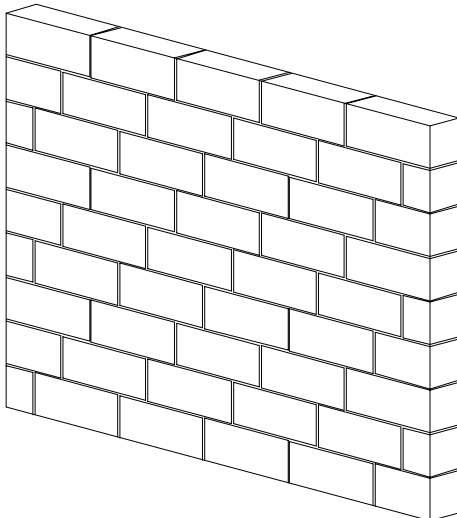
The most traditional bond pattern for concrete masonry is running bond. Of the various running bond patterns available, the most common is half bond, where vertical head joints of successive courses are offset by one-half the unit length. Building code design provisions are based primarily on structural research of wall panels laid in running bond construction. As such, the *Specification for Masonry Structures* (Ref. 2.2) requires the use of running bond unless otherwise specified. When a different bond pattern is used, the designer should consider its influence on the performance and structural capacity of the element as defined by the governing building code. In each of the details below, the nominal height and length of the units shown is provided.



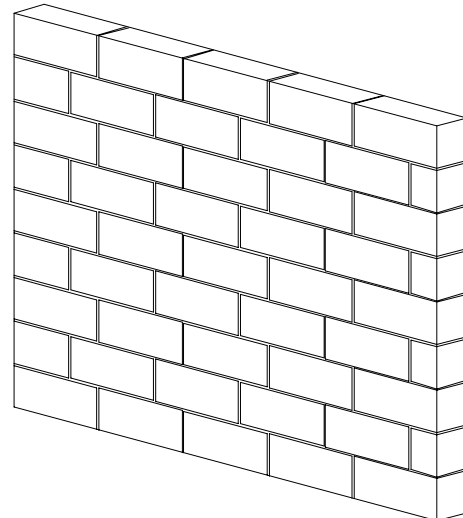
Running (Half) Bond
 Standard unless otherwise specified
 (8x16 inch (203x406 mm) units shown)



One-Fourth Running Bond
 Patterned offset
 (8x16 inch (203x406 mm) units shown)



One-Third Running Bond
 Staggered offset
 (8x16 inch (203x406 mm) units shown)

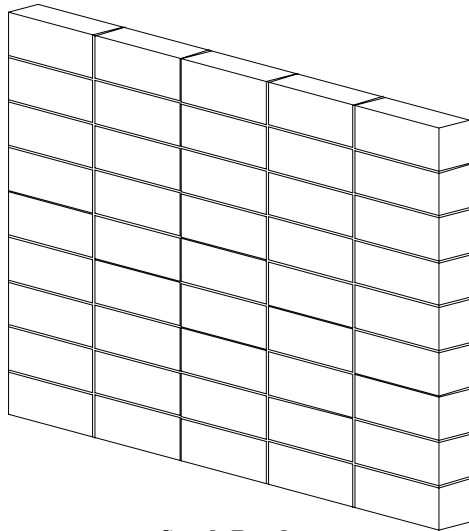


One-Third Running Bond
 Patterned offset
 (8x16 inch (203x406 mm) units shown)

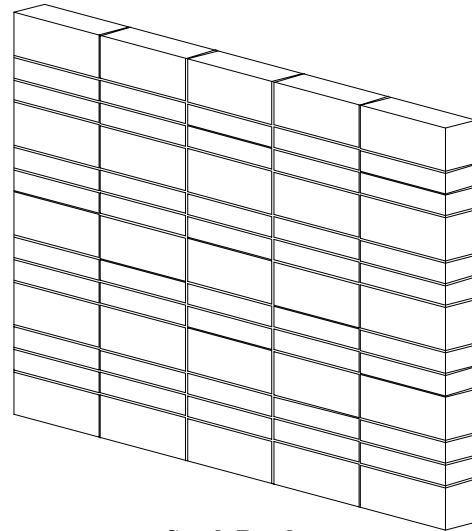
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Stack Bond

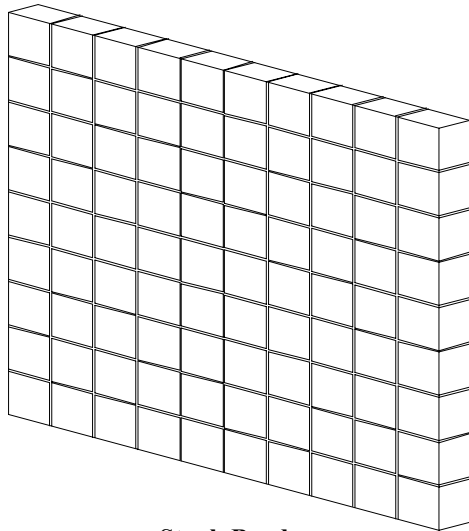
Second to running bond, the most commonly used bond pattern in concrete masonry construction is stack bond. Stack bond construction typically refers to masonry laid such that the head joints are vertically aligned. In accordance with the *Building Code Requirements for Masonry Structures* (Ref. 2.1), any bond pattern laid such that the head joints in successive courses are horizontally offset less than one quarter of the units' length (to which stack bond would apply) is defined as 'other than running bond'. To ensure structural continuity along the length of a wall constructed in stack bond the *Building Code Requirements for Masonry Structures* (Ref. 2.1) requires a minimum amount of horizontal reinforcing steel to be included. (See Figure 1E.21.)



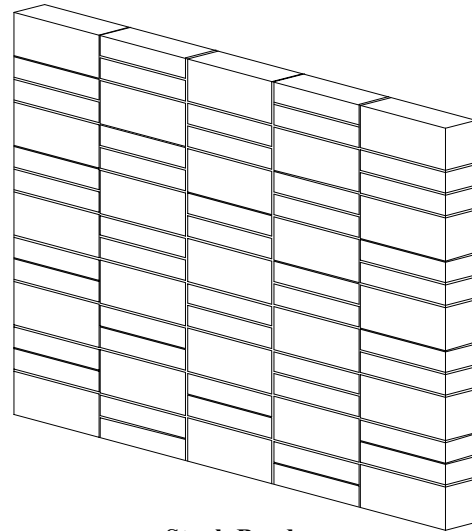
Stack Bond
 (8x16 inch (203x406 mm) units shown)



Stack Bond
 (4x16, 8x16 inch (102x406,
 203x406 mm) units shown)



Stack Bond
 (8x8 inch (203x203 mm) units shown)

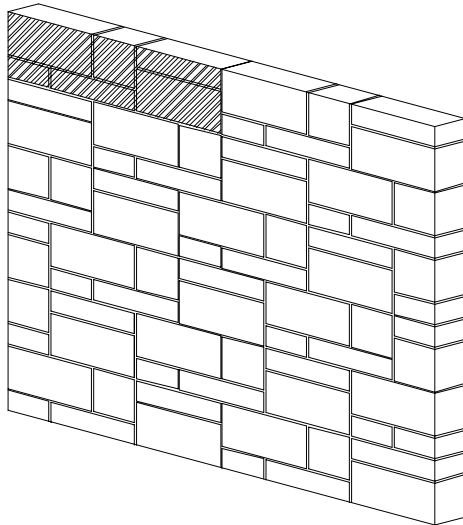


Stack Bond
 (4x16, 8x16 inch (102x406,
 203x406 mm) units shown)

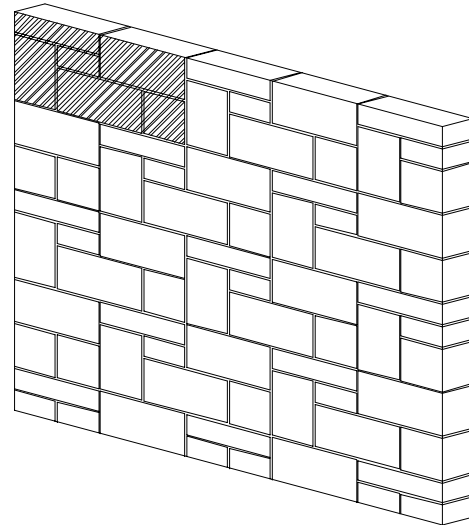
Last Modified: October, 2002

Patterned Ashlar Bond Patterns

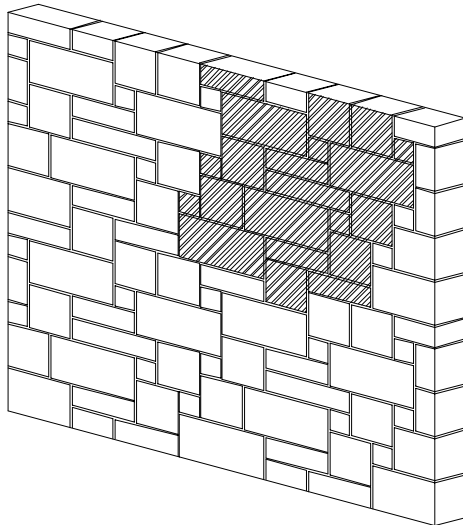
Although patterned ashlar bond pattered can create an appealing finished wall assembly, they can require the use of numerous unit sizes and shapes. Because of the unique orientation of the units, patterned ashlar bond patterns are primarily only applicable to solid concrete masonry units. (The pattern is created by repeating a set configuration of units, which is shown shaded in the figures below.)



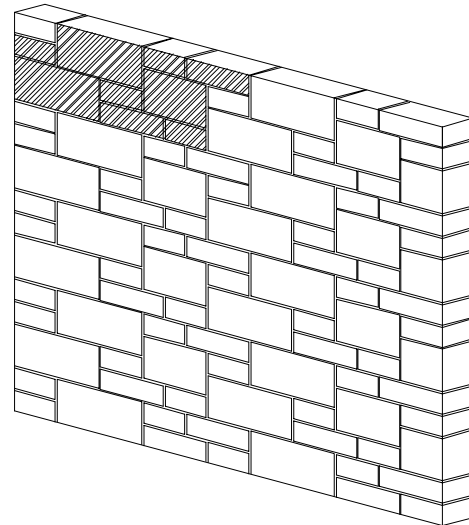
Patterned Ashlar Bond
 (4x8, 4x16, 8x8, 8x16 inch (102x203, 102x406, 203x203, 203x406 mm) units shown)



Patterned Ashlar Bond
 (4x8, 4x16, 8x8, 8x16, 12x8 inch (102x203, 102x406, 203x203, 203x406 305x203 mm) units shown)



Patterned Ashlar Bond
 (4x4, 4x12, 4x16, 8x8, 8x16 inch (102x102, 102x305, 102x406, 203x203, 203x406 mm) units shown)

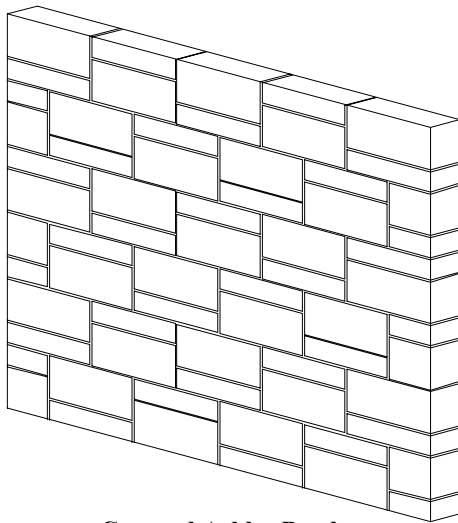


Patterned Ashlar Bond
 (4x8, 4x12, 8x12, 8x16 inch (102x203, 102x305, 203x305, 203x406 mm) units shown)

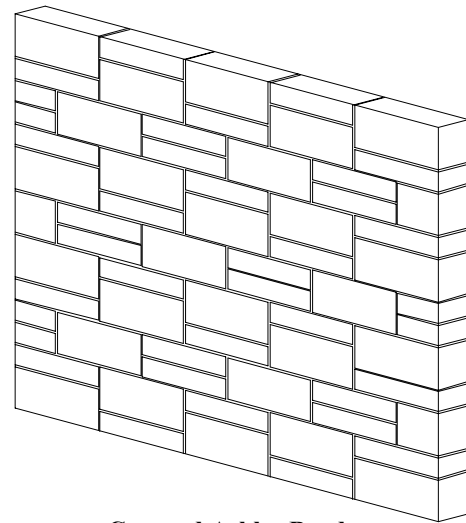
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Coursed Ashlar Bond Patterns

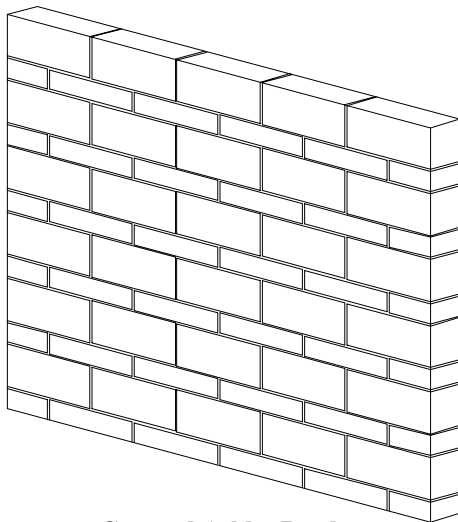
A merging of running bond and patterned ashlar bond patterns create a coursed ashlar appearance. The benefit of a coursed bond over a patterned ashlar bond is that coursed ashlar more readily permits construction using hollow units and the incorporation of vertical reinforcement within the cells of the units.



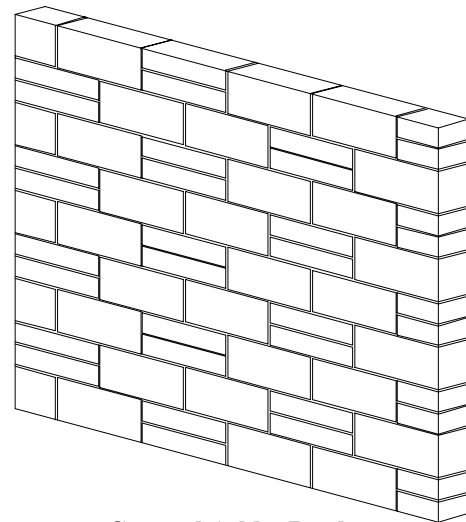
Coursed Ashlar Bond
(4x16, 8x16 inch (102x406,
203x406 mm) units shown)



Coursed Ashlar Bond
(4x16, 8x16 inch (102x406,
203x406 mm) units shown)



Coursed Ashlar Bond
(4x16, 8x16 inch (102x406,
203x406 mm) units shown)

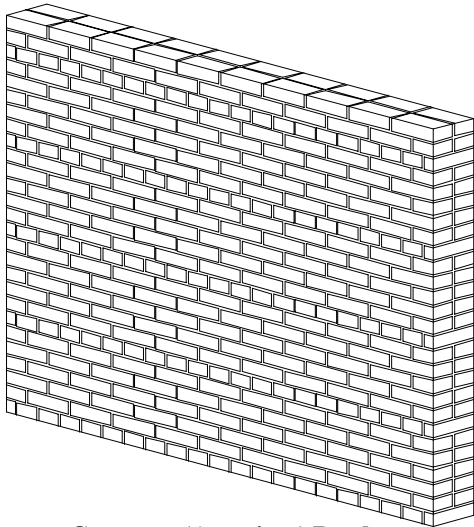


Coursed Ashlar Bond
(4x16, 8x16 inch (102x406,
203x406 mm) units shown)

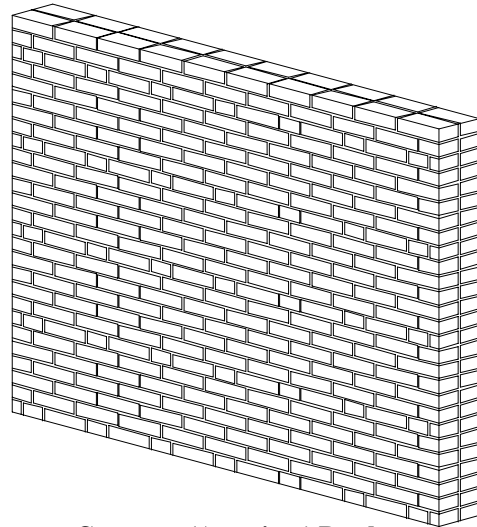
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Multiwythe Bond Patterns

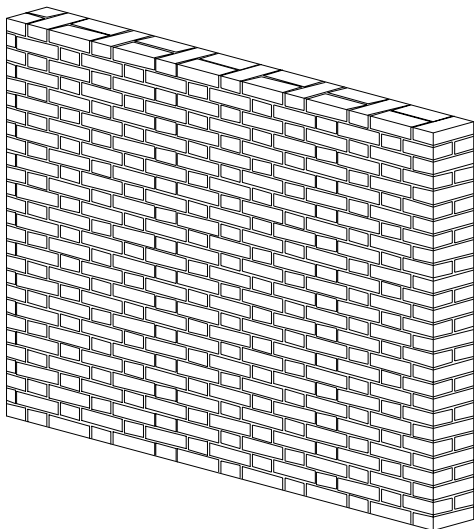
Composite masonry walls are typically constructed with wall ties to structurally tie two or more wythes of masonry together (see Figure 1E.19), although it is possible to construct composite walls using masonry headers or rowlocks. When units are used to tie wythes of masonry together, a common or Flemish bond pattern is typically used. Although the use of headers is allowed by the Code (Ref. 2.1), it is no longer a typical or recommended practice because of the tendency for water penetration across the headers and the overall increase in the cost of construction. In addition, headers are inherently less ductile than metal wall ties. Hence, differential movement, particularly with a combination of concrete and clay masonry, can result in the shearing of the headers, effectively eliminating the composite action.



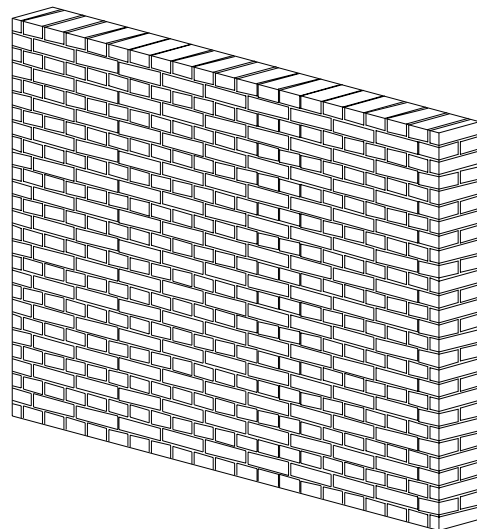
Common (American) Bond
6th Course Headers
(brick units shown)



Common (American) Bond
6th Course Flemish Headers
(brick units shown)



Flemish Bond
(brick units shown)



English Bond
(brick units shown)

Last Modified: October, 2002

2B - MORTAR JOINTS

While mortar generally constitutes less than ten percent of a typical concrete masonry wall surface area, it can significantly influence both long-term and short-term performance of a masonry assemblage. Mortar has several functions in masonry construction. Mortar serves to bond individual unit together, allowing them to act as a composite structural assembly. Conversely, mortar can also act to hold units apart, creating a discrete barrier between units that can accommodate slight variations in dimensional tolerances. Finally, mortar also seals joints against moisture and air leakage while bonding to joint reinforcement, anchors and ties to help ensure all elements perform as a unit.

Masonry mortars have two distinct sets of important properties; those related to plastic mortars and those related to hardened mortars. Many mortar properties are not quantitatively definable in precise terms. As such, the specification of mortars leans heavily on prescriptive measurement and historical precedent.

When selecting a mortar for a specific project, a good rule of thumb is to choose the lowest compressive strength mortar required for structural and durability considerations. Lower compressive strength mortars exhibit better workability, flow, and water retentivity than a comparable higher strength mortar. In general, when considered together, these properties produce a product superior to one incorporating a mortar that was selected solely on compressive strength. While there is no single mortar mix that satisfies all situations, one must consider and evaluate all properties and select the mortar providing the best compromise for the particular requirements.

Building codes generally specify mortar types as referenced in *Standard Specification for Mortar for Unit Masonry*, ASTM C 270 (Ref. 2.4). Four mortar types, M, S, N and O are included in this standard, however, Types M, S and N are typically required by building codes for the construction of structural elements. Building codes may also restrict the use of some mortars for particular applications. For example, in Seismic Design Categories D, E and F as well as for the empirical design of foundation walls, Type S or M mortar is required. Similarly, glass unit masonry requires the use of Type N or S mortar (Ref. 2.1).

As further guidance for the selection and use of masonry mortars, ASTM C 270 includes the following table for specifying mortars based on the intended application:

Guide for the Selection of Masonry Mortars^A

Location	Building Segment	Mortar Type	
		Recommended	Alternative
Exterior, above grade	loadbearing wall	N	S or M
	nonloadbearing wall	O ^B	N or S
	parapet wall	N	S
Exterior, at or below grade	foundation wall, retaining wall, manholes, sewers, pavements, walks, and patios	S ^C	M or N ^C
Interior	loadbearing wall	N	S or M
	nonloadbearing wall	O	N

^A This table does not provide for many specialized mortar uses, such as chimneys, reinforced masonry and acid-resistant mortars.

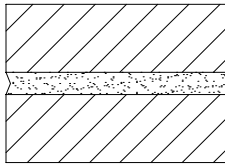
^B Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated, or unlikely to be subjected to high winds or other significant lateral loads. Type N or S mortar should be used in such cases.

^C Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to weathering. Mortar for such masonry should be selected with due caution.

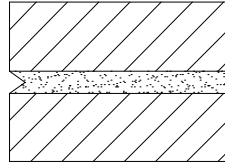
Mortar Joints

Head and bed joints are typically $\frac{3}{8}$ inch (9.5 mm) thick (see Figure 1D.1), except for the initial bed joint at foundations, which can range from $\frac{1}{4}$ to $\frac{3}{4}$ inch (6.4 to 19 mm) to accommodate surface irregularities in the foundation. Mortar should extend fully across the thickness of the face shells of hollow units so that both head and bed joints will be completely filled. Solid units are required to be fully bedded in mortar. All voids in mortar joints (except weep holes) should be filled with mortar and tooled. While it is important to provide sufficient mortar to properly bed concrete masonry units, mortar should not extend excessively into drainage cavities or into cores to be grouted. For grouted masonry, mortar protruding more than $\frac{1}{2}$ inch (13 mm) into the cells or cavities to be grouted is not permitted (Ref. 2.1).

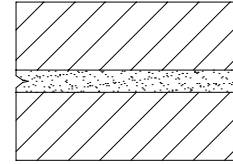
Mortar joints should be tooled when thumbprint hard. For walls exposed to weather, concave or V-shaped joints improve water penetration resistance by directing water away from the wall surface and by compacting the mortar against the concrete masonry unit to seal the joint. Tooling mortar joints also helps to seal the outer surface of the joint. Raked, flush, struck, beaded or extruded joints are not recommended for exterior construction since they generally do not provide as tight a seal and may create ledges that can hold water near the wall face. For walls not exposed to weather, the selection of the joint profile can be based on aesthetics rather than functionality.



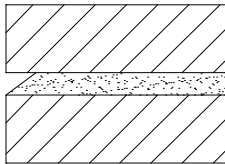
Concave Joint (standard unless otherwise specified)



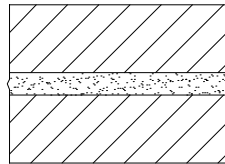
"V" Joint



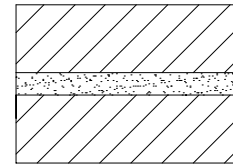
Grapevine Joint



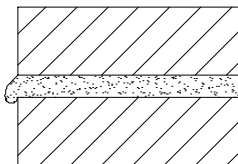
Weather Joint



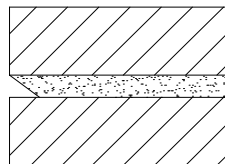
Beaded Joint*



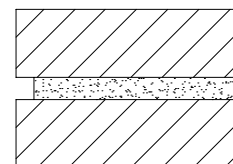
Flush Joint*



Squeezed Joint*



Struck Joint*



Raked Joint*

*Potentially poor weathering joints, not recommended for exterior construction.

SECTION 2C - CONTROL JOINTS

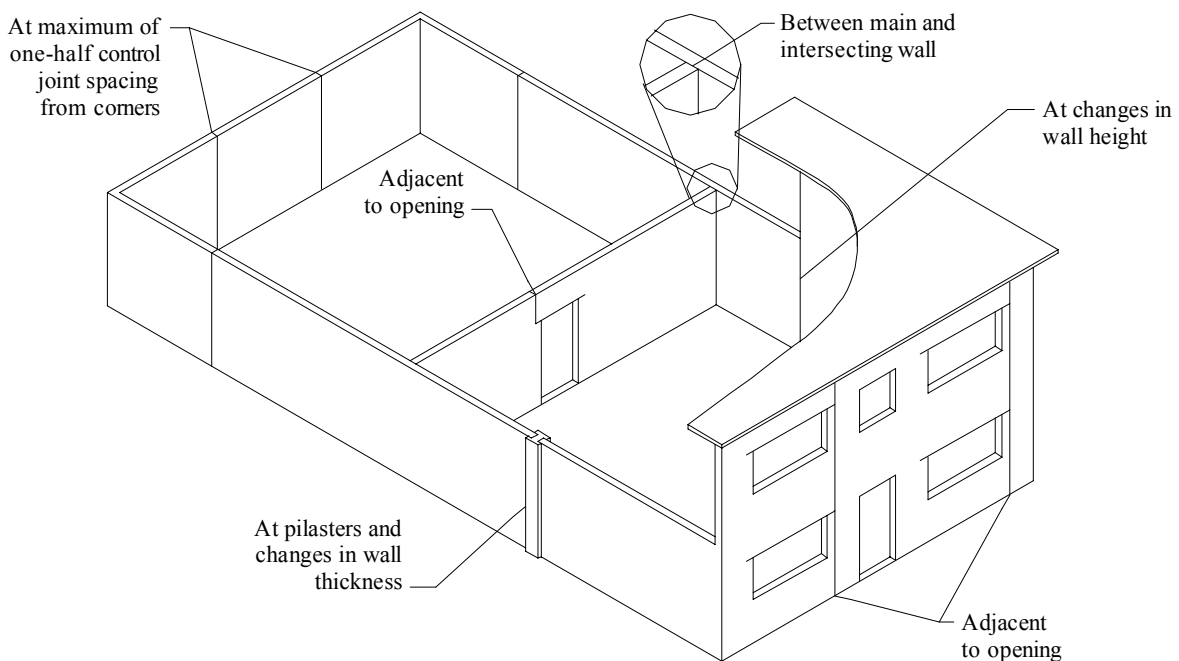
Control joints are planes of weakness built into a masonry wall to reduce restraint and permit longitudinal movement due to anticipated shrinkage. A bond break is accomplished by replacing a vertical mortar joint with a backer rod and sealant. This keeps the joint watertight while accommodating small movements. Joint reinforcement, as well as other horizontal reinforcement, should be discontinued at the control joint unless it is required for structural purposes, as it will act to restrain longitudinal movement.

Control joints are typically only required in exposed concrete masonry walls, where shrinkage cracking may detract from wall aesthetics or reduce water penetration resistance. Shrinkage cracks in concrete masonry walls are usually an aesthetic, rather than a structural concern. Walls with adequate horizontal reinforcement may not require control joints because the reinforcement effectively reduces the width and noticeable appearance of shrinkage cracks. Further, below grade walls traditionally do not require control joints since movement due to shrinkage is less significant in below grade walls due to relatively constant temperature and moisture conditions.

When required, control joints should be located where volume changes or stress concentrations are likely to occur. In addition to empirical criteria for locating control joints (typically at $1\frac{1}{2}$ times the wall height, 25 feet (7.6 m) maximum), care should be taken to provide joints at locations of stress concentrations, such as:

- at changes in wall height,
- at changes in wall thickness, such as at pipe and duct chases and pilasters,
- at (above) movement joints in foundations and floors,
- at (below) movement joints in roofs and floors that bear on a wall,
- near one or both sides of door and window openings (Generally a control joint is placed at one side of an opening less than 6 feet (1.8 m) wide and at both jambs of openings over 6 feet (1.8 m) wide. Control joints can be away from the opening if adequate tensile reinforcement is placed above, below and beside wall openings.), and
- adjacent to corners of walls or intersections within a distance not exceeding one-half the control joint spacing.

Consideration must be given to the effect of control joint placement on load distribution within the wall. For example, locating control joints at the ends of lintels prevents arching action from occurring. Therefore, the lintel must be designed to carry the full weight of the wall above it in addition to any superimposed loads. Detailed criteria for locating control joints is included in TEK 10-2B *Control Joints for Concrete Masonry Walls - Empirical Method* (Ref 2.3).



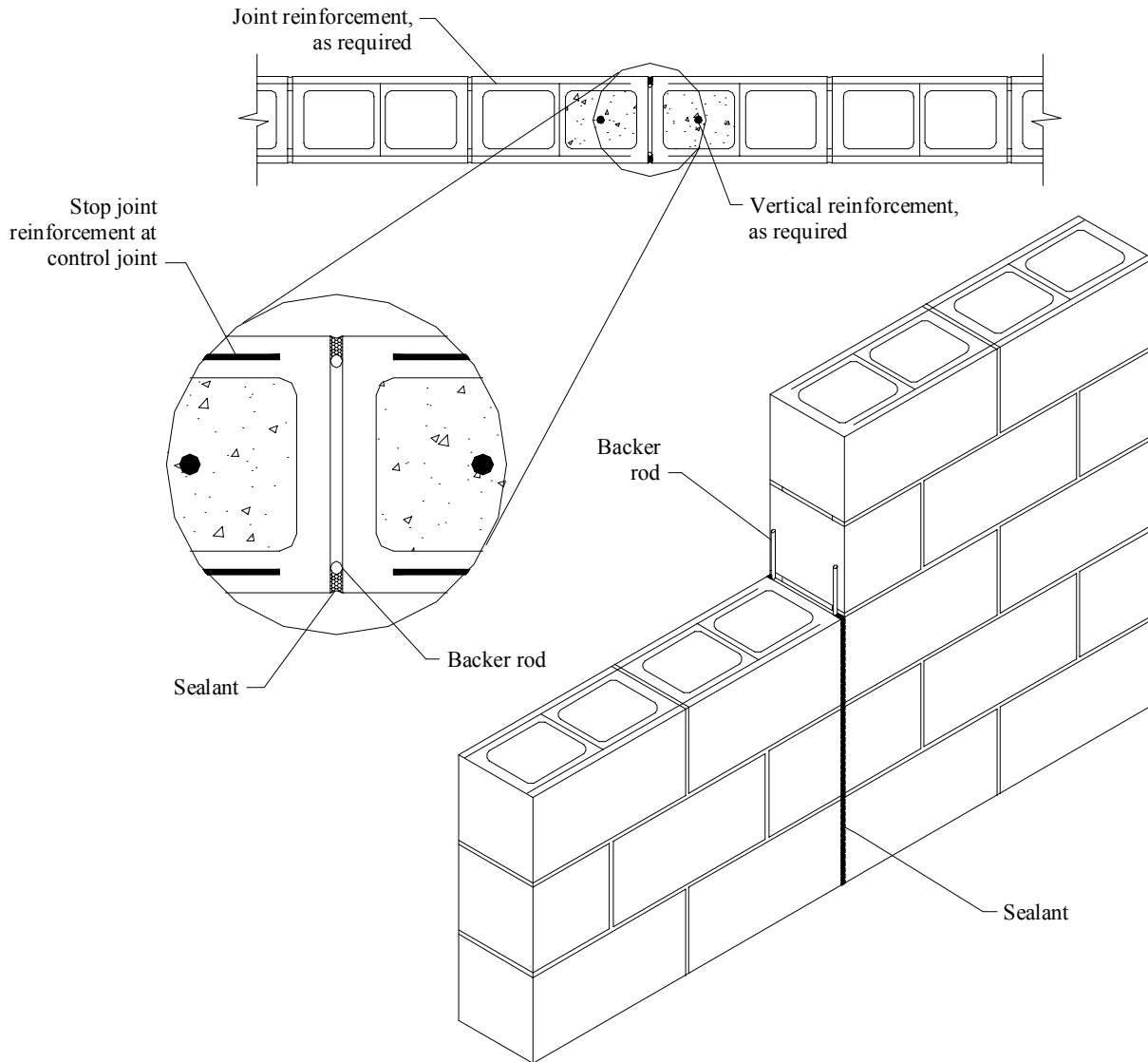
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Standard Control Joints

When the transfer of out-of-plane loads between two panels separated by a control joint is not critical, or when fire resistance is not a controlling design feature, most control joints are constructed simply to provide longitudinal movement and stress relief at specified locations.

To provide a joint that is sealed against the passage of air, water, and sound, caulking or other appropriate sealant is used. Here, and with all similar control joints, the backer rod is installed to provide a uniform foundation for which to apply the sealant.

When horizontal reinforcement is incorporated for the sole purpose of controlling of shrinkage cracking, it should be discontinued at the control joint location. However, when serving as primary structural reinforcement, such as bond beams located at floor and roof levels, the reinforcement should be continuous through the control joint.



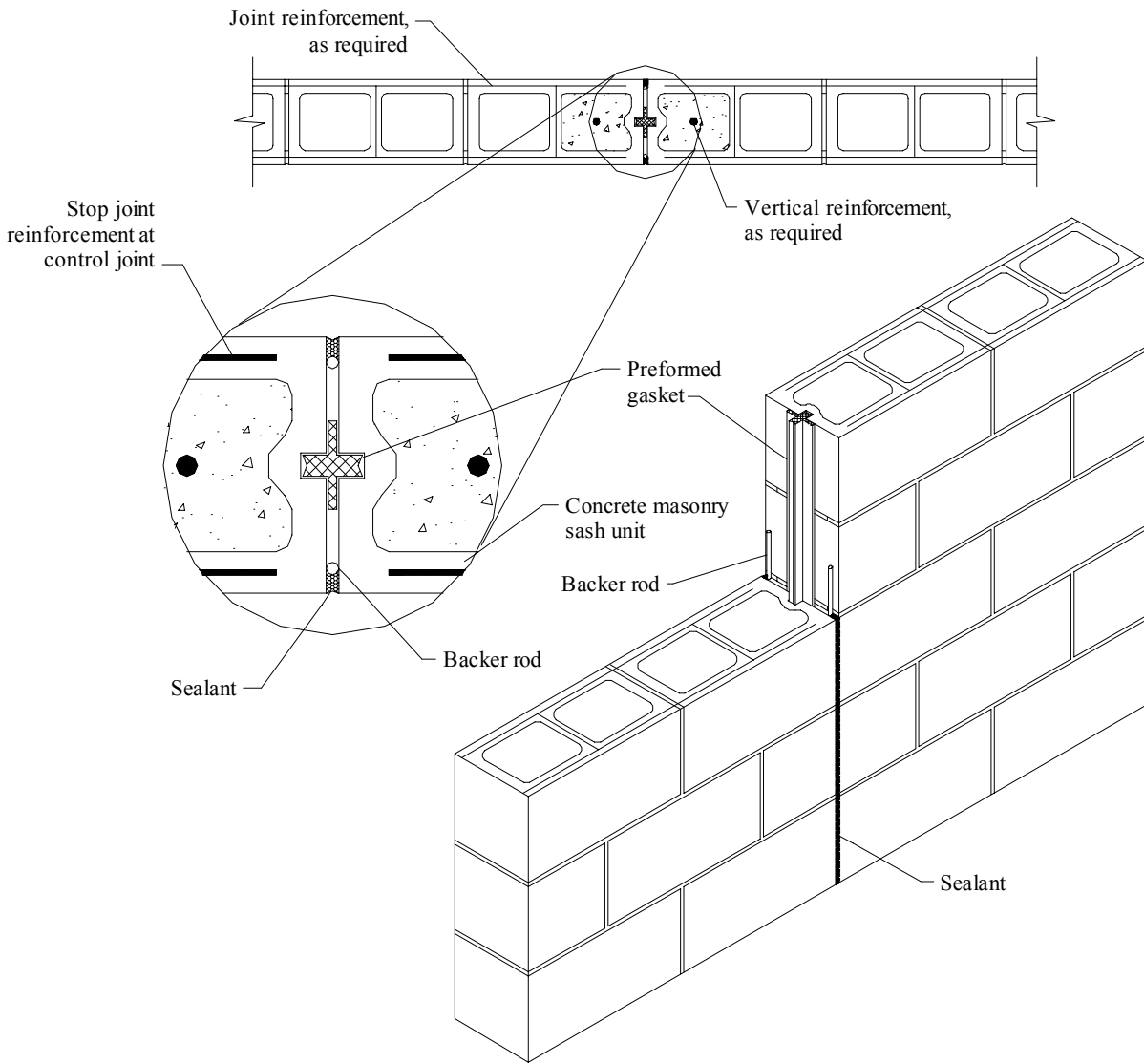
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Control Joints with Preformed Gaskets

Control joints constructed using sash units, which accommodate the flanges of the preformed control joint gaskets, are generally available in either PVC, complying with ASTM D 2287 *Standard Specification for Nonrigid Vinyl Chloride Polymer and Copolymer Molding and Extrusion Compounds* (Ref. 2.9) or rubber compounds, complying with ASTM D 2000 *Standard Classification System for Rubber Products in Automotive Applications* (Ref. 2.10).

When used as a shear key to transfer out-of-plane loads between two panels separated by a control joint containing a preformed gasket, the gasket material should be tested to determine its strength and applicability in this application. This information is generally available from manufacturers of preformed gaskets.

In accordance with *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies* (Ref. 2.11), this control joint will meet the requirements of a two-hour fire resistance rating given the masonry assemblage has at least a two hour fire rating.



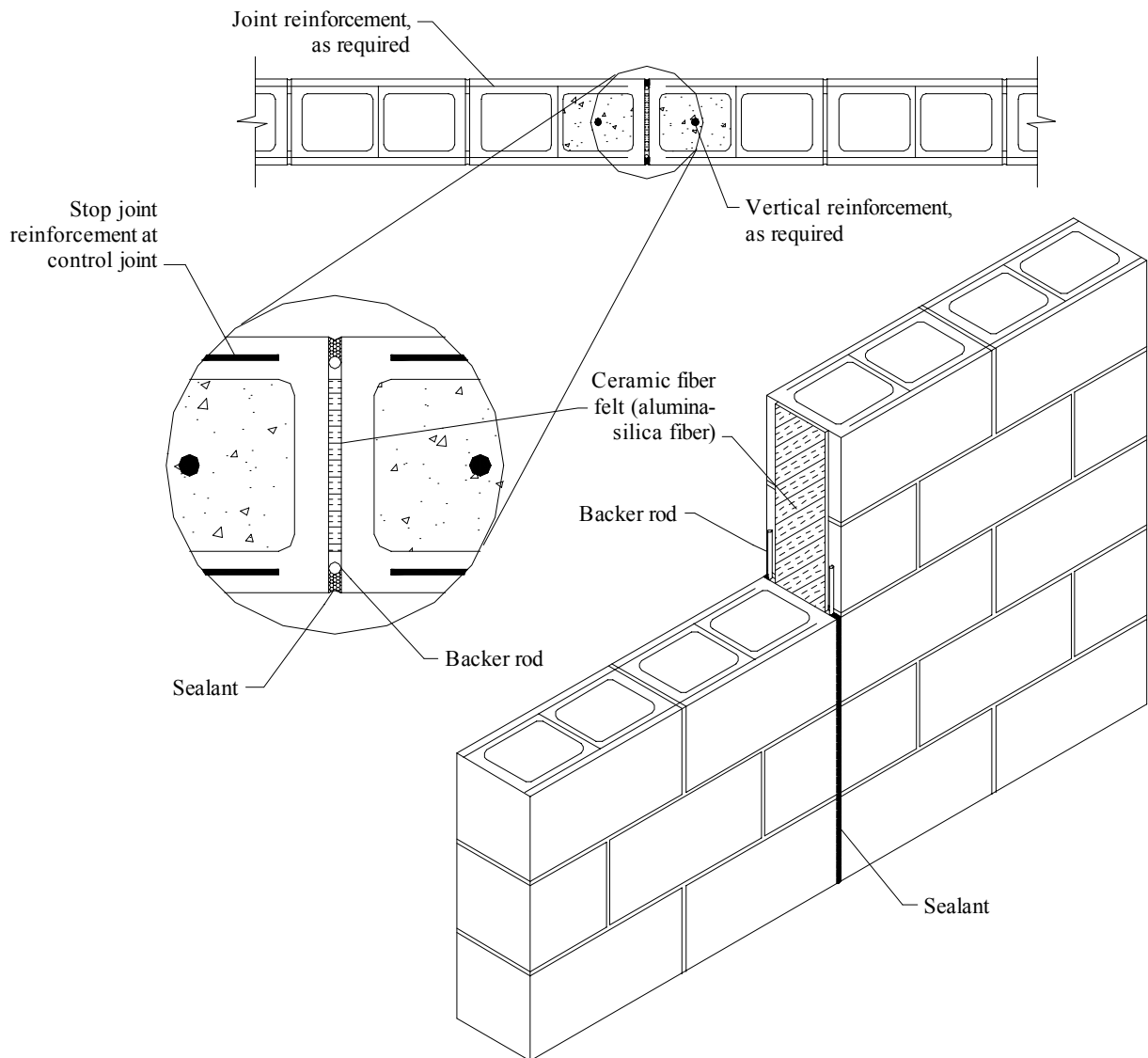
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Control Joints with Ceramic Fiber Felt

When the fire resistance of the assemblage is a controlling design feature, a simple and cost-effective means of constructing a fire-rated control joint is with ceramic fibers.

In accordance with *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies* (Ref. 2.11), this control joint will meet the requirements of a four-hour fire resistance rating.

Because no mechanical interlock is provided between the two panels separated by a ceramic or alumina-silica fiber filled control joint, out-of-plane loads are not transferred across this joint.



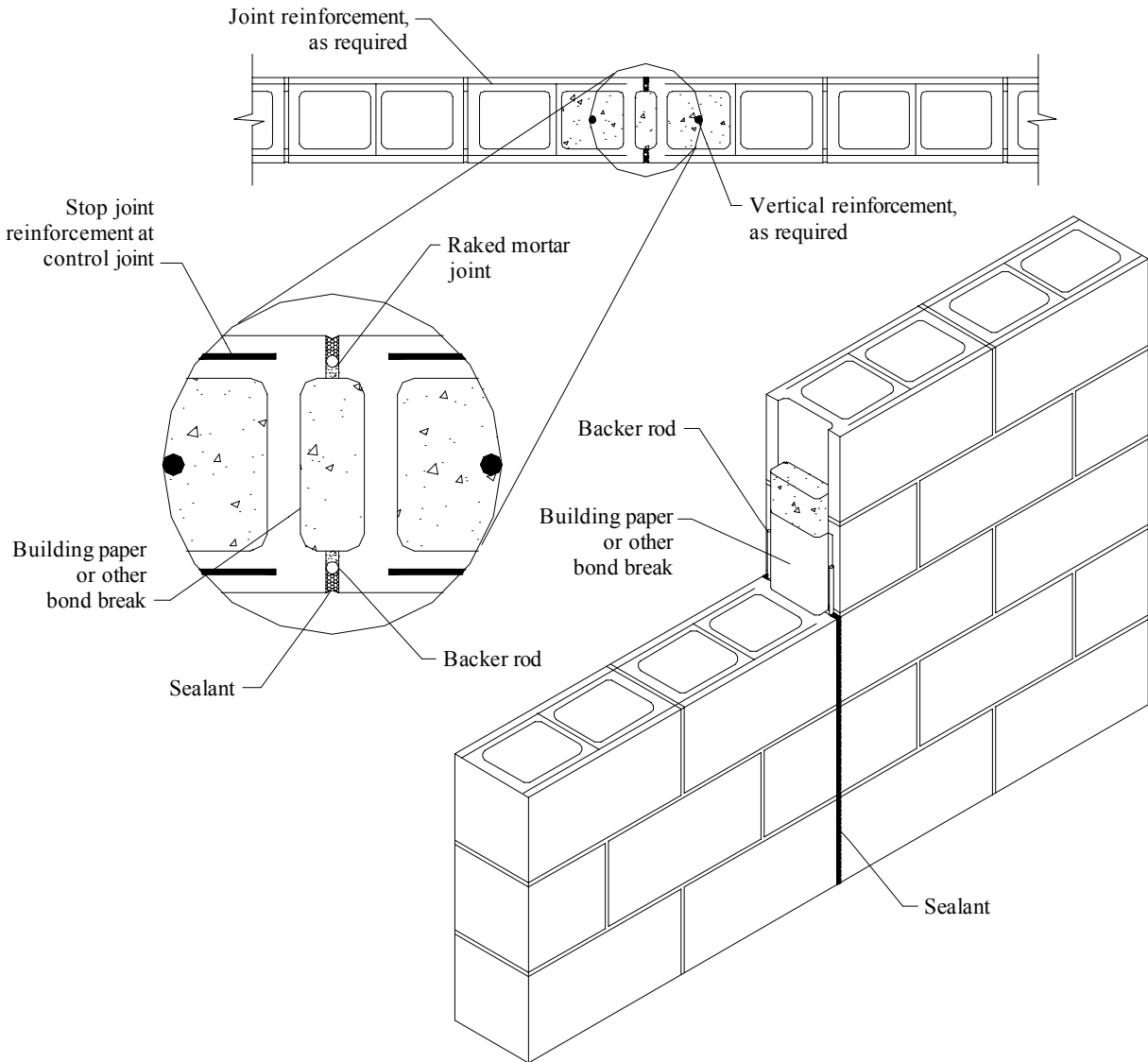
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Keyed Control Joints

When design necessitates the construction of a control joint that provides a rated fire resistance and out-of-plane load transfer, a grouted shear key may be used. For this joint, the out-of-plane load transfer mechanism is provided by filling the adjoined ends of two stretcher units. To help ensure that the grout does not bond to one side of the control joint, thereby invalidating the stress relief between the two panels, building paper or other similar material is installed to break the bond between the grout and the masonry units.

The building paper, or other material serving as a bond break between the grout key and concrete masonry unit, should be terminated behind the backer rod to allow full contact between the sealant and concrete masonry unit.

In accordance with *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies* (Ref. 2.11), this control joint will meet the requirements of a four-hour fire resistance rating.

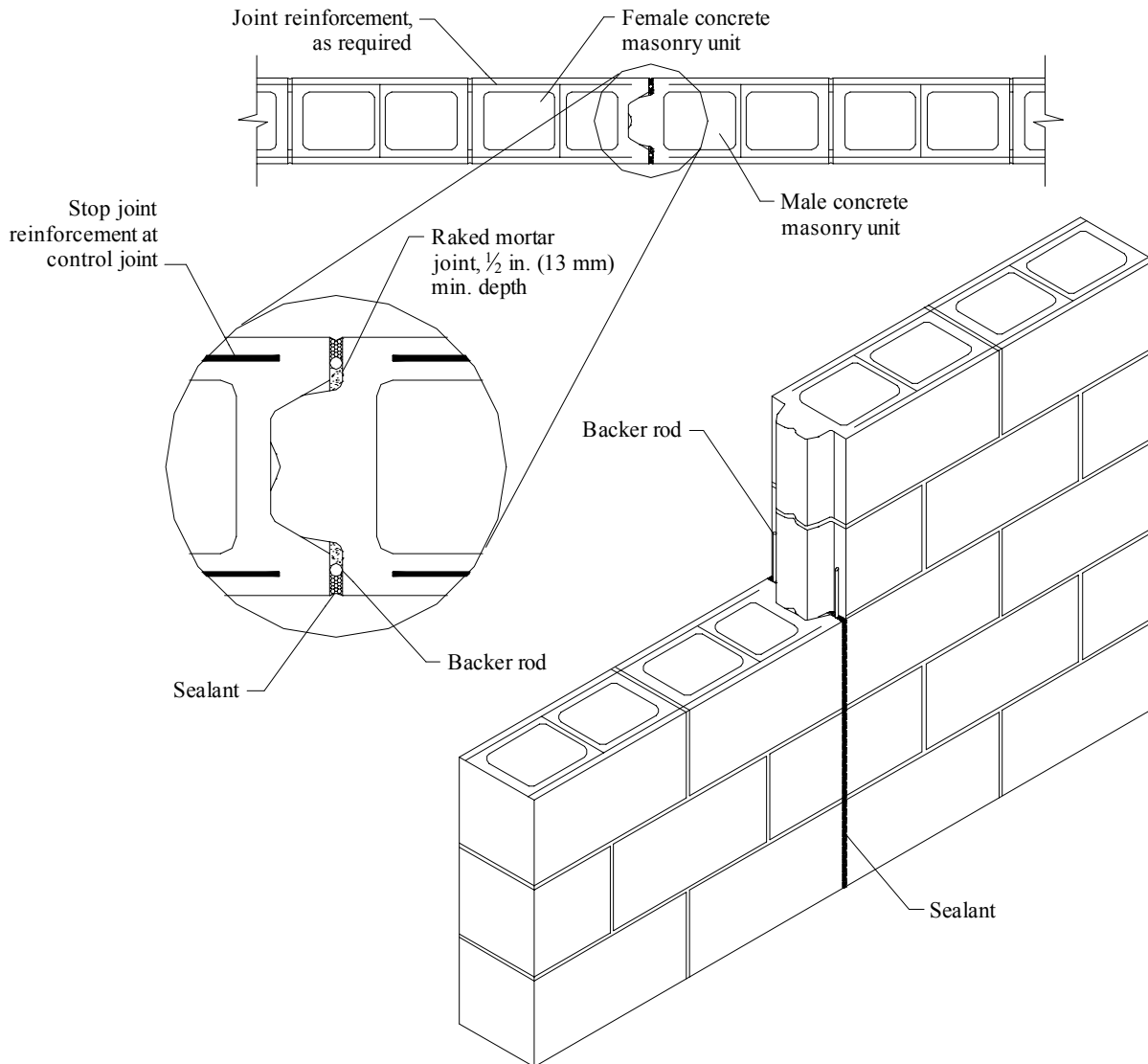


Last Modified: October, 2002

Control Joints with Special Unit Shapes

When design necessitates the construction of a control joint that provides a rated fire resistance and out-of-plane load transfer, another option is the use of special unit configurations such as those illustrated below. Before specifying the use of this type of control joint, the availability of these unit shapes should be verified with local manufacturers. Care should be taken when constructing this type of control joint to ensure that excessive mortar is not placed in the head joint of the two control joint units, which can potentially lead to the bonding of the two panels.

In accordance with *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies* (Ref. 2.11), this control joint will meet the requirements of a four-hour fire resistance rating.



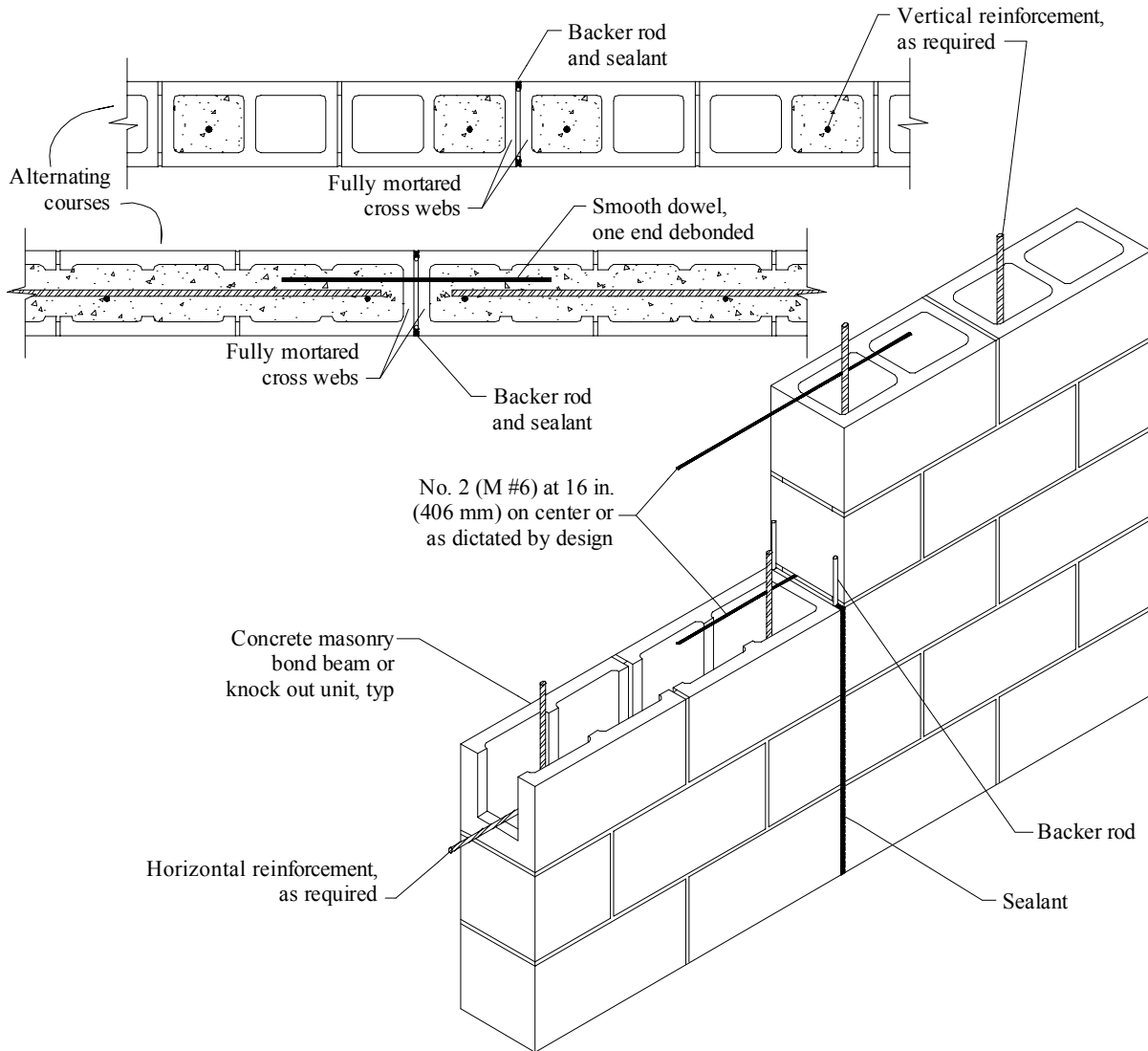
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Control Joint Reinforcement

As discussed in the previous details for control joints, when horizontal reinforcement is incorporated for the sole purpose of controlling shrinkage cracking, it should be discontinued at the control joint location. However, when serving as primary structural reinforcement, such as bond beams located at floor and roof levels, the reinforcement should typically be continuous through the control joint.

When discontinuing horizontal bond beam reinforcement at a control joint, the cross webs directly adjacent to the control joint should be fully mortared to prevent grout from seeping into the head joint and bonding the two masonry panels together.

When out-of-plane load transfer is required between the panels on either side of a control joint, a smooth dowel may be placed across the control joint. So that in-plane differential movement can occur between each masonry panel, one side of the dowel should be greased or otherwise prevented from bonding to the grout in which it is embedded.

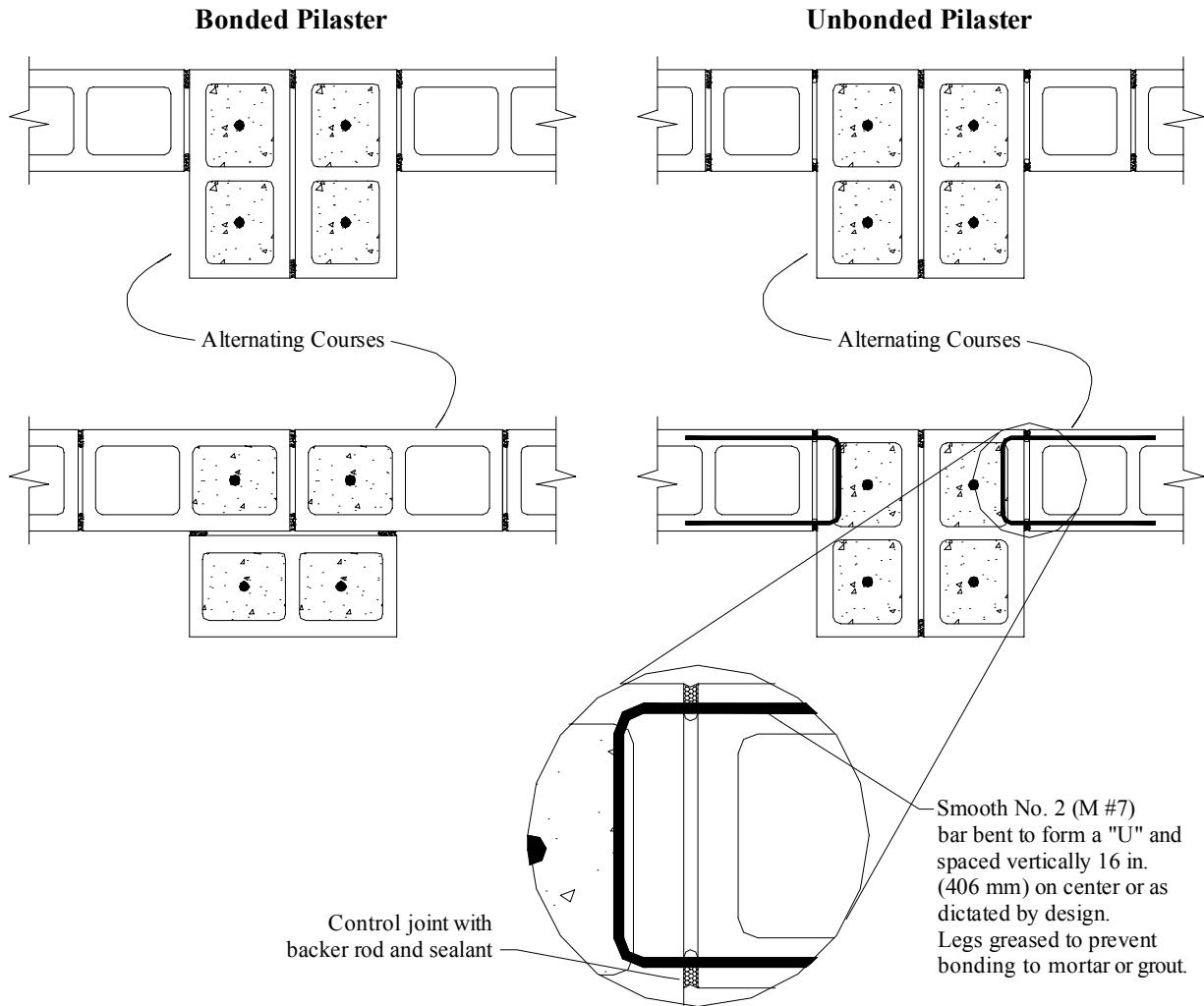


Last Modified: October, 2002

Control Joints at Pilasters

Masonry pilasters can typically be classified as one of two types: bonded (built integrally with the adjacent masonry wall) or unbonded (not built integrally with the adjacent masonry wall). A single pilaster can also be a composite of the two, where only one side of the pilaster is bonded to the adjacent masonry. To accommodate longitudinal shrinkage that may occur, at least one side of a pilaster is typically constructed without bonding into the adjacent masonry. At such locations, control joints are incorporated. Conversely, bonded pilasters can effectively be used in designs incorporating a sufficient amount of horizontal reinforcement such that the need for control joints is eliminated.

While incorporating control joints on one or both sides of a pilaster helps to alleviate the development of tensile stresses and the resulting shrinkage cracks that may potentially form, control joints can also impact the structural capacity of the system and should accordingly be evaluated. Since pilasters are often used to support horizontally spanning wall sections, the introduction of a control joint between the pilaster and adjacent wall effectively prevents the transfer of stresses. To permit the transfer to out-of-plane loads from the wall to the pilaster while preventing the transfer of in-plane loads (i.e., shrinkage stresses), dowels can be installed in the mortar joints. Each leg of the dowel is greased, or otherwise prevented from bonding, to the surrounding mortar or grout within which it is embedded. When the adjacent masonry is unbonded from an adjoining pilaster, it cannot be considered effective when determining the pilaster's capacity.

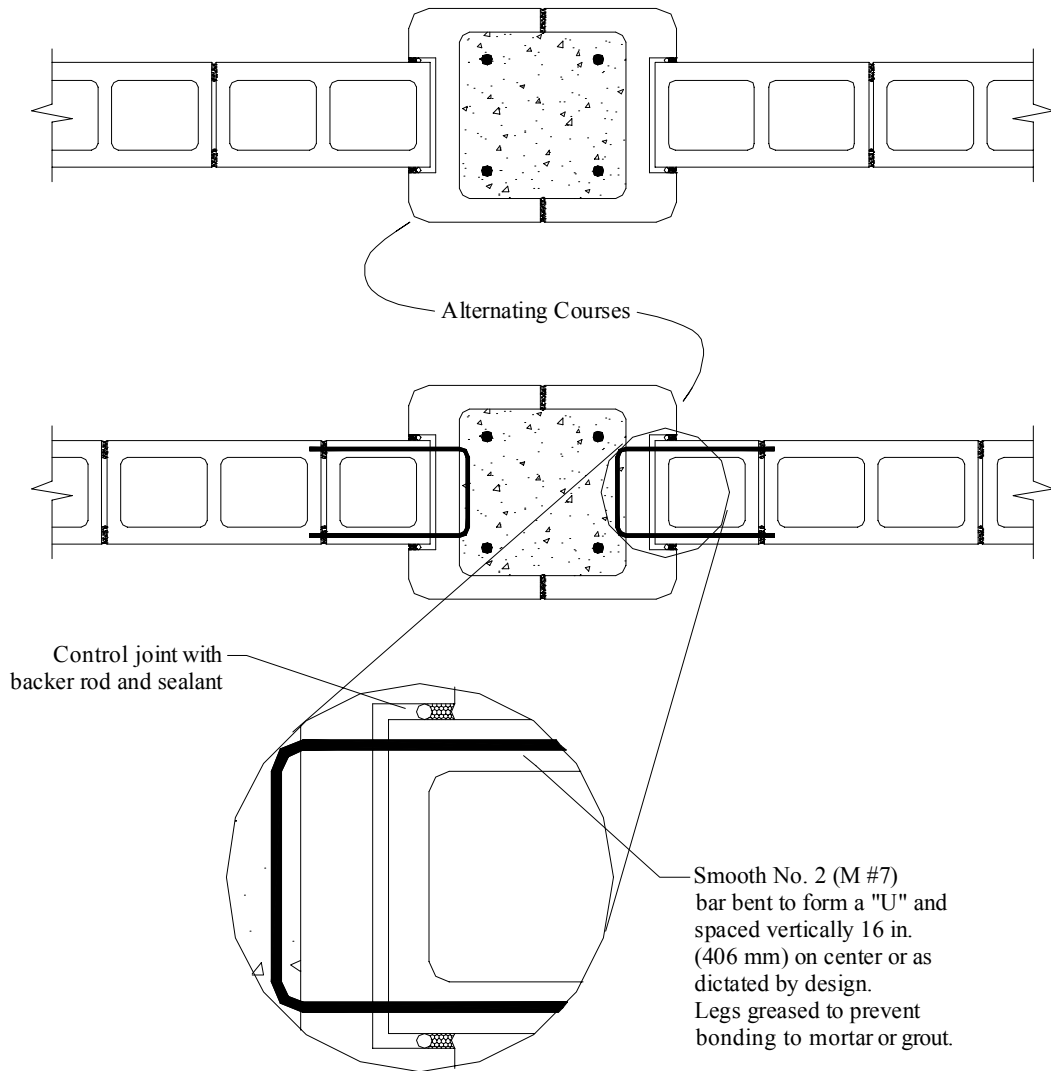


Last Modified: November, 2002

Control Joints at Pilaster Block

In some locations, specially configured units are used to form and construct masonry pilasters. Such units have varying shapes and configurations to allow either bonded or unbonded construction. (Local manufacturers should be consulted for their availability prior to specifying such units.) As with all types of pilasters, the incorporation of control joints on one or both sides of a pilaster for crack control purposes effectively isolates the pilaster from the adjacent wall sections.

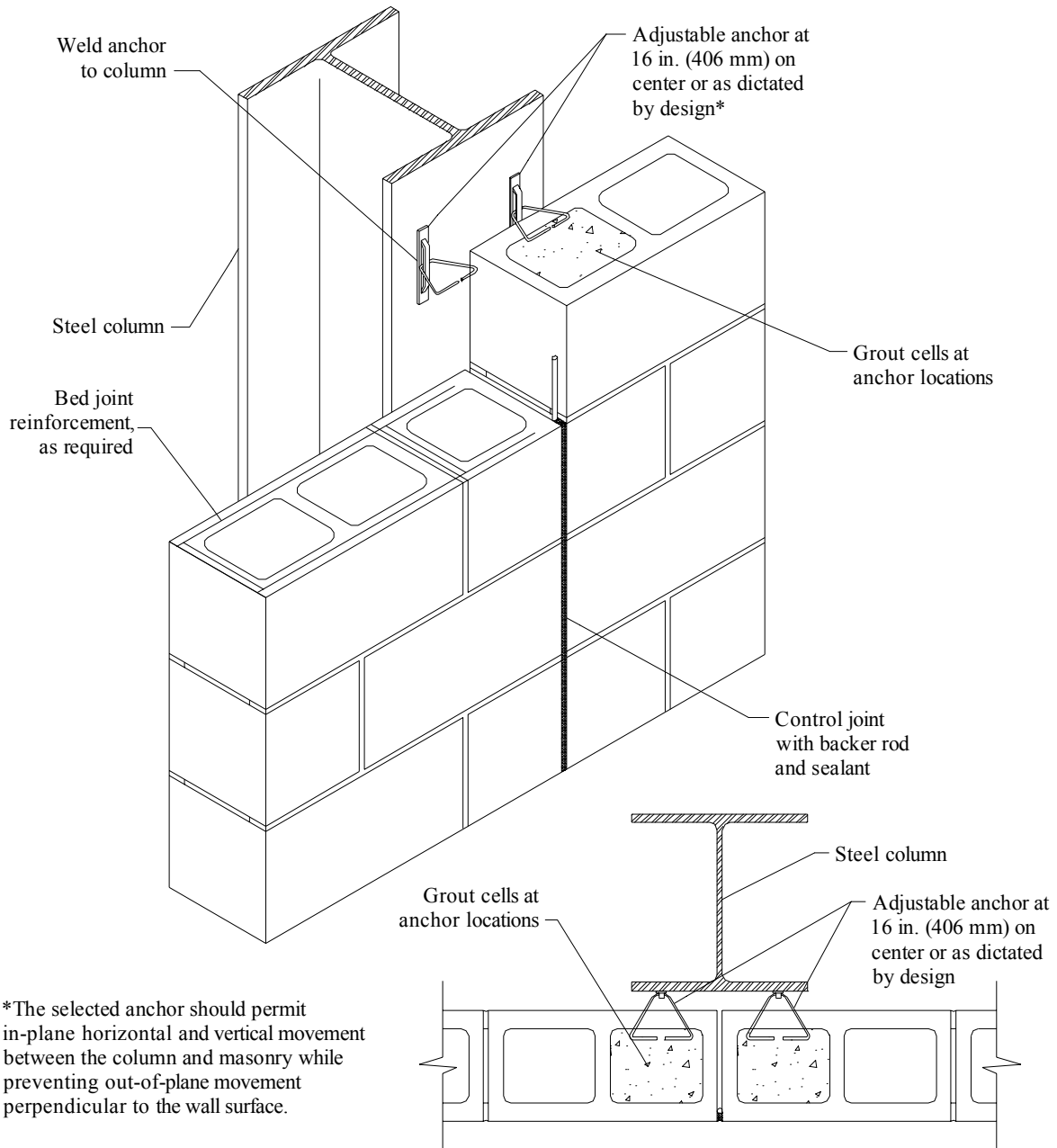
In the figures shown below, the control joints are used to allow the unrestrained shrinkage of the masonry. To effectively use the pilaster as a collector element for a horizontally spanning masonry wall, dowels must be installed in the mortar joints to transfer out-of-plane loads from the wall to the pilaster. Each leg of the dowel is greased, or otherwise prevented from bonding, to the surrounding mortar or grout within which it is embedded. (Note, when using units that provide large grout cells such as those shown below, consideration should be given to decreasing the water content of the grout as high grout fluidity is likely unnecessary due to the large cell size and relatively low water absorption by the units.)



Last Modified: November, 2002

Control Joints at Frame Lines

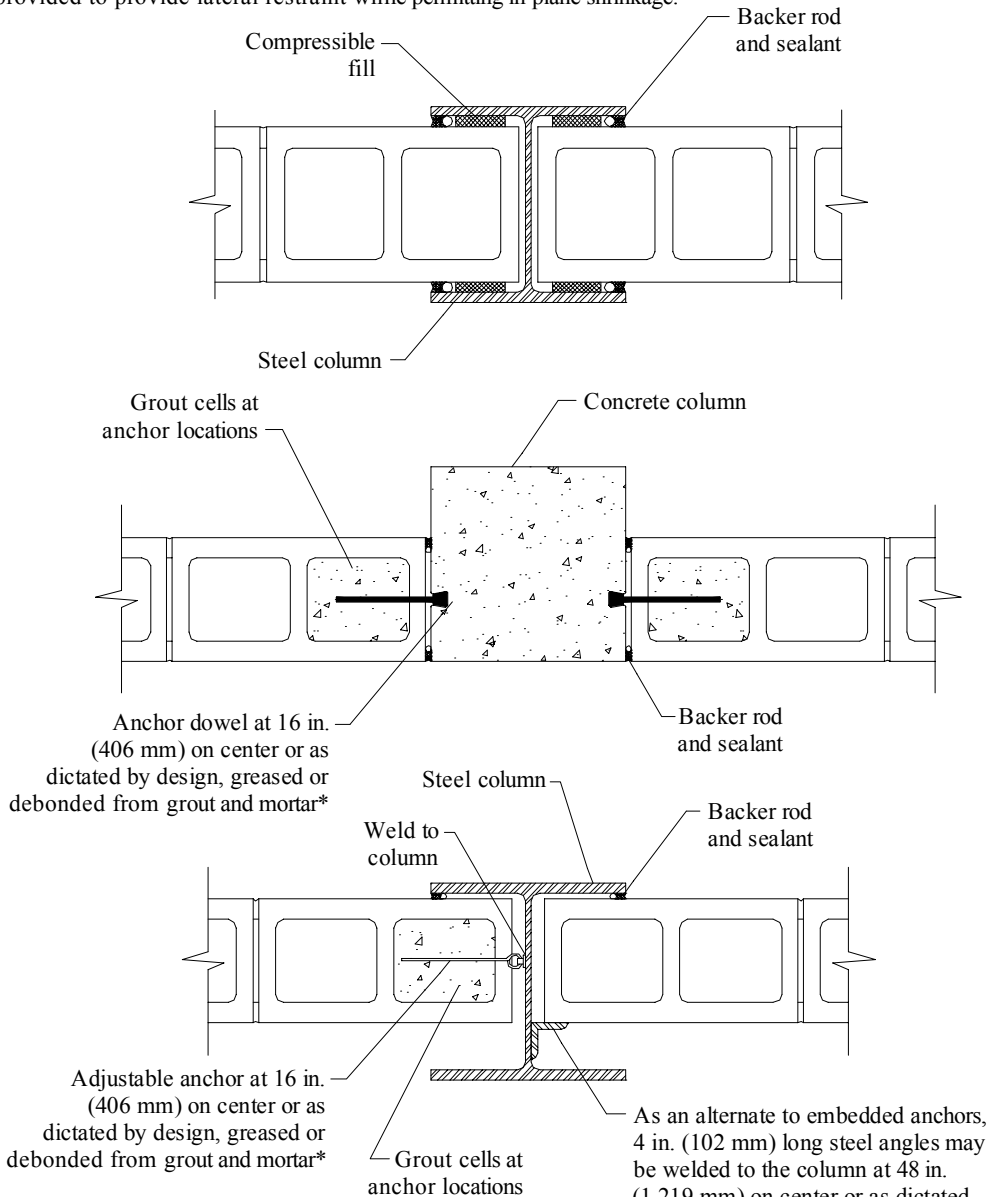
In conditions where the concrete masonry is not used as the primary structural system, or where hybrid systems of steel and concrete masonry are used, control joints are often located at column or frame lines. (A similar detail can also be applied to control joints at concrete columns.) To provide lateral support to the masonry, anchors are incorporated on either side of the control joint. Note that the interior head joint at the control joint typically does not contain mortar or sealant due to its inaccessibility. In extreme environments or critical conditions, a double layer of sealant can be used at the exterior surface to mitigate air and water infiltration.



Last Modified: November, 2002

Control Joints at Column Intersections

Typically, when masonry is framed into steel columns, the columns are sized slightly larger than the specified thickness of the masonry wall. This provides lateral support to the masonry for out-of-plane loads while permitting in-plane movement due to shrinkage. However, in cases where the steel column is larger than the masonry wall (such as in cases where a veneer may be added to the exterior) or when masonry frames into concrete columns, anchorage must be provided to provide lateral restraint while permitting in-plane shrinkage.



*The selected anchor should permit in-plane horizontal and vertical movement between the column and masonry while preventing out-of-plane movement perpendicular to the wall surface.

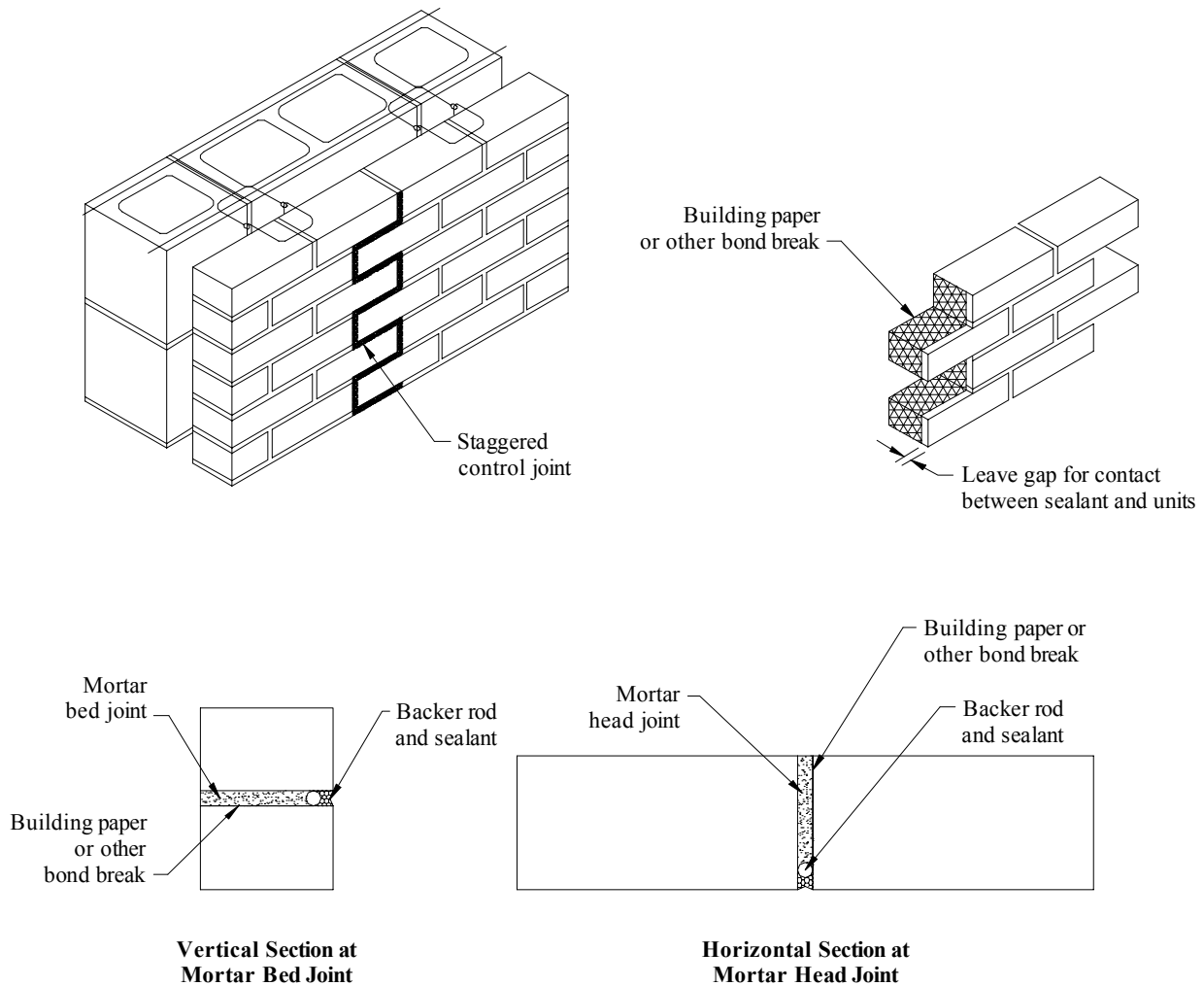
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Staggered Control Joints

Staggered (also called zipper) control joints are an alternative when the need to minimize the visual impact resulting from a control joint takes precedence. (A more common method of minimizing the aesthetic impact of a control joint is to press sand into the fresh sealant thereby reducing the color difference between the control joint and surrounding mortar joints.) This type of control joint should be used with caution, as it can be difficult properly construct and could substantially increase the cost of construction.

Unlike conventional control joints, which accommodate movement along a single vertical plane, staggered control joints require both the vertical and horizontal legs of the joint to accommodate movement. As such, a horizontal bond break is provided along the mortar bed joints to alleviate the development of tensile stresses due to shrinkage.

This type of joint is best used where the weight of the masonry will not cause enough friction to restrain movement at the horizontal legs of the control joint. As such, this type of control joint is primarily applicable to veneers and nonloadbearing walls of single story structures or where the veneer is vertically supported at each story level of multi-story structures.



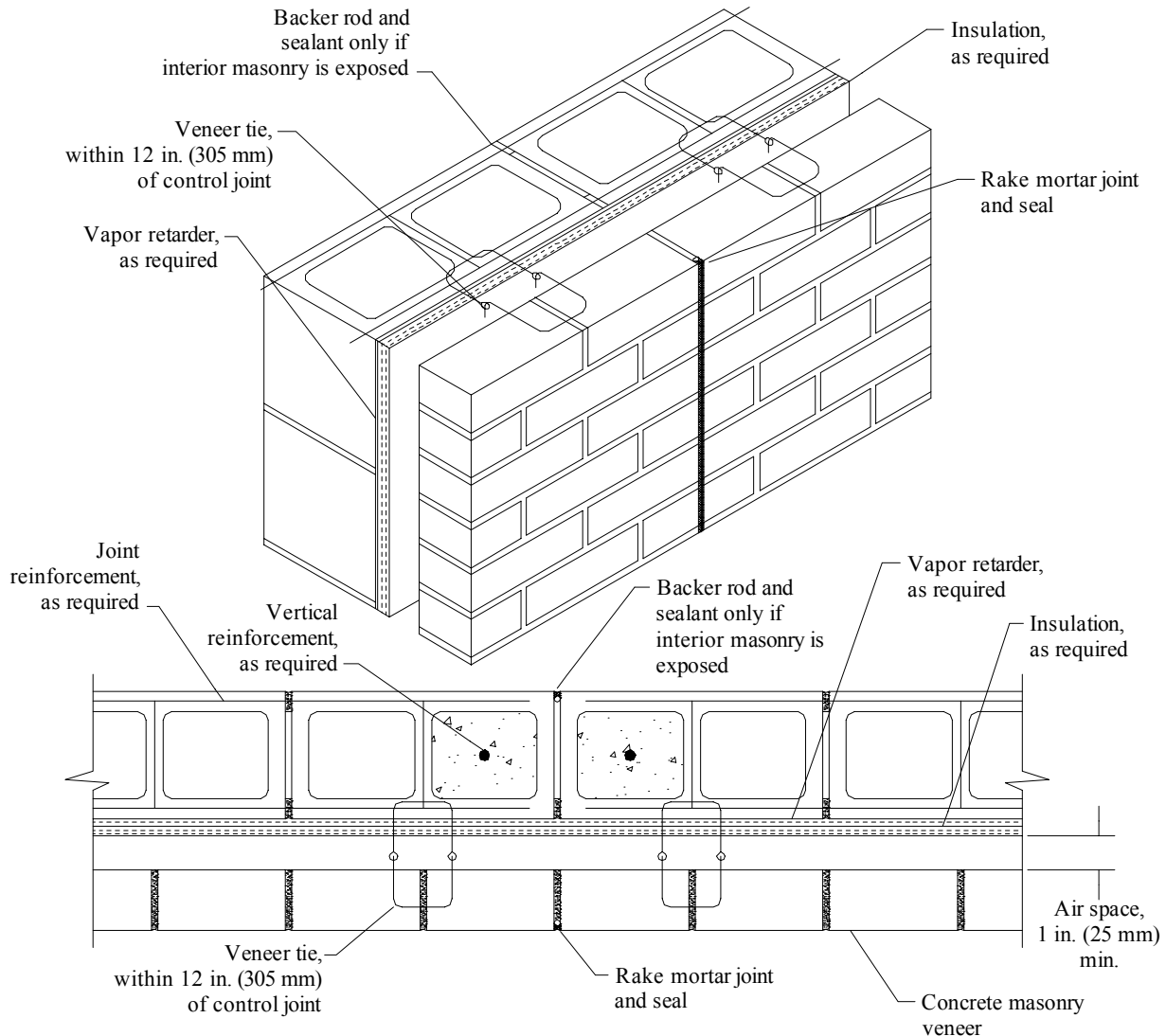
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Veneer Control Joints

Structural masonry walls require that control joints permit free longitudinal movement while resisting lateral or out-of-plane shear loads. Because veneers are nonstructural, veneer control joints need only permit unrestricted longitudinal movement. This is typically accomplished by raking out the mortar joint and installing backer rod and an appropriate sealant.

To provide sufficient support, wall ties should be placed within 12 inches (305 mm) of both sides of the control joint. When flexible wall ties are used (see Section 2F), veneer control joint locations need not line up with control joints in the backup wythe when a masonry backup is used. However, it is considered good practice to align them as closely as possible. If the veneer is rigidly bonded to a masonry backup, however, control joints should extend through the backup and veneer in the same location.

When the backup masonry is to be exposed to the interior during its service then control joints should be incorporated into the backup wythe. If the backup wythe is to be finished with another material, then control joints in the backup are typically not necessary as any hairline cracks that may develop will not be exposed.



Last Modified: November, 2002

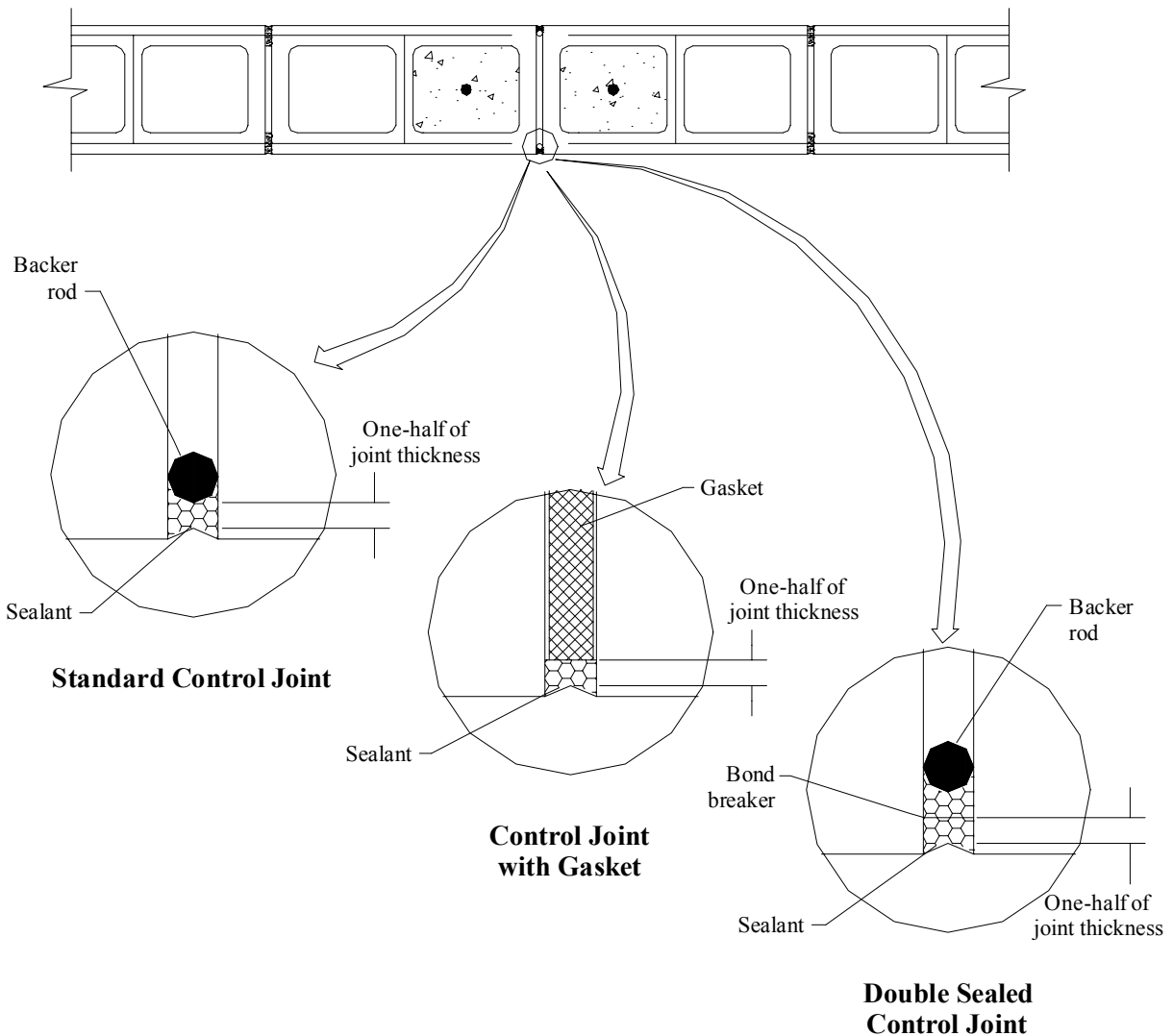
Control Joint Details

The details in this section have reviewed and highlighted the proper placement and installation of control joints within a concrete masonry structure. The following details illustrate three alternative recommended construction techniques for control joints.

A backer rod is used to prevent the sealant from bonding to the mortar (when present) while simultaneously providing a support backing for the sealant. A backer rod, or similar material, is typically recommended for good control joint performance.

The depth of the sealant itself should typically be approximately one-half of the joint thickness when measured at its minimum cross-section. Deeper, or shallower, sealant depths may lead to a premature failure of the sealant.

In extreme environments, or when the depth of the sealant dictates, a double sealant joint may be used. To preclude the construction of an excessively deep sealant joint, the sealant should be installed in two layers with a backer rod or other bond breaker between each layer.



Last Modified: November, 2002

SECTION 2D - FLASHING AND WEEPS

The design and construction of exterior walls must take into consideration water penetration resistance, with flashing and weep holes playing a necessary part. Flashing is installed to collect moisture and direct it to the exterior of the structure through weep holes, open head joints, or drain vents. Although this section focuses on flashing and weeps, other design considerations can also impact a wall's water-tightness; including mortar joint profiles, water repellents, crack control measures, vapor retarders, as well as proper detailing and protection of roofs, windows, joints, and other features.

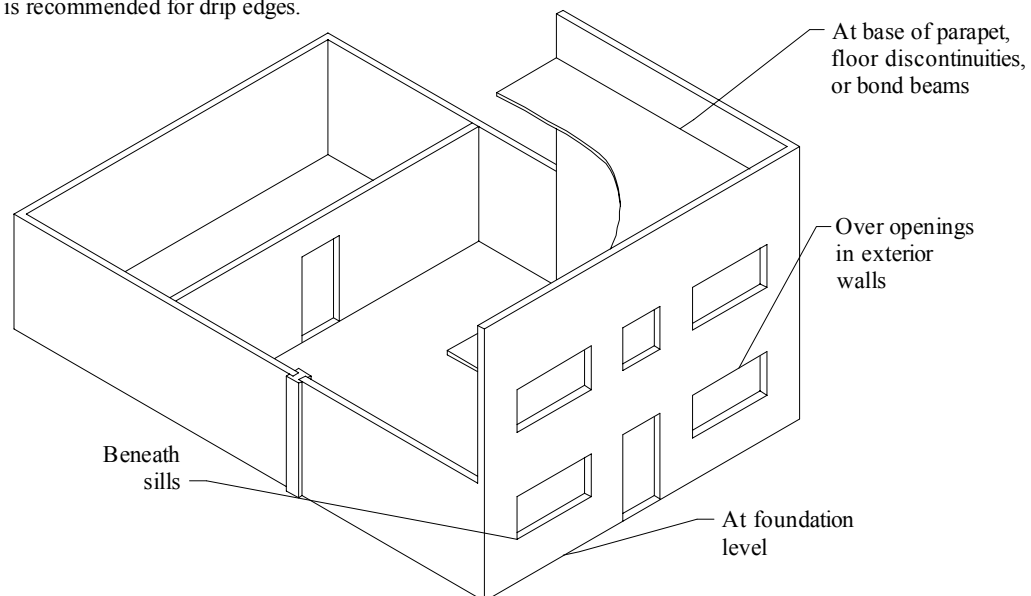
Weep holes should be located at the flashing elevation and should provide free movement of water to the exterior of the concrete masonry wall. Any construction practice that allows uninhibited water flow may be used, although cotton sash cords (which must be removed to allow free-drainage) and partially open head joints are most common. If necessary, vents or stainless steel wool can be used in the weep holes to prevent insect entry.

To properly function, weeps must remain open and kept clear of mortar droppings and other debris. This is typically accomplished using a cavity filter or other mortar collection device. A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as washed pea stone or proprietary mortar collection devices. As an alternative to cavity filters, clean outs can be used to remove mortar droppings, however this is often only feasible at the foundation level.

Flashing should be designed to perform for the life of the building since repair or replacement can be cost prohibitive. Flashing materials include stainless steel, cold-rolled copper, galvanized steel, lead-coated copper, copper laminates, ethylene propylene diene monomer (EPDM), rubberized asphalt, and polyvinyl chloride (PVC). In addition to conventional flashing systems, proprietary flashing systems and specialty concrete masonry units that facilitate drainage are also available from some manufacturers. Additional information is available in TEK 19-4A *Flashing Strategies for Concrete Masonry Walls* (Ref. 2.12). It should be stressed that flashing is typically not necessary in fully grouted masonry construction.

As a general rule, flashing should be located anywhere water will tend to collect. Some critical locations include at all horizontal obstructions (such as over openings, beneath sills, above shelf angles, and at the wall base), at tops of walls and parapets, and at grade (for parapets, also see Section 9A).

Once flashing locations are determined, the flashing is detailed to be impervious so that water cannot migrate behind, around or through the flashing layer. To help facilitate the removal of moisture away from the face of the masonry, the flashing should continue beyond the exterior masonry face and terminate with a sloped drip edge. A minimum $\frac{1}{4}$ inch (6.4 mm) extension is recommended for drip edges.

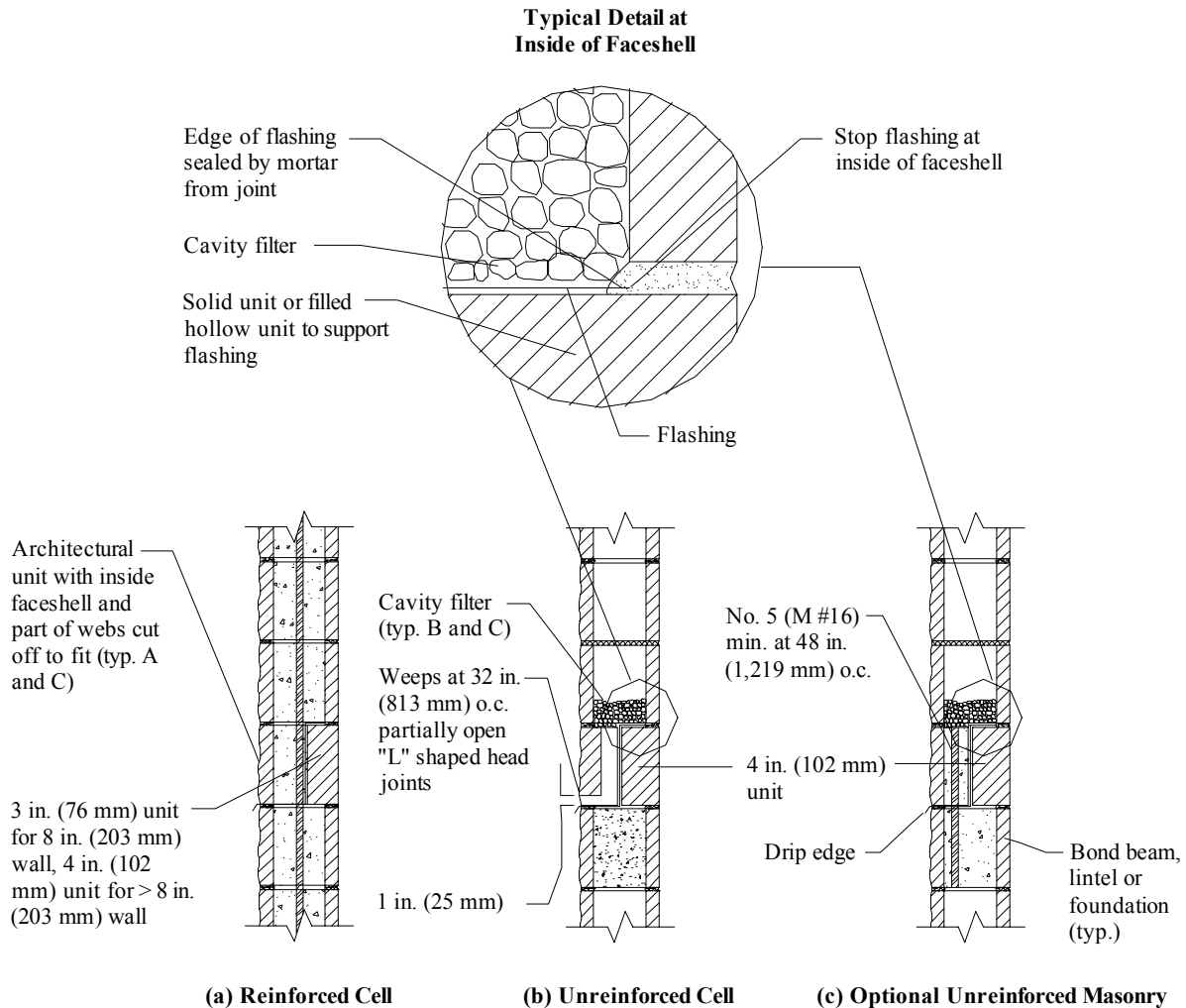


Last Modified: December, 2002

Flashings to Maintain Structural Continuity

Through-wall flashing (see Figure 2D.3) in single wythe walls creates a bond break. The potential impact on the wall's structural capacity should be evaluated in these cases. Flashing should be stopped short of the inside faceshell of the wall, as shown in detail 2D.1, to retain some shear and flexural capabilities across the mortar joint. In reinforced walls, some shear resistance is provided by the reinforcement. Proper grouting effectively seals where the vertical reinforcement penetrates the flashing. The absence of this doweling in unreinforced masonry may be more of a concern, but loads tend to be relatively low in these applications. If needed for structural capacity, a short reinforcing bar through the flashing with cells grouted directly above and below the flashing can be provided as shown in detail 2D.1 (C). A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as washed pea stone. As an alternate, every other reduced thickness facing unit can be left out on top of the flashing to serve as cleanouts until the wall is completed. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up.

Using solid 4 inch (102 mm) units or filled hollow units on the interior supports the cavity filter material and the flashing.

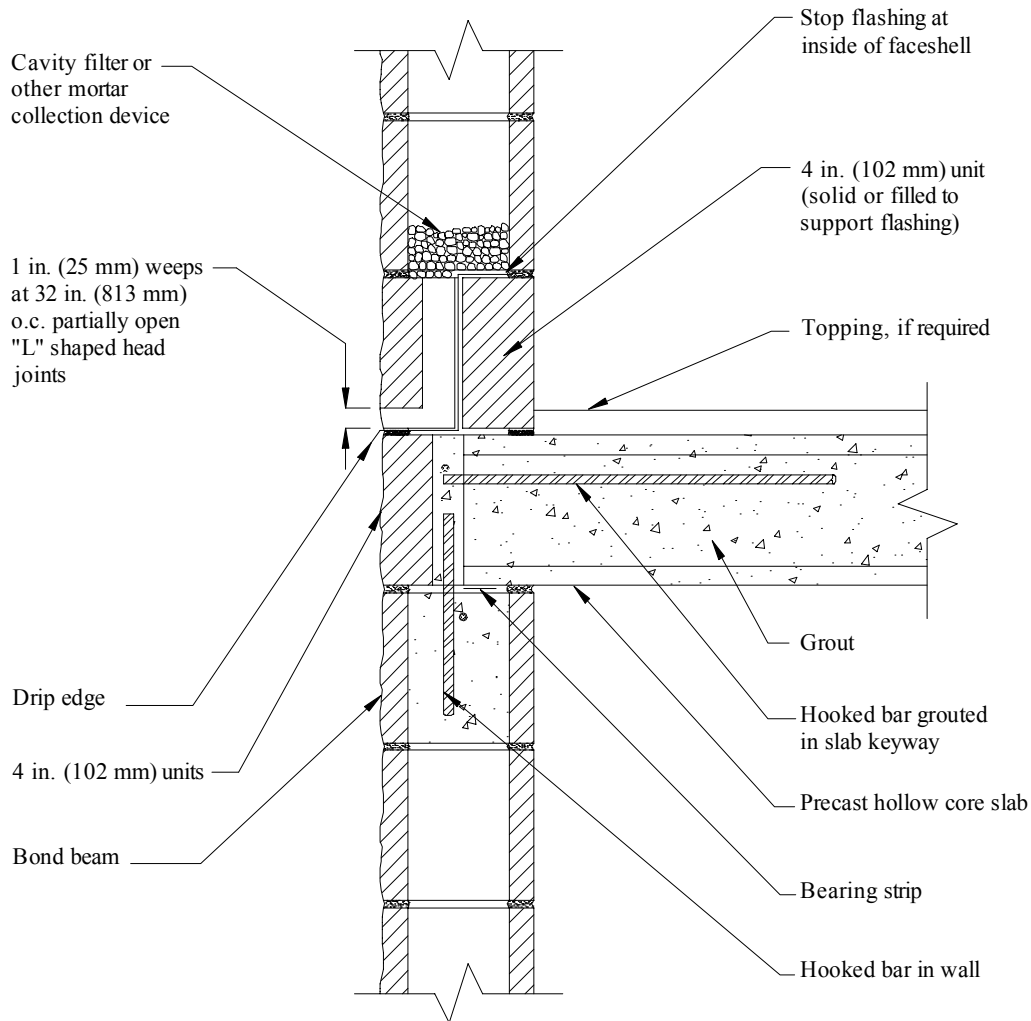


Last Modified: December, 2002

Flashing Single Wythe Wall at Floor Slab

See Detail 2D.1 notes regarding the bond break at flashing. A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as 2 inches (51 mm) of washed pea stone. As an alternate, every other reduced thickness facing unit can be left out on top of the flashing to serve as cleanouts until the wall is completed. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up.

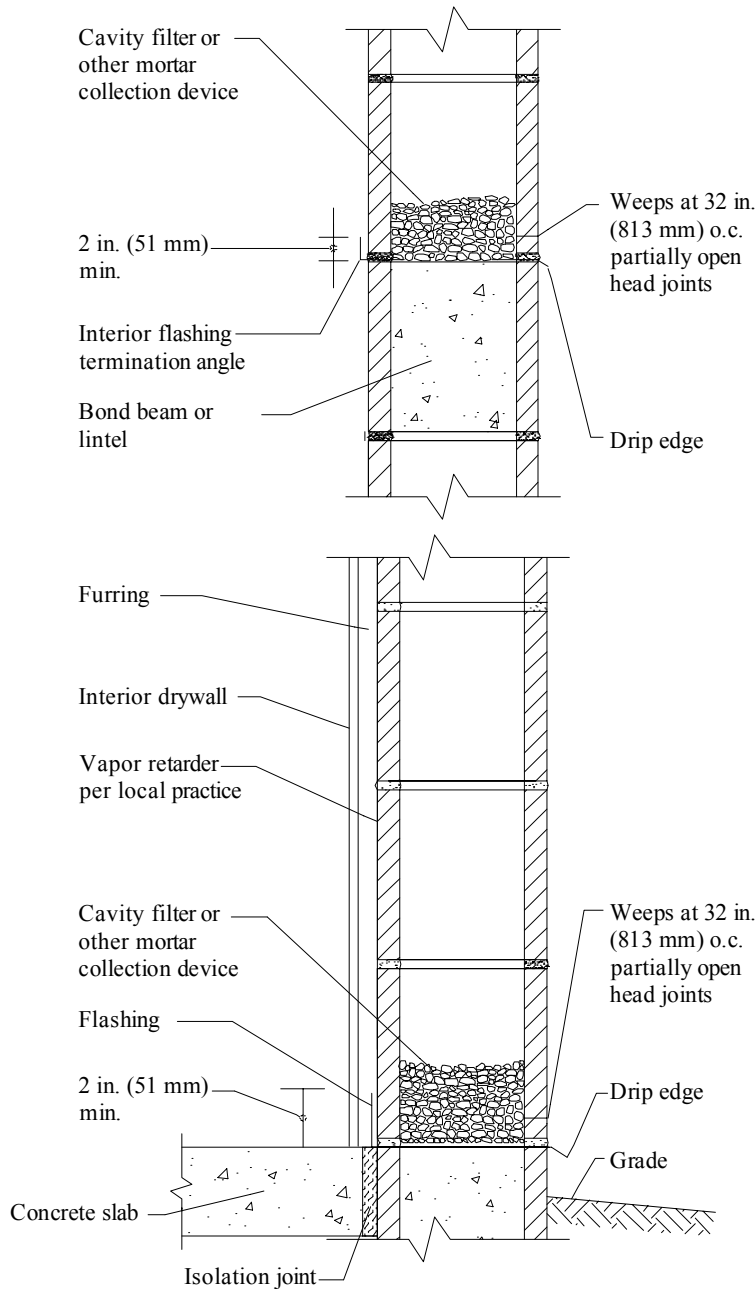
Using solid 4 inches (102 mm) units or filled hollow units on the interior supports the cavity filter material and the flashing.



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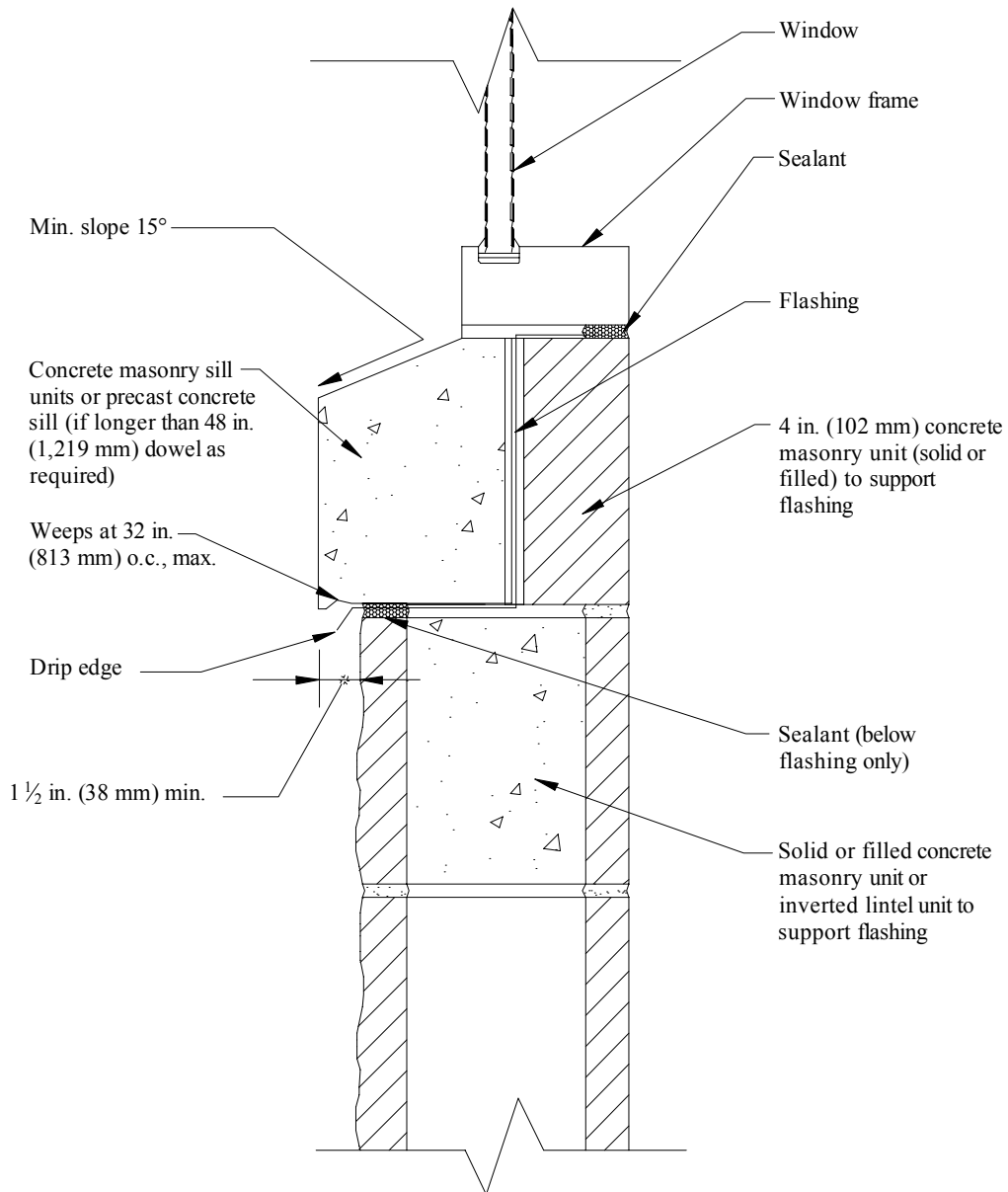
Single Wythe Through-Wall Flashing

When used with interior finishes, the furring strips on the wall interior hold the flashing in position. See Detail 2D.1 notes regarding the bond break at flashing. A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as 2 inches (51 mm) of washed pea stone. As an alternate, every other unit can be left out on top of the flashing to serve as cleanouts until the wall is completed. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up.



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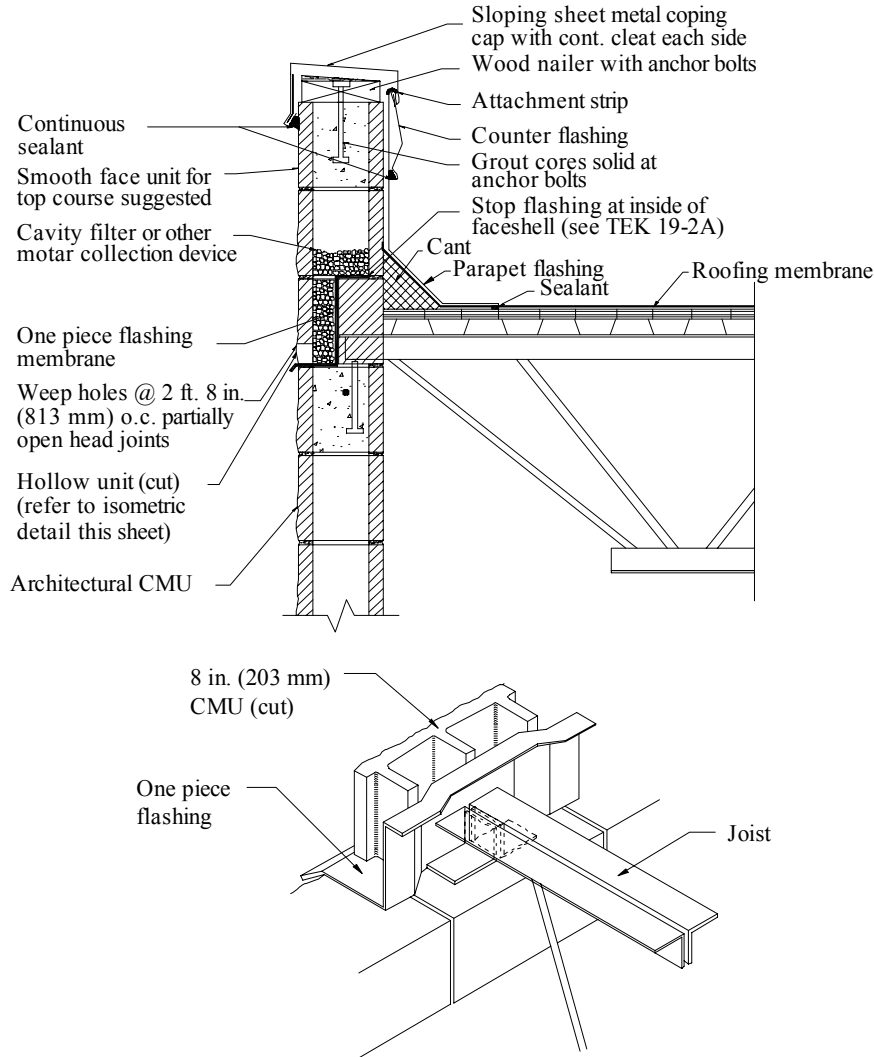
Flashing Single Wythe Wall at Sill



Last Modified: December, 2002

Flashing Single Wythe Wall at Roof/Parapet

Parapet flashing overlaps roofing membrane to allow differential movement between the two materials without compromising the joint. (Alternatively, roofing membrane may be extended over the top of the parapet.) Metal caps require wooden nailers. Place a grout stop over cores on the second course below the coping/cap so that grout can be placed in the top course for positioning anchor bolts. The coping/cap should be sloped to prevent water from draining onto the exposed masonry and should extend at least 4 inches (102 mm) over the face of the masonry, and be sealed on both sides. Smooth-textured concrete masonry units will allow a tighter fit between the cap and the masonry. When precast concrete copings are used, penetrations of through-wall flashings should be sealed to prevent water entry. Coping units should be placed on a full mortar bed, with full head joints. Joints between units should then be raked and a joint sealer applied. Coping unit should be sized to allow overhangs and a drip reveal on both sides of the wall. See Detail 2D.1 notes regarding the bond break at flashing. A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as 2 inches (51 mm) of washed pea stone. As an alternate, every other reduced thickness facing unit can be left out on top of the flashing to serve as cleanouts until the wall is completed. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up. Using solid 4 inch (102 mm) units or filled hollow units supports the cavity filter material and the flashing.



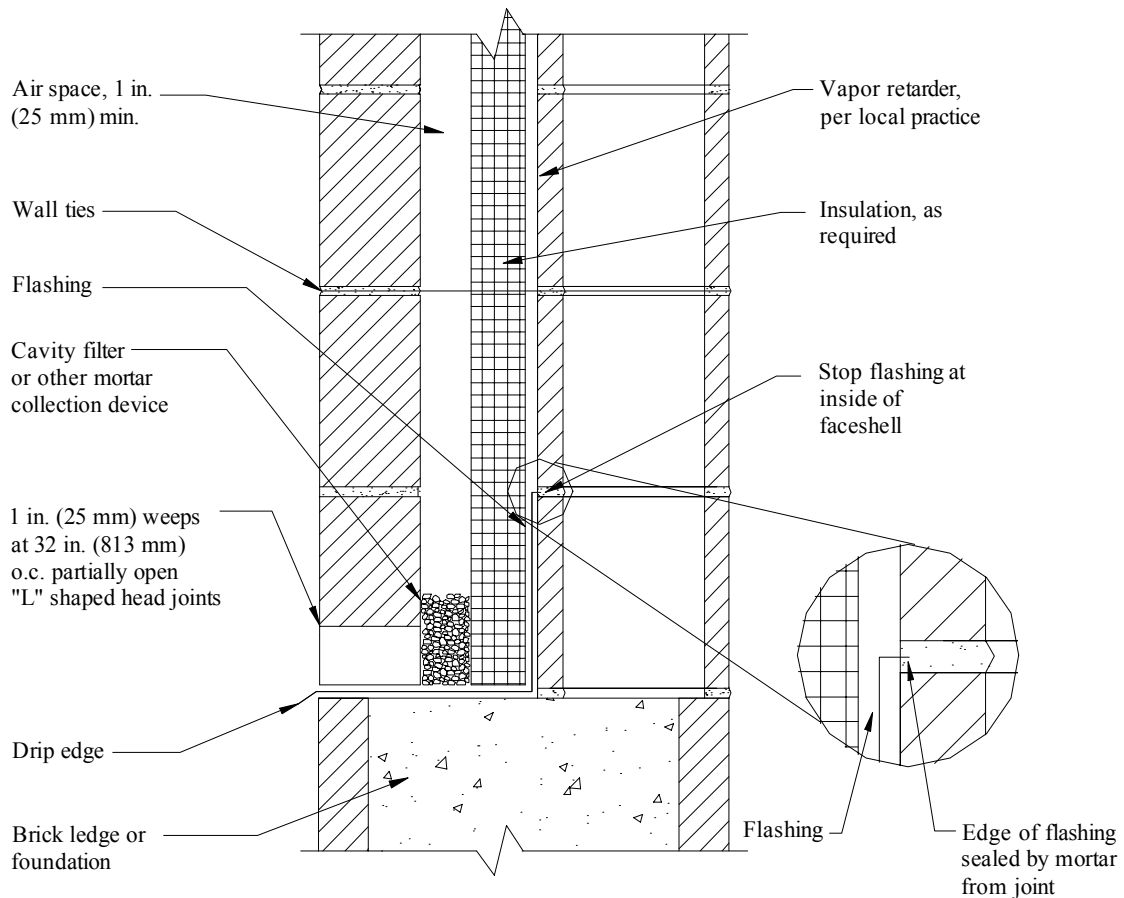
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Flashing Cavity Walls at Foundation

Cavity widths typically range from 2 to 4 ½ inches (51 to 114 mm) with a minimum 1 inch (25 mm) clear airspace for drainage. Cavities wider than 4 ½ inches (114 mm) are permitted only if a detailed analysis is performed on the wall ties per *Building Code Requirements for Masonry Structures* (Ref. 2.1). With glazed masonry veneer, a 2 inch (51 mm) wide airspace is recommended with air vents at the top and bottom of the wall because of the impermeable nature of these masonry units.

Although not shown, vents can be installed at the top of masonry walls to provide natural convective air flow within the cavity to facilitate drying. A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings. As an alternate, every other veneer unit can be left out on top of the flashing to serve as cleanouts until the wall is completed.

A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity). Otherwise, a 2 inch (51 mm) air space is preferred. As an alternative, proprietary insulating drainage products can be used.



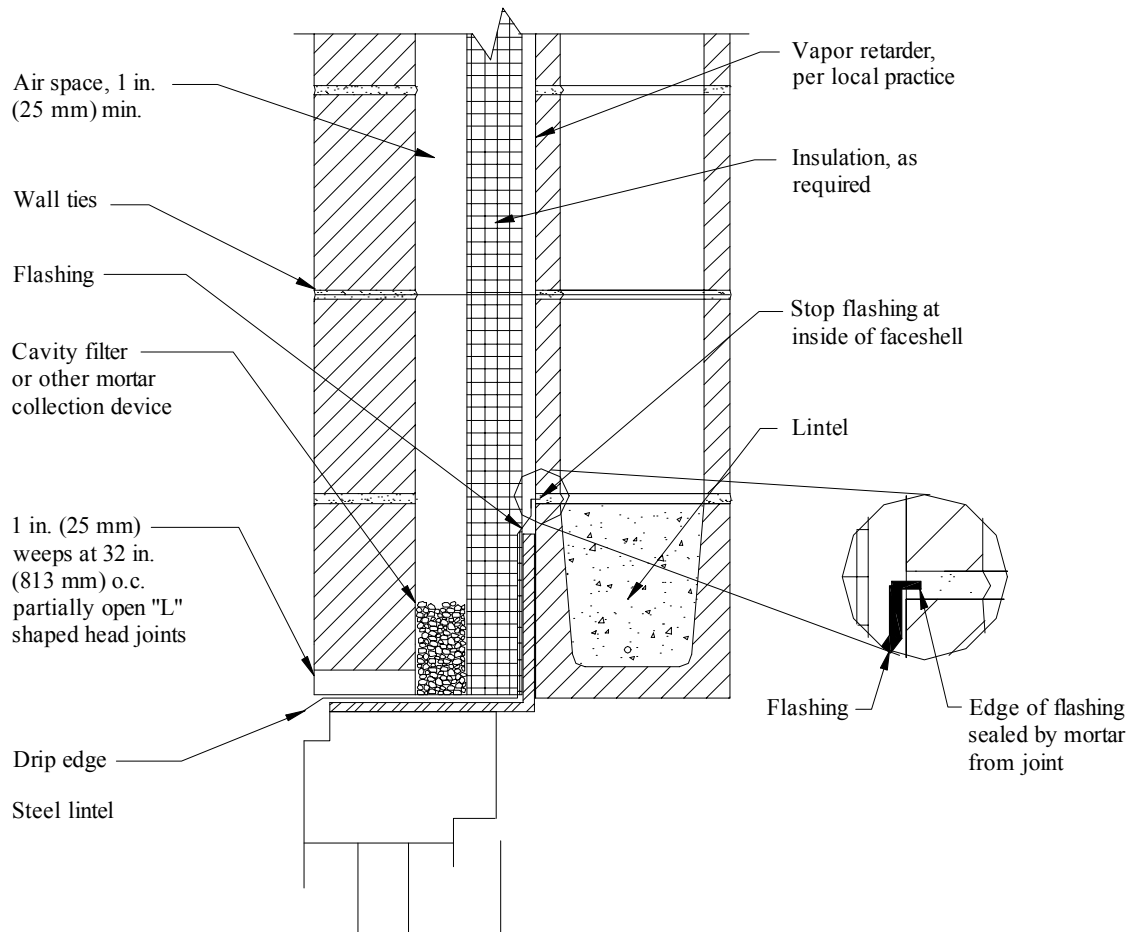
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Flashing Cavity Walls at Bond Beam

Cavity widths typically range from 2 to 4 ½ inches (51 to 114 mm) with a minimum 1 inch (25 mm) clear airspace for drainage. Cavities wider than 4 ½ inches (114 mm) are permitted only if a detailed analysis is performed on the wall ties per *Building Code Requirements for Masonry Structures* (Ref. 2.1). With glazed masonry veneer, a 2 inch (51 mm) wide airspace is recommended with air vents at the top and bottom of the wall because of the impermeable nature of these masonry units.

Although not shown, vents can be installed at the top of masonry walls to provide natural convective air flow within the cavity to facilitate drying. A cavity filter is any material used to prevent mortar droppings from clogging the weeps, such as 2 inches (51 mm) of washed pea stone. As an alternate, every other veneer unit can be left out on top of the flashing to serve as cleanouts until the wall is completed. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up.

A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or by drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) air space is preferred. As an alternative, proprietary insulating drainage products can be used without the need for a clear air space.



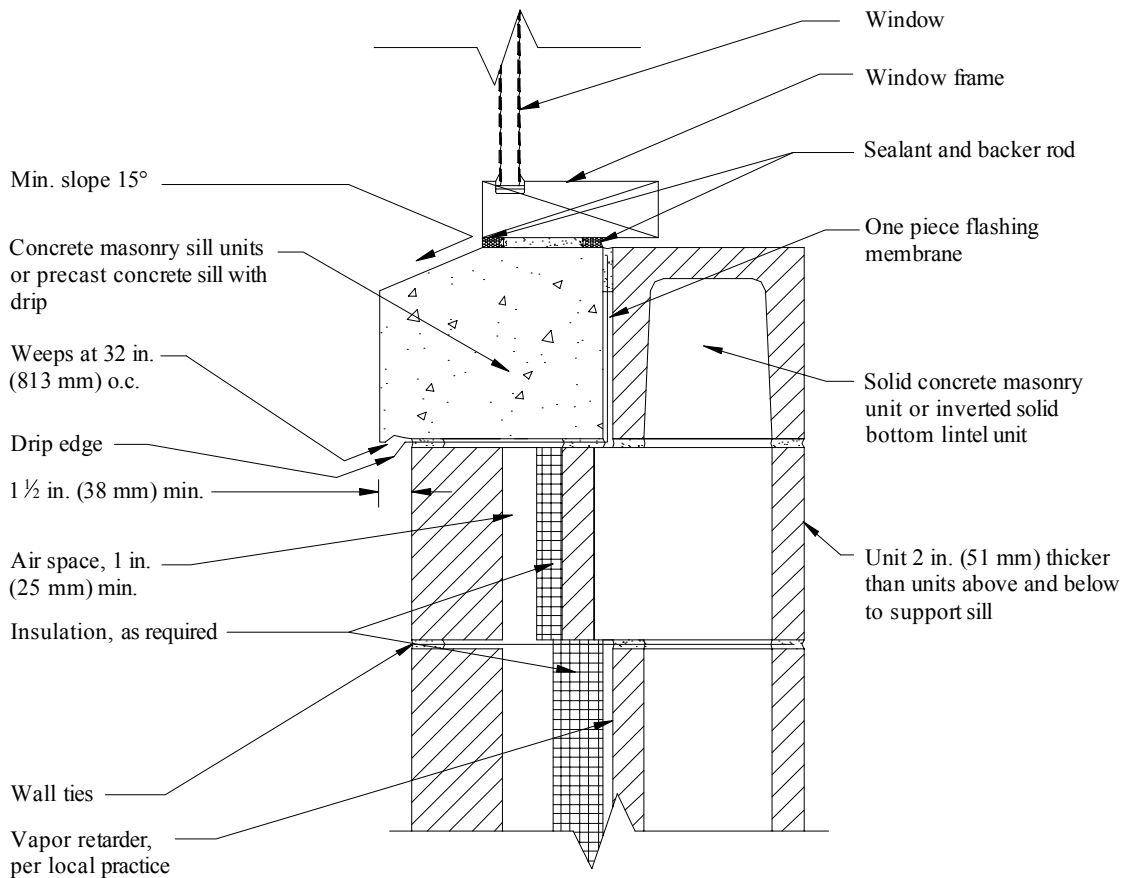
Last Modified: December, 2002

Flashing Cavity Walls at Sill

Cavity widths typically range from 2 to 4 ½ inches (51 to 114 mm) with a minimum 1 inch (25 mm) clear airspace for drainage. Cavities wider than 4 ½ inches (114 mm) are permitted only if a detailed analysis is performed on the wall ties per *Building Code Requirements for Masonry Structures* (Ref. 2.1). With glazed masonry veneer, a 2 inch (51 mm) wide airspace is recommended with air vents at the top and bottom of the wall to enhance drainage and preclude a pressure differential between the cavity and the exterior of the wall. This is due to the impermeable nature of these masonry units.

Although not shown, vents can be installed at the top of masonry walls and below sills to provide natural convective air flow within the cavity to facilitate drying and minimize pressure differential between the cavity and the exterior of the wall.

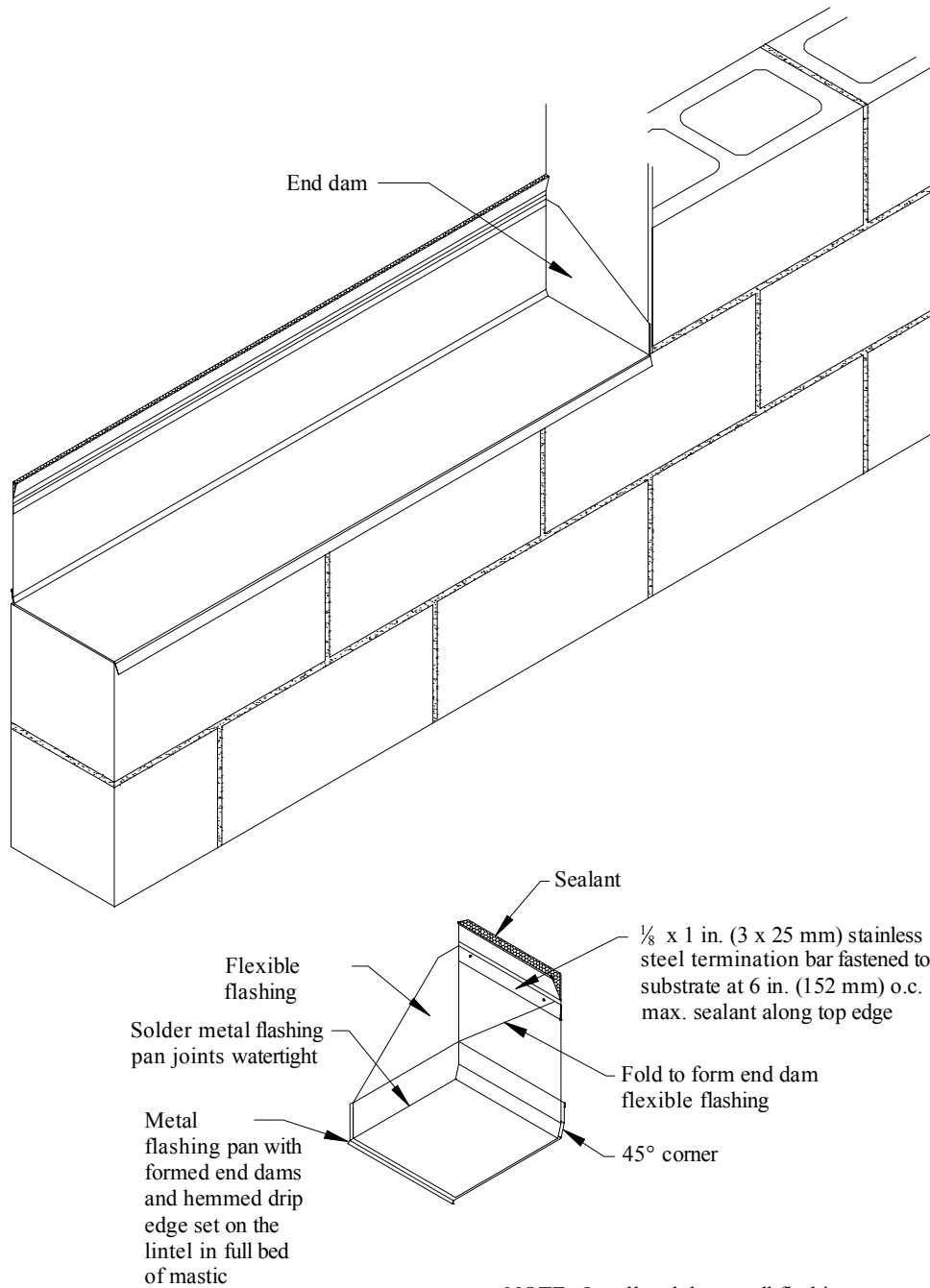
A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or by drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) air space is preferred. As an alternative, proprietary insulating drainage products can be used without the need for a clear air space.



Last Modified: December, 2002

End Dam

Properly constructed end dams help prevent water from flowing past the ends and into the masonry below. When constructed in the field, all joints and overlaps must be properly sealed. Prefabricated end dams may also be available. Seal all lap joints if using prefabricated end dams.

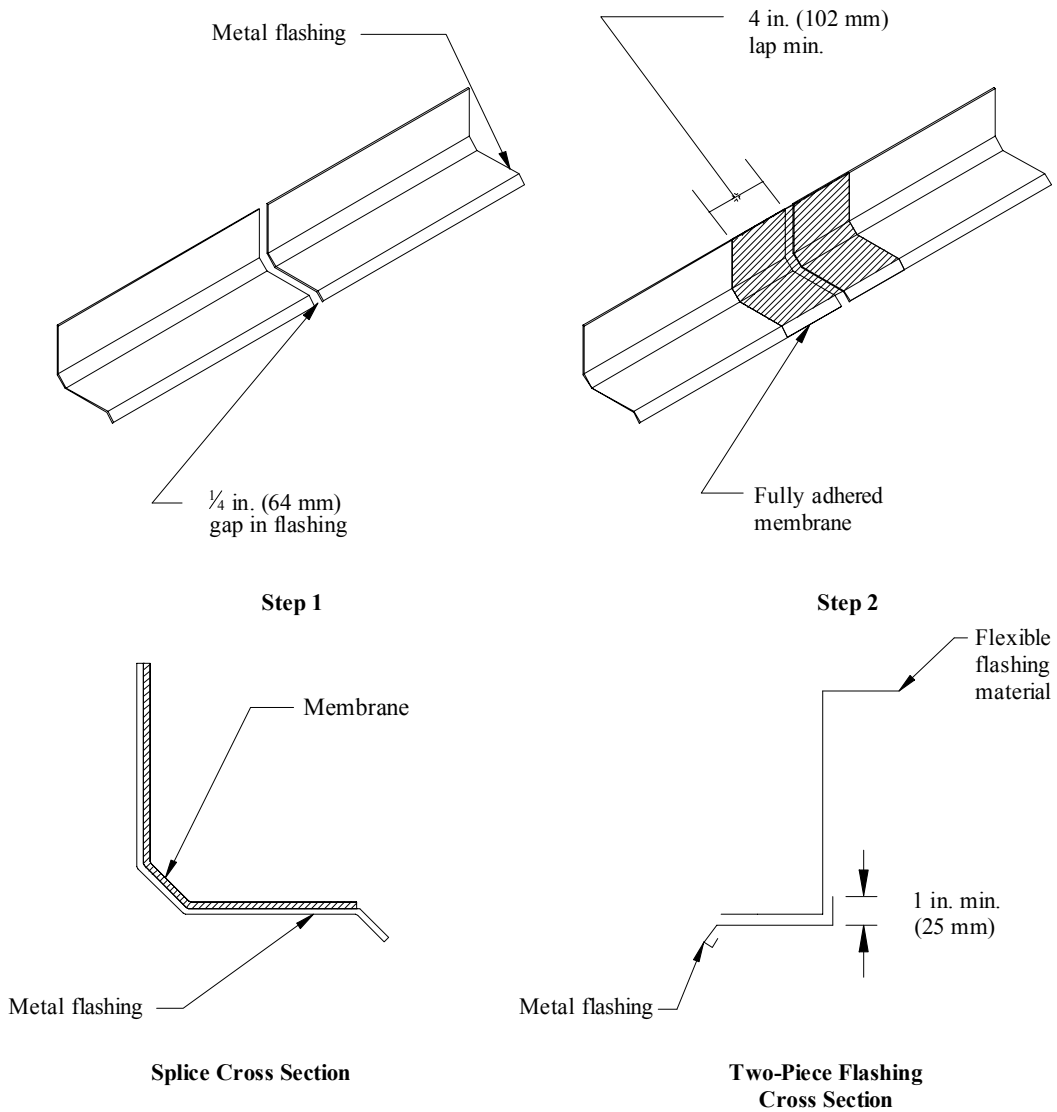


NOTE: Install end dam at all flashing terminations unless otherwise indicated.

Last Modified: December, 2002

Metal Flashing Splice

Flashing splices must be watertight, otherwise the function of the flashing is negated. For this reason, flashing should be continuous wherever possible. Separate pieces of plastic and rubber flashings should be overlapped a minimum of 4 inches (102 mm), and bonded together with adhesive unless they are self-adhering. The edges of laps in self-adhesive flashing should be covered in mastic. Lap splicing is not recommended for metal flashing, since the flashing material will contract and expand at a different rate from the surrounding masonry, which can result in sealant failure and potential moisture entry. A typical metal flashing splice involves two pieces of flashing laid with an approximate ¼ inch (6.4 mm) gap between them. This gap allows for flashing expansion. The two sections are connected and sealed using a piece of pliable self-adhering membrane, such as rubberized asphalt. If the membrane is not self-adhering, it should be set in a mastic and fully bonded to the flashing on both sides of the gap.



Last Modified: December, 2002

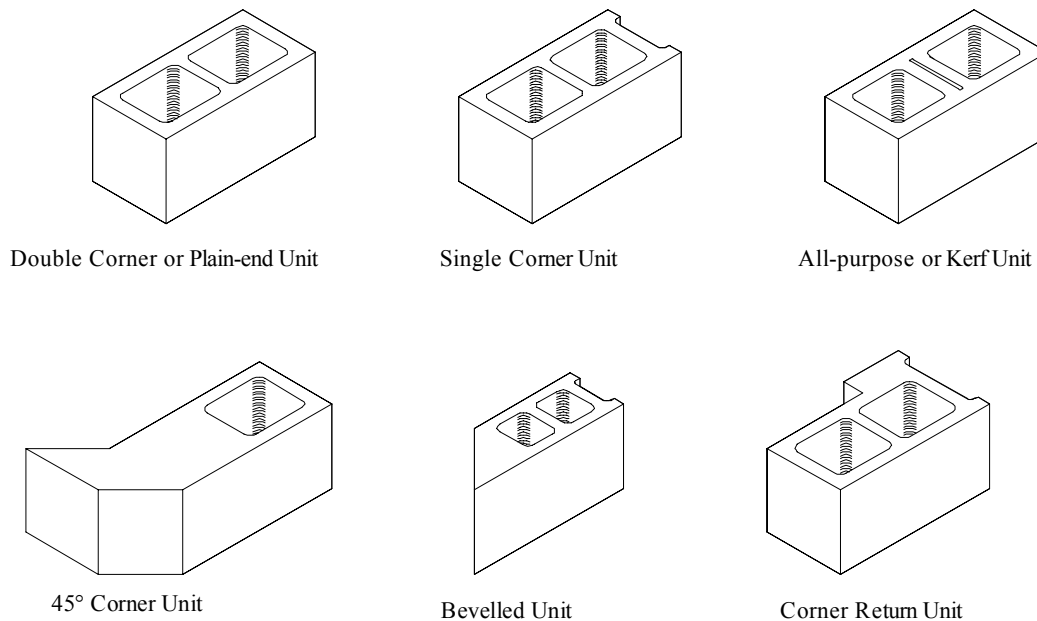
2E - Corners

Unlike stretcher units, units used in corner construction have square ends. In addition, all-purpose or kerf units are available, with two closely spaced webs in the center which allow the unit to be easily split on the jobsite, facilitating corner construction. Other special units may also be available, such as bevelled-end units, forming a 45° angle with the face of the unit, which are used to form walls intersecting at 135° angles. Units in adjacent courses overlap to form a running bond pattern at the corner. Architectural units, such as those with split or scored faces, are often available with the architectural finish on two sides to accommodate corner construction.

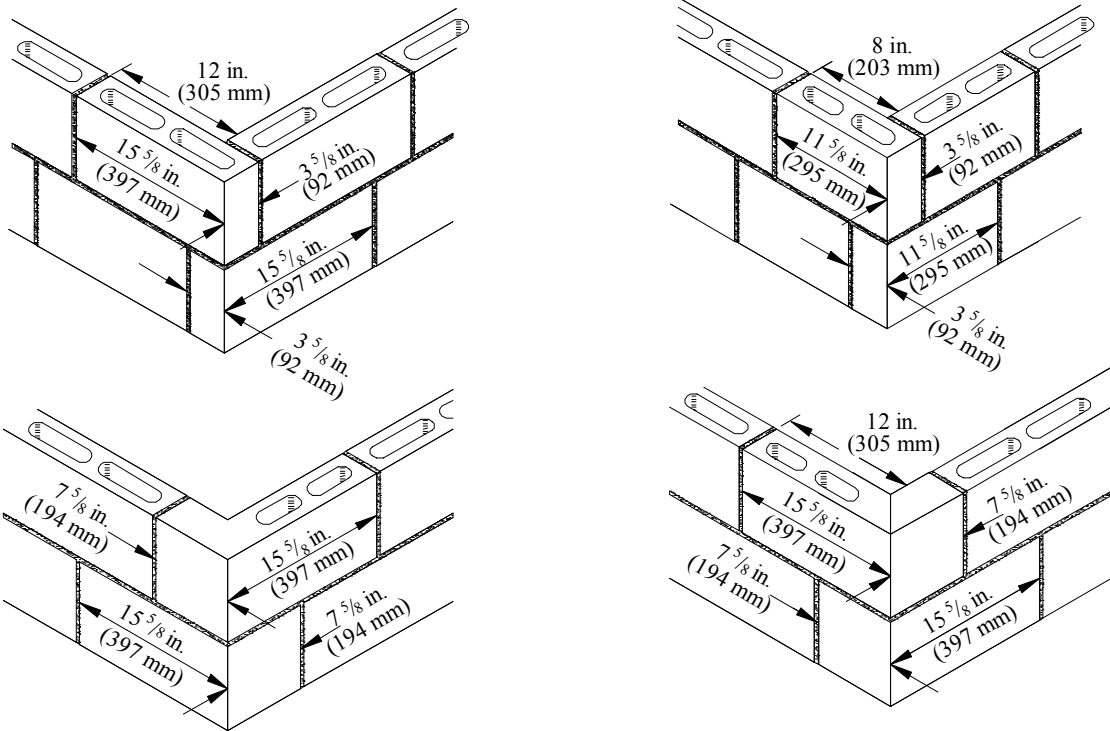
If applicable, corners are typically constructed first, then the remaining wall section is filled in. Because they guide the construction of the rest of the wall, building the corners requires special care. It is essential that the corner be built as shown on the foundation or floor plan to maintain modular dimensions.

The following details show how corners can be constructed to minimize cutting of units. Vertical steel, while not always required, is often used at corner intersections.

Figure 2-2 - Concrete Masonry Units used for Corner Construction

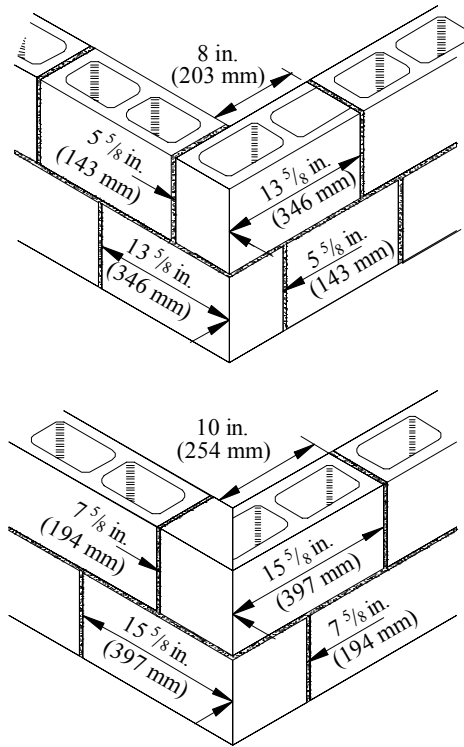


Corner Details, 4 Inch (102 mm) Walls

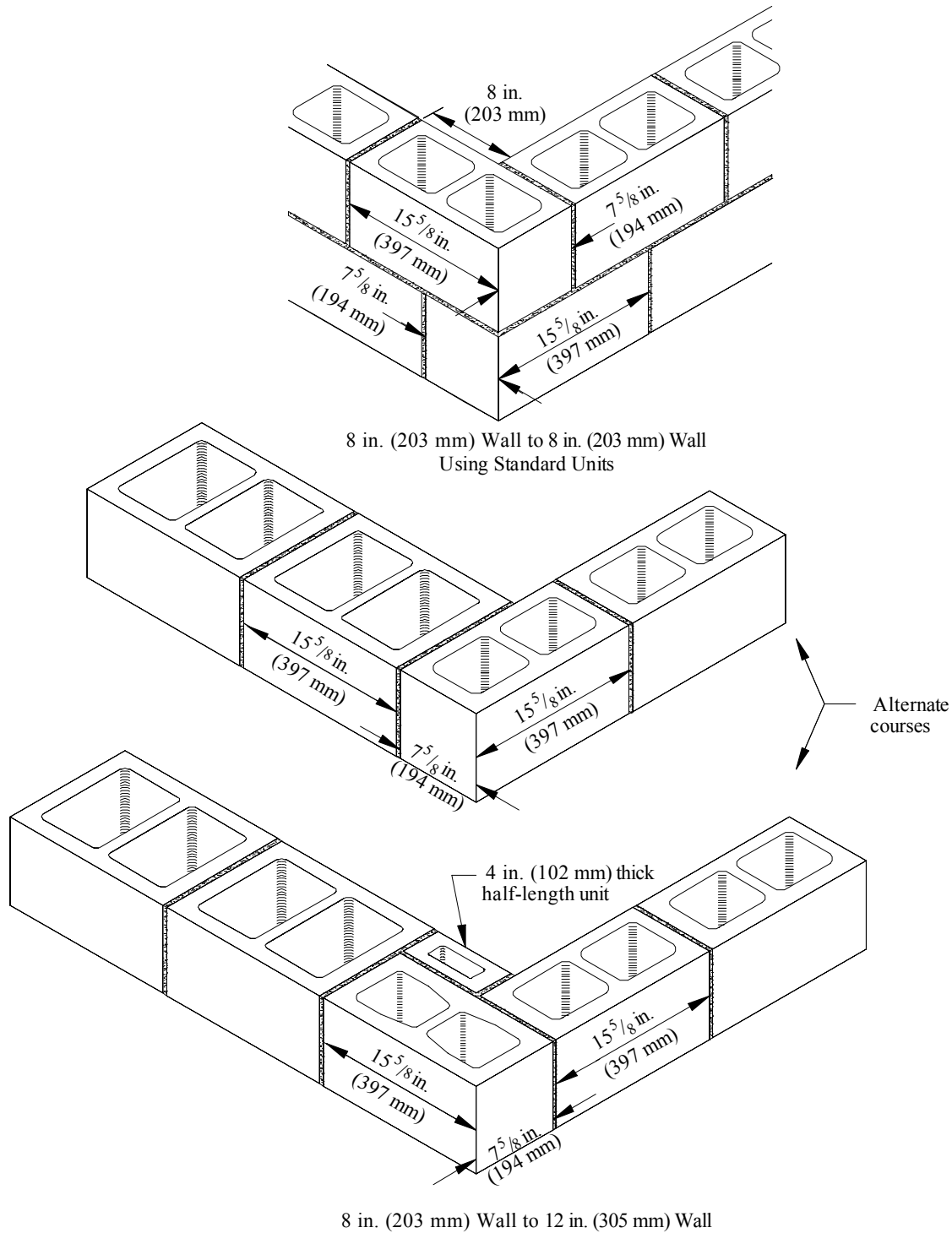


Last Modified: December, 2002

Corner Details, 6 Inch (152 mm) Walls

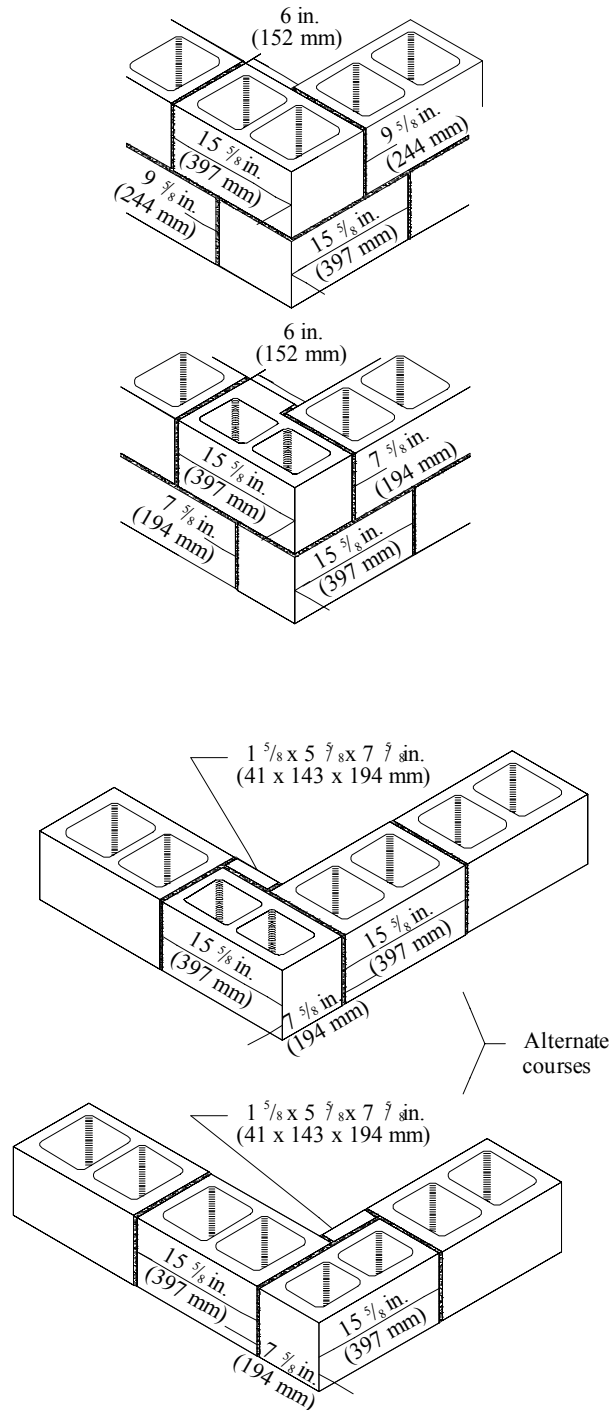


Corner Details, 8 Inch (203 mm) Walls



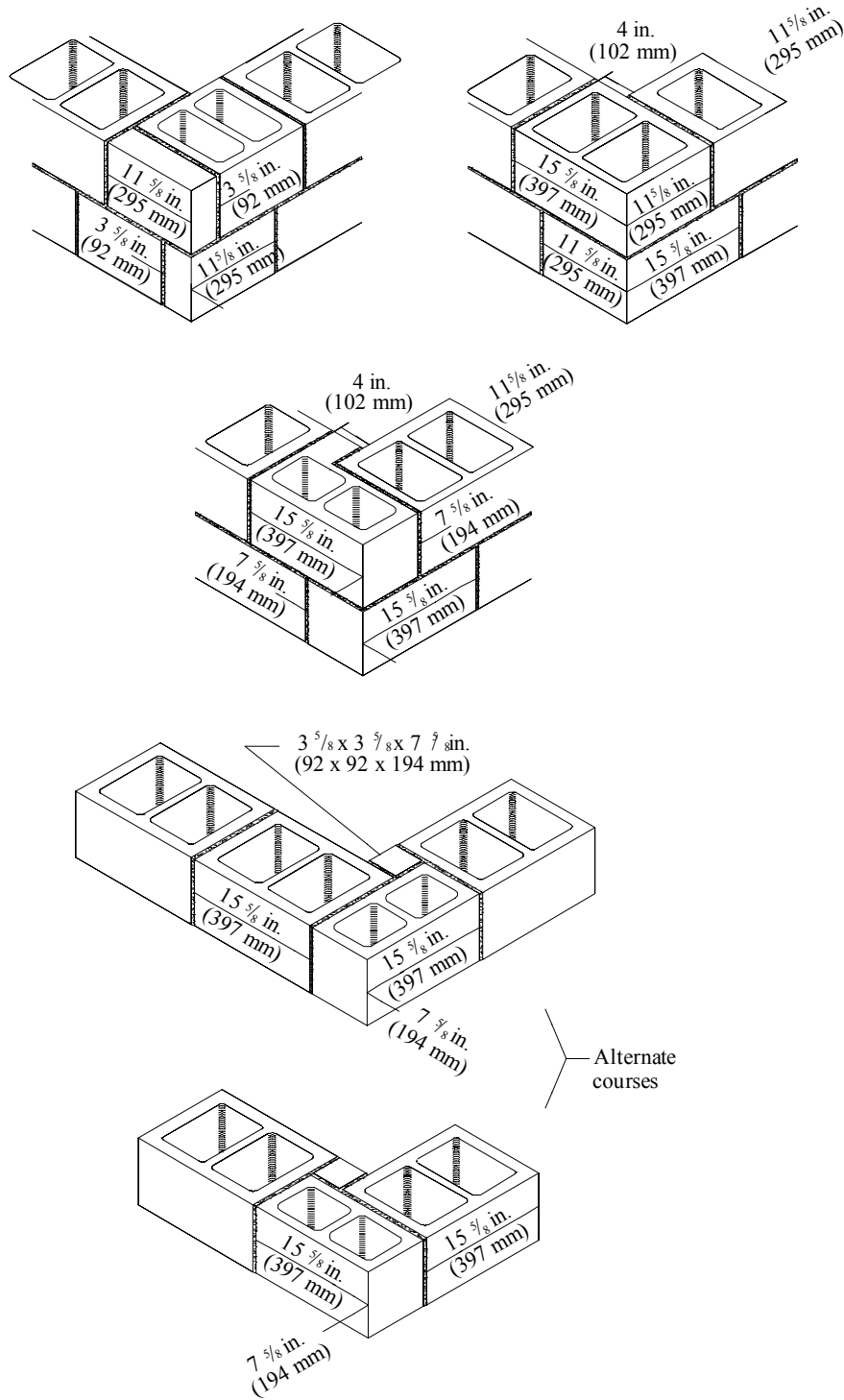
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Corner Details, 10 Inch (254 mm) Walls



Last Modified: December, 2002

Corner Details, 12 Inch (305 mm) Walls



Last Modified: December, 2002

2F - Joint Reinforcement

Joint reinforcement for masonry is a factory-fabricated welded wire assembly typically consisting of two or more longitudinal wires connected with cross wires forming a truss or ladder configuration. Its primary function is for control of wall cracking associated with thermal or moisture shrinkage or expansion. Other functions include: (1) metal tie system for bonding adjacent masonry wythes or intersecting walls, and (2) structural steel reinforcement for increasing masonry's resistance to flexural, shear, and tensile stresses. Joint reinforcement should comply with *Standard Specification for Masonry Joint Reinforcement*, ASTM A 951 (Ref. 2.4), which governs tensile strength, shear strength of the welds and corrosion protection requirements.

Joint reinforcement is usually placed in bed joints at a minimum spacing of 8 inches (203 mm) and a maximum of 24 inches (610 mm) apart depending on wall height and spacing of control joints, if used. Mortar cover requirements are discussed in Chapter 1. Corners are accommodated either by overlapping the two pieces of joint reinforcement or by using prefabricated "T" and "L" sections.

Joint reinforcement should typically be discontinued at control joints, as it can restrain movement at the joint (see Section 2C).

Recommended joint reinforcement applications are shown in the following table.

Recommended Joint Reinforcement Applications

Wall Configuration	Truss type	Ladder type	Three-wire	Double wire ladder	Continuous tab tie	Adjustable truss	Adjustable ladder	Adjustable tab tie	Seismic adjustable truss	Seismic adjustable ladder
Single-Wythe Walls:	Not permitted in composite or empirically designed walls									
with vertical steel	○	●								
without vertical steel	●	●								
Multiwythe Walls:	Both wythes "course out" and are laid simultaneously									
<u>Backup:</u>	<u>Outside (exterior):</u>									
Concrete masonry	Concrete masonry		● ^A	● ^B	○ ¹	○ ¹	○ ¹	○ ¹	●	●
Concrete masonry	Clay brick				●	●	●	●	●	●
As above in Seismic Design Category C or Higher										
<u>Backup:</u>	<u>Outside (exterior):</u>									
Concrete masonry	Concrete masonry		● ^A	● ^B						●
Concrete masonry	Clay brick		●							●
Wythes do not "course out" or are laid at different times										
<u>Backup:</u>	<u>Outside (exterior):</u>									
Concrete masonry	Concrete masonry					○ ¹	○ ¹	○ ¹	●	●
Concrete masonry	Clay brick					●	●	●		
As above in Seismic Design Category C or Higher										
<u>Backup:</u>	<u>Outside (exterior):</u>									
Concrete masonry	Concrete masonry									●
Concrete masonry	Clay brick									●
Recommended	●	Acceptable	○							
¹ This can be used if ladder reinforcement is installed in the veneer in course above or below for crack control.										

A = If outside wythe is laid with solid mortar bedding

B = If outside wythe is laid with face shell bedding

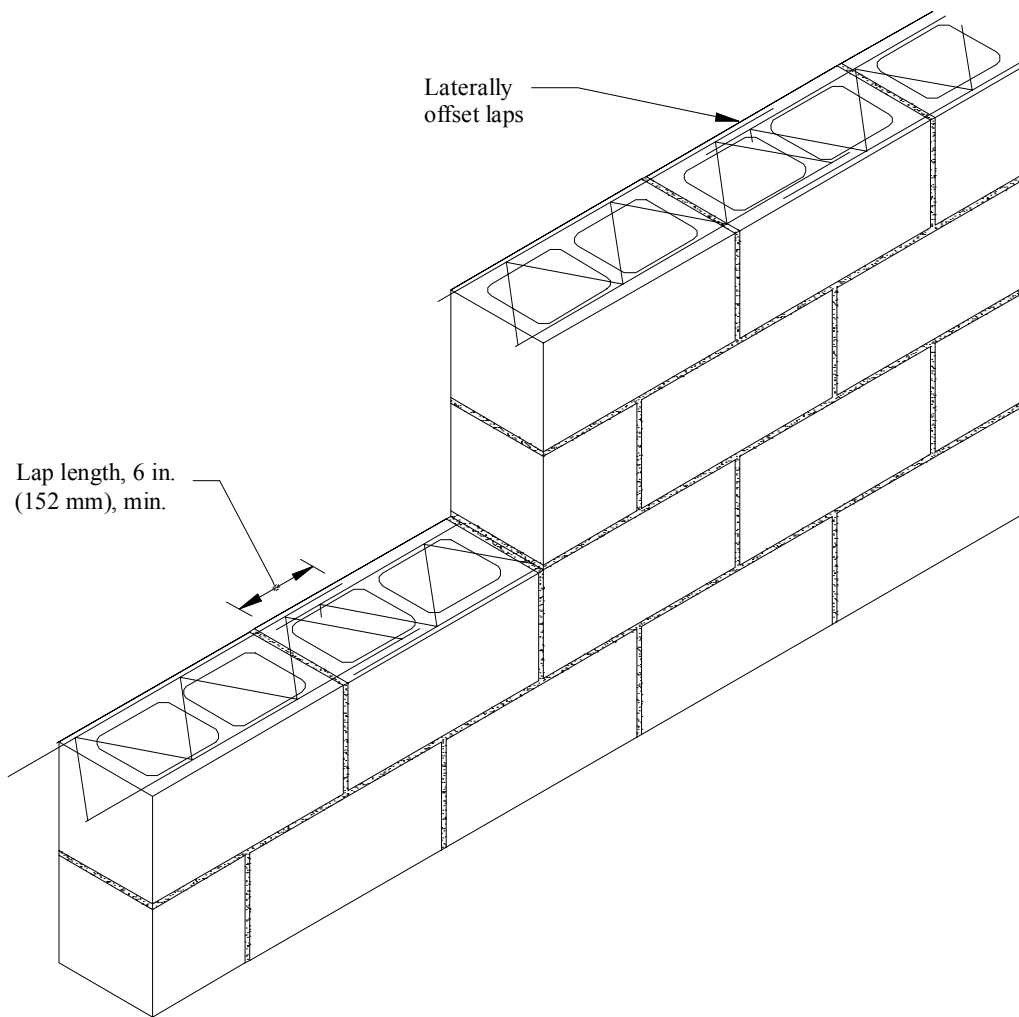
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When horizontal joint reinforcement is used to tie two masonry wythes together, ladder type reinforcement is preferred over truss type, because the shape of the ladder type allows for in-plane movement of the wythes. This is particularly important when the wythes are expected to experience significant differential movement, such as in an insulated cavity wall, or a clay brick/concrete masonry cavity wall. The truss shape is relatively stiff in the plane of a wall, and therefore tends to restrict this differential movement. When joint reinforcement is used to tie adjacent wythes of masonry together, the bed joints of the adjacent wythes must align, and there should generally be at least one wire in each mortar bed joint. When bed joints do not align, which happens when the wythes utilize units which do not course out evenly, joint reinforcement with adjustable ties should be used. Seismic anchors are also available for use in seismic design.

In reinforced concrete masonry, the ladder shape also causes less interference with vertical reinforcement than truss type.

Splicing Joint Reinforcement

With ladder-type joint reinforcement, centering the cross wires on the concrete masonry webs will minimize interference with vertical reinforcement. Laps should be staggered across the face of the wall as shown below while maintaining the minimum code required cover distance. Lap splice for all joint reinforcement types and wire sizes is 6 inches (152 mm).



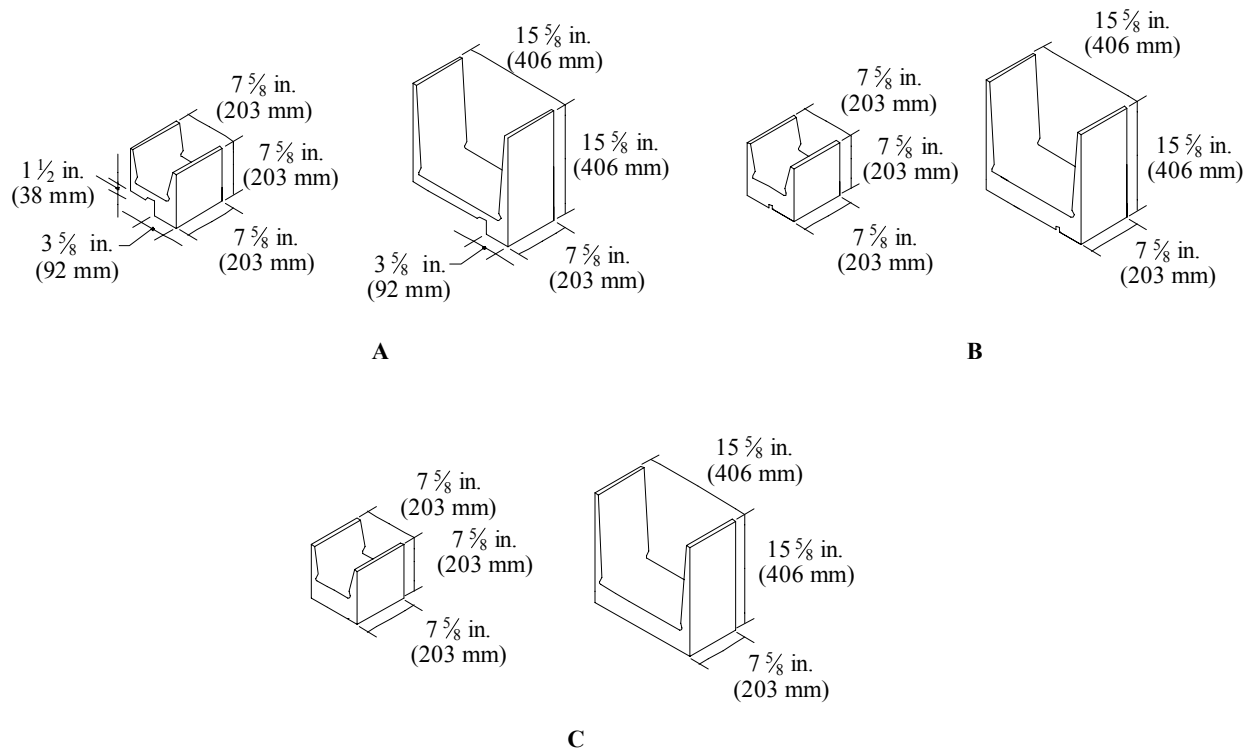
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2G - Lintels

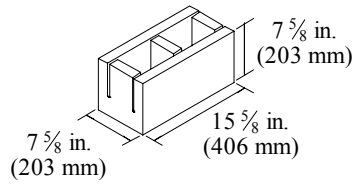
Lintels function as beams to support the wall weight and other loads over an opening, and to transfer these loads to the adjacent masonry wall or structural element. Lintels for concrete masonry construction can be made of precast reinforced concrete, reinforced concrete masonry units, or structural steel.

Masonry will typically distribute loads so that the loads do not act directly on the lintel. This is called "arching action of masonry" and is based on the amount of masonry that is above the lintel. Note that movement joints at or near the end of the lintel can influence loads and support conditions. Arching will not occur with control joints at or near the jamb. Other design considerations include the size of the opening, type and magnitude of lintel loads, length of lintel end support, lintel depth, and lintel reinforcement. A full discussion of these issues is included in *Design Tables for Concrete Masonry and Precast Concrete Lintels* (Ref. 2.5).

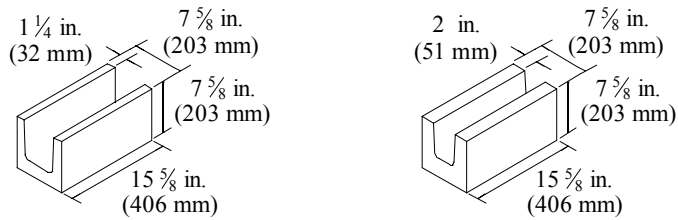
Concrete masonry units suitable for lintel construction are available in a variety of shapes and sizes, as shown in Figure 2-3. Lintel units are often U-shaped to accommodate the horizontal reinforcement while the solid bottom confines grout to the lintel. When knock-out bond beam units are used to construct lintels, the bottom is blocked to confine the grout.



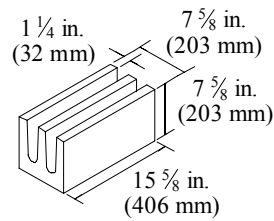
- A. For metal or wood sash installed after wall is erected. These units make an efficient and weather tight joint.
- B. For metal sash only installed as wall is erected.
- C. For finished masonry openings, or metal and wood sash.



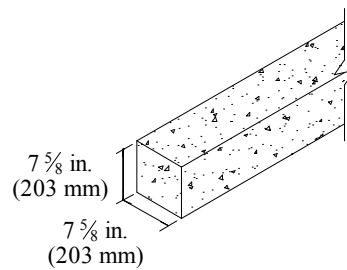
Knock Out Bond Beam



Bond Beam



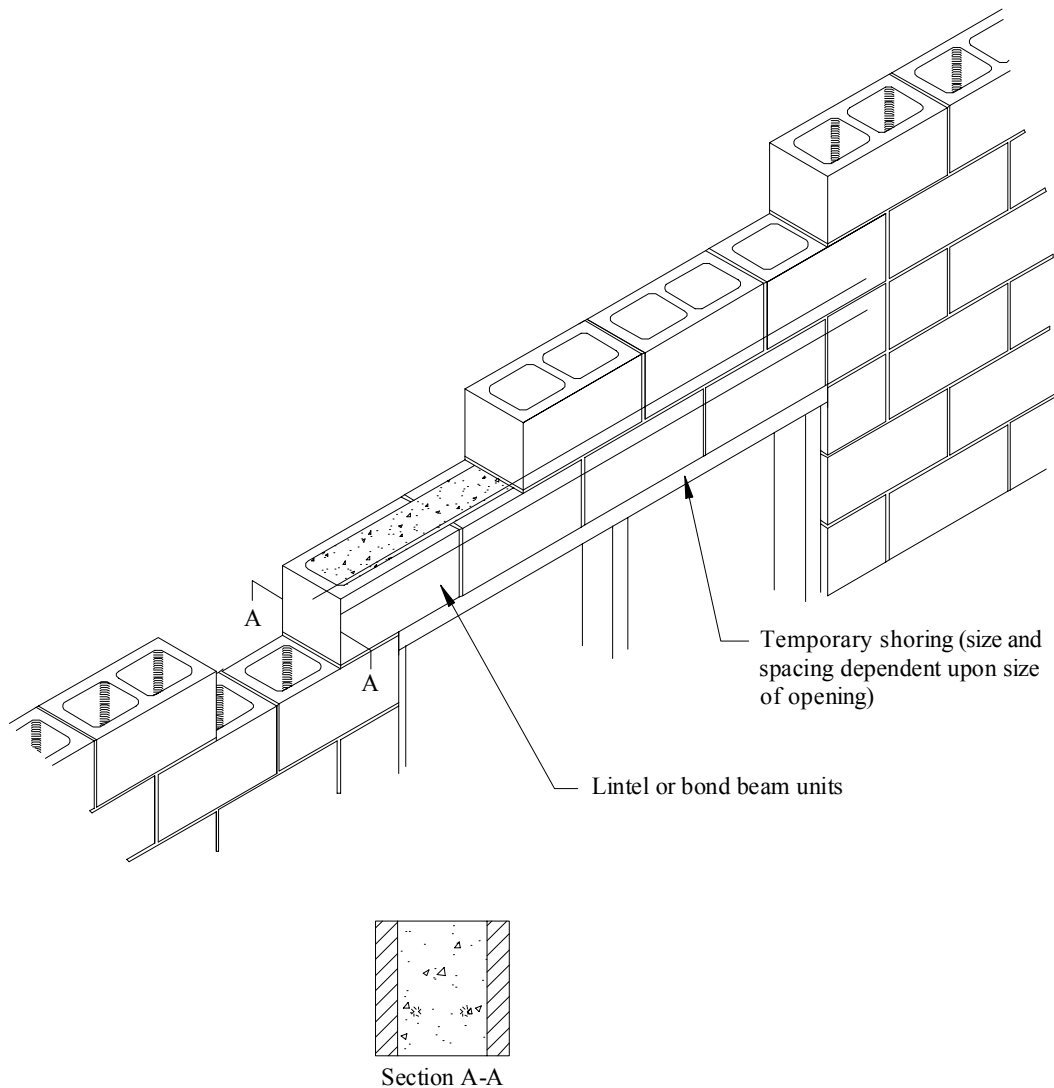
Bond Beam Double Core



Precast Concrete

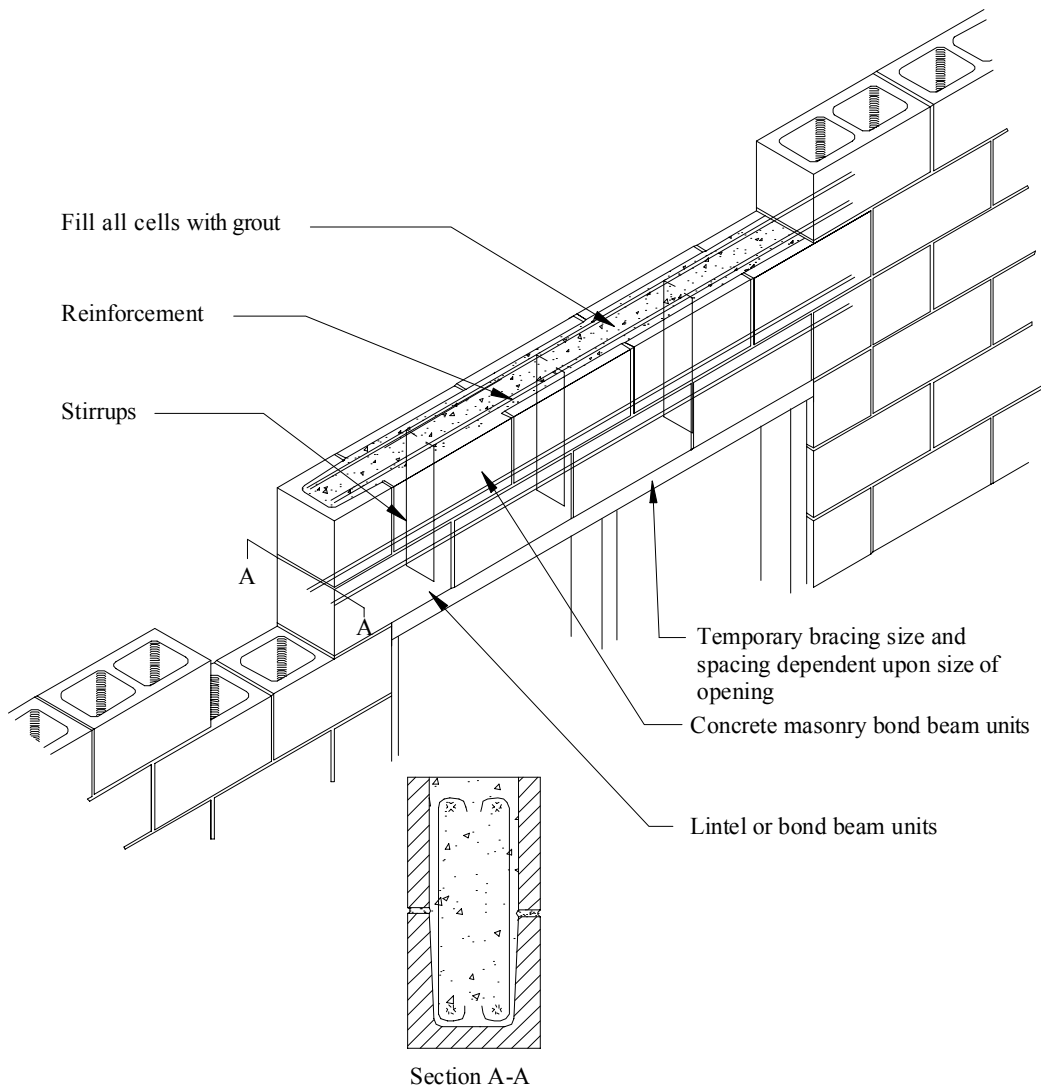
Concrete Masonry Lintel

Temporary shoring contains the grout, if solid bottomed units are not used for lintel construction. Weep holes should be spaced a maximum of 32 inches (813 mm) apart on top of lintel.



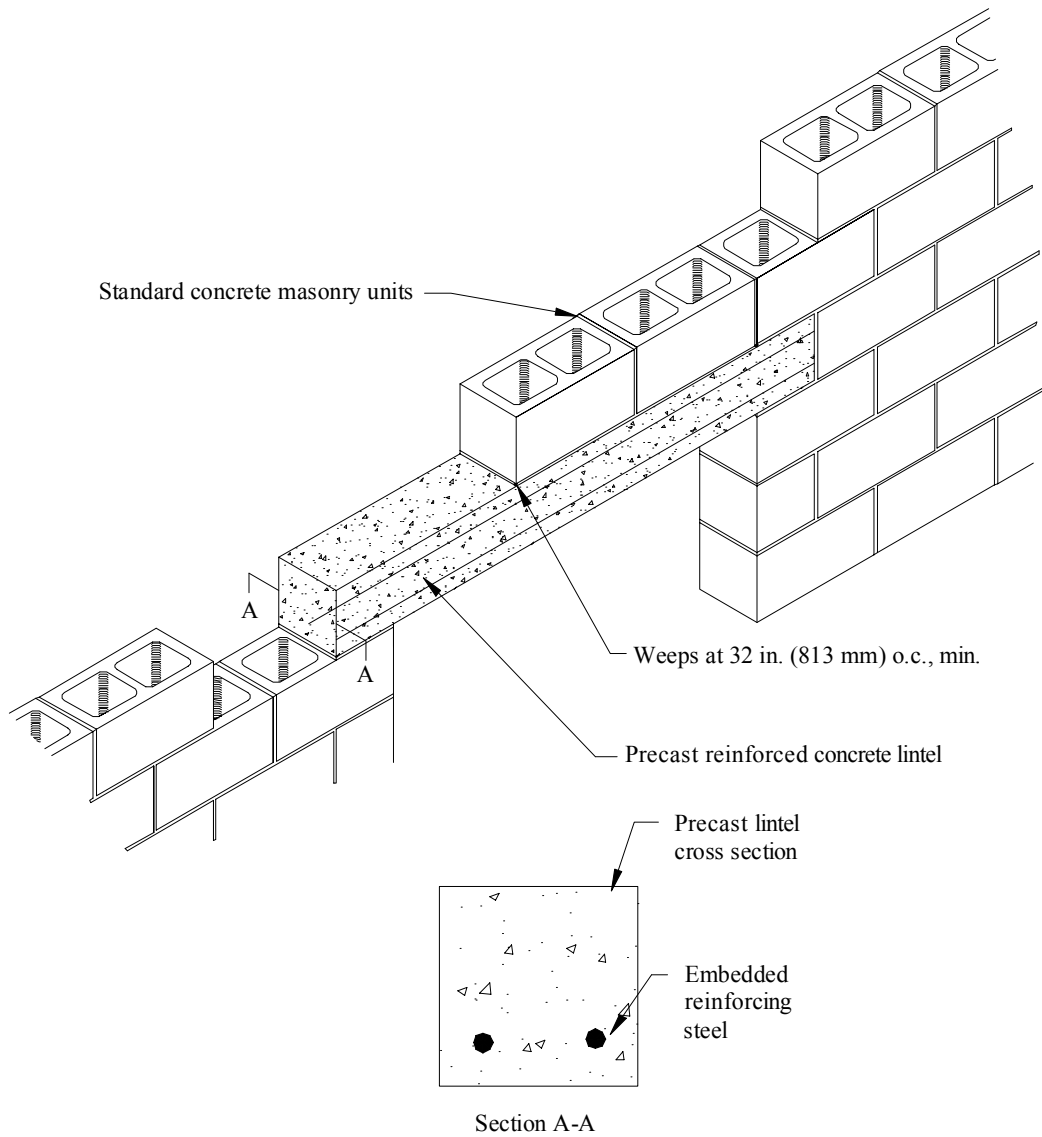
16 Inch (406 mm) Deep Concrete Masonry Lintel With Stirrups

Temporary shoring contains the grout, if solid bottomed units are not used for lintel construction. Weep holes should be spaced a maximum of 32 inches (813 mm) apart on top of lintel. Concrete masonry lintels are sometimes constructed as a portion of a continuous bond beam. This construction provides several benefits: it is considered to be more beneficial in high seismic areas or in areas where high winds may be expected; control of wall movement due to shrinkage or temperature differentials is more easily accomplished; and lintel deflection is often substantially reduced. Concrete masonry lintels have the advantages of easily maintaining the bond pattern, color and surface texture of the surrounding masonry. They can also be placed in the wall without the need for special lifting equipment, which is common for precast items. Shear reinforcement, usually in the form of stirrups, is used to control diagonal cracking in the lintel. Hooks for stirrups incorporate either 90 or 135 degree bends, with minimum extensions of six bar diameters or 2 1/2 inches (64 mm), whichever is greater (see Chapter 1, Figure 1E.5).



Precast Concrete Lintel Assembly

Precast lintels should bear on the masonry a minimum of 4 inches (102 mm) on each side of the opening.



REFERENCES

- 2.1 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02, Reported by the Masonry Standards Joint Committee, 2002.
- 2.2 *Specification for Masonry Structures*, ACI 530.1-02/ASCE 6-02/TMS 602-02, Reported by the Masonry Standards Joint Committee, 2002.
- 2.3 *Control Joints for Concrete Masonry Walls - Empirical Method*, TEK 10-2B, National Concrete Masonry Association, 2001.
- 2.4 *Standard Specification for Mortar for Unit Masonry*, ASTM C 270-01a, American Society for Testing and Materials, 2001.
- 2.5 *Standard Specification for Masonry Joint Reinforcement*, ASTM A 951-00, American Society for Testing and Materials, 2000.
- 2.6 *Design Tables for Concrete Masonry and Precast Concrete Lintels*, TR 91A, National Concrete Masonry Association, 1996.
- 2.7 *Inspection of Concrete Masonry Construction*, TR 156, National Concrete Masonry Association, 1996.
- 2.8 *Masonry Structures: Behavior and Design*, TR 129, National Concrete Masonry Association, 1993.
- 2.9 *Standard Specification for Nonrigid Vinyl Chloride Polymer and Copolymer Molding and Extrusion Compounds*, ASTM D 2287-96 (2001), American Society for Testing and Materials, 2001.
- 2.10 *Standard Classification System for Rubber Products in Automotive Applications*, ASTM D 2000-01, American Society for Testing and Materials, 2001.
- 2.11 *Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies*, ACI 216.1-97/TMS 0216-98, The Masonry Society, 1997.
- 2.12 *Flashing Strategies for Concrete Masonry Walls*, TEK 19-4A, National Concrete Masonry Association, Hemdon, VA, 2001.

Chapter 3 - Single Wythe Construction

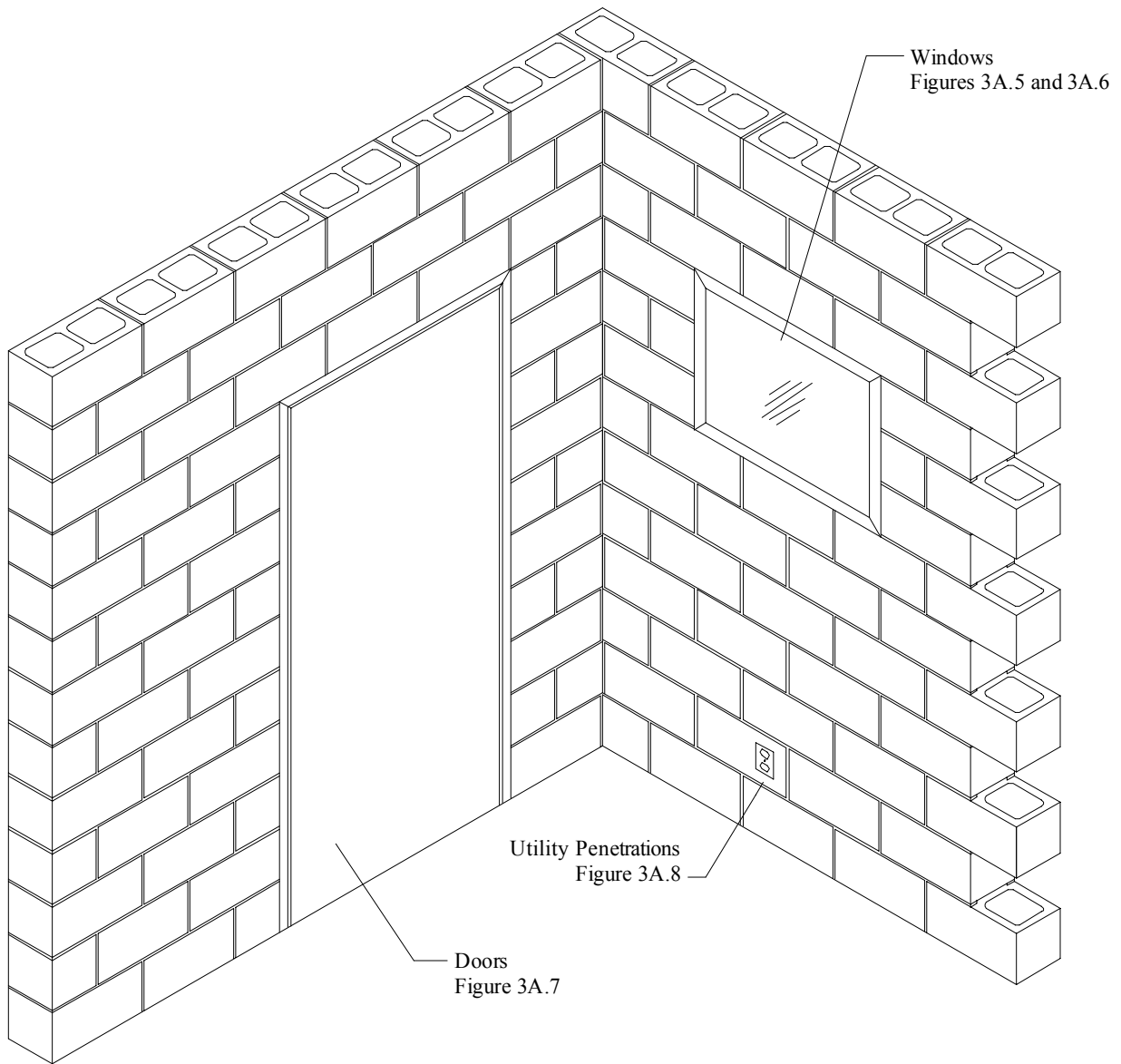
With the increased use of integrally colored architectural concrete masonry units, single wythe concrete masonry walls have become a predominant type of construction. By providing both the structural and the architectural facade in a single building element, single wythe walls have proven their economy and efficiency in nearly all forms of construction.

Chapter 3 addresses detailing recommendations for several common types of single wythe concrete masonry walls, including:

- Above Grade Walls (Section 3A)
- Curtain Walls (Section 3B)
- Infill Walls (Section 3C)
- Prestressed Masonry Walls (Section 3D)
- Foundation Walls (Section 3E)

While these are not the only design and construction consideration that must be accounted for, other important topics, such as water penetration resistance (Section 2D), are covered in other sections of this manual.

SECTION 3A - ABOVE GRADE WALLS



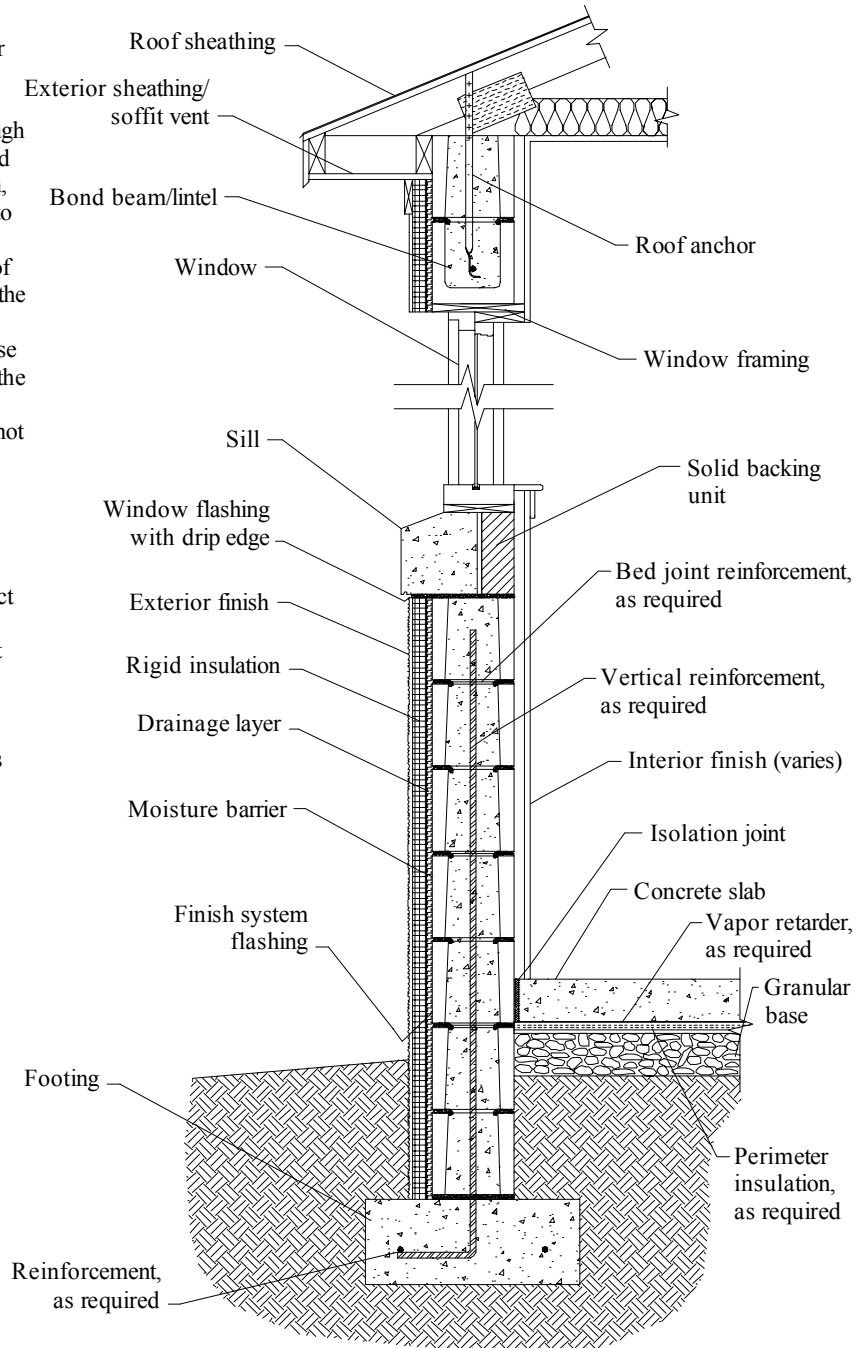
Exterior Insulation Wall Section

Due to the benefits associated with using exterior insulation (which helps to isolate the concrete masonry from the exterior environment thereby employing it as an efficient heat sink), this system of construction may be ideally suited in regions where extreme fluctuations in daily temperature are expected. The following detail illustrates a generic cross section of such a system. Specific details related to this type of construction can be found in subsequent sections and chapters.

The finished appearance of the exterior surface, which uses a modified stucco (also referred to as synthetic stucco) resembles that of classic stucco, although classic stucco is generally not permitted to be applied to a backing of insulation, but instead should be applied directly to the concrete masonry units. Note that some local codes may restrict the use of insulation below grade in areas where the hazard of termite damage is high. Likewise, some codes may require the use of perimeter slab insulation, however, the combination of below grade insulation and perimeter slab insulation is likely not necessary.

This type of construction can be used with both reinforced and unreinforced concrete masonry walls, as dictated by design. Where wood is in direct contact with masonry materials, it should be treated, isolated, or of a decay resistant species to prevent the absorption of moisture from the masonry.

Since many exterior insulating systems are proprietary, manufacturer's recommended installation procedures should be followed.



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Stucco Wall Section

Classic stucco (also called portland cement plaster) is a versatile and proven finishing system that provides a wide variety of finishes and textures. Due to the similarities between concrete masonry and stucco, concrete masonry provides an excellent base for stucco. The following detail illustrates a generic cross section of such a system. Specific details related to this type of construction can be found in subsequent sections and chapters.

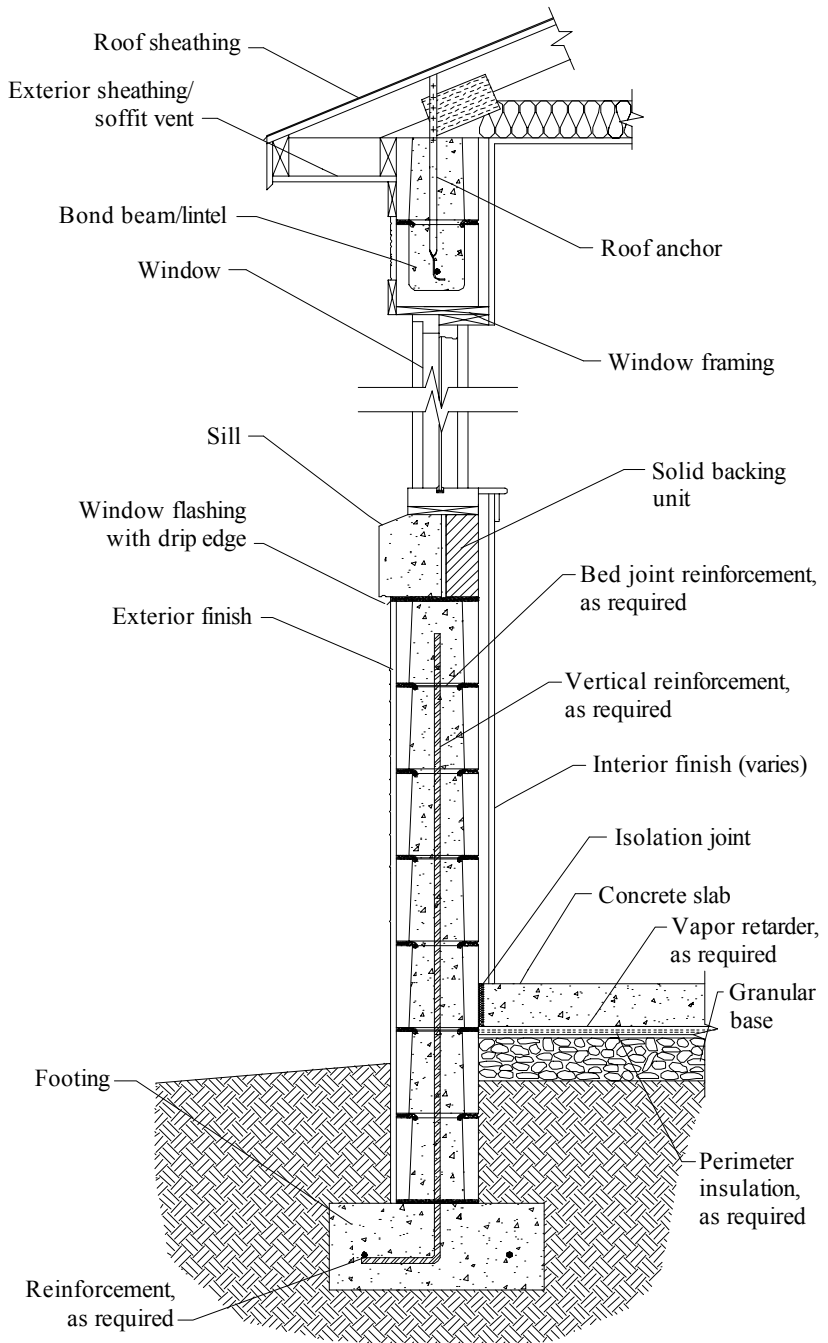
When constructing concrete masonry walls that are to be plastered, use open-textured concrete masonry units to promote a good mechanical bond between the stucco and the masonry. Concrete masonry walls should be clean and free of any surface contaminations to promote good bond between the stucco and the masonry backing. Further, to provide a uniform surface to adhere to, mortar joints should be cut flush rather than tooled or floated.

A two-coat application (base coat and finish coat) is most often used when stucco is applied directly to concrete masonry. However, differential absorption between the concrete masonry units and the mortar joints may cause the joints to be visible in the finished surface. To avoid 'ghosting' of the mortar joints on the finished surface, the base coat should be sufficiently thick and the wall should be properly cured and not contain excessive moisture.

Prior to applying stucco, the concrete masonry wall should be properly cured and be carrying almost all of its design dead load before plaster is applied. This will help avoid cracking the stucco that may result from the application of load.

This type of construction can be used with both reinforced and unreinforced concrete masonry walls, as dictated by design. Where wood is in direct contact with masonry materials, it should be treated, isolated, or of a decay resistant species to prevent the absorption of moisture from the masonry.

Additional information on stucco and its application to concrete masonry walls is available in TEK 9-3A *Plaster and Stucco for Concrete Masonry* (Ref. 3.8).

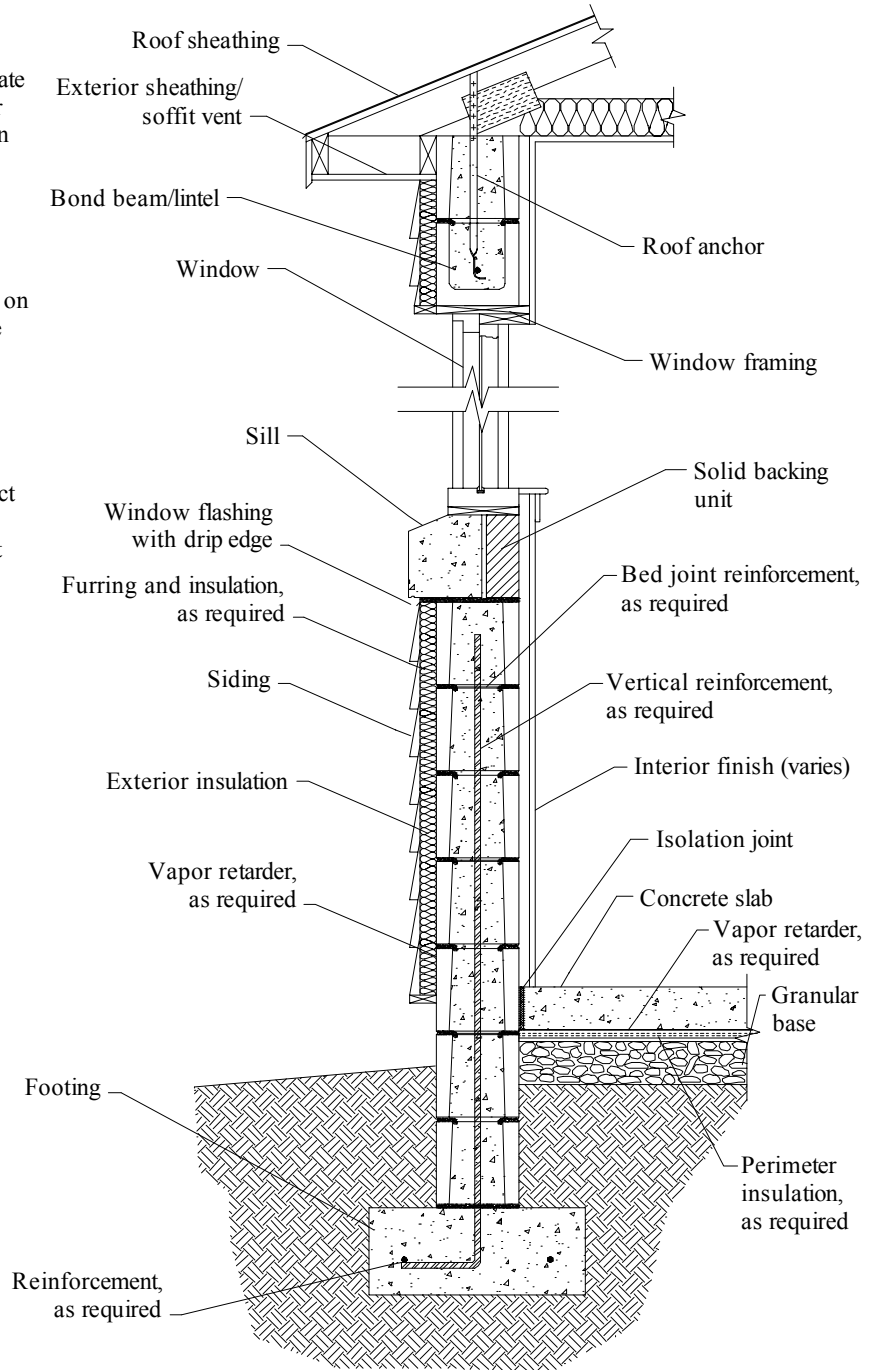


Siding Wall Section

On occasion, exterior siding is used to finish a concrete masonry wall, or is used to highlight or offset sections of a masonry wall. The siding material can take many forms, including: cement board, vinyl, wood, or metal. The following detail illustrates a generic cross section of such a system. Specific details related to this type of construction can be found in subsequent sections and chapters.

The advantage of an exterior siding application is it permits the use of exterior insulation (which helps to isolate the concrete masonry from the exterior environment thereby employing it as an efficient heat sink). This system of construction may be ideally suited in regions where extreme fluctuations in daily temperature are expected. Insulation may also be incorporated within the cells of the masonry wall or on the interior, if an interior finish is to be incorporated.

This type of construction can be used with both reinforced and unreinforced concrete masonry walls, as dictated by design. Where wood is in direct contact with masonry materials, it should be treated, isolated, or of a decay resistant species to prevent the absorption of moisture from the masonry.

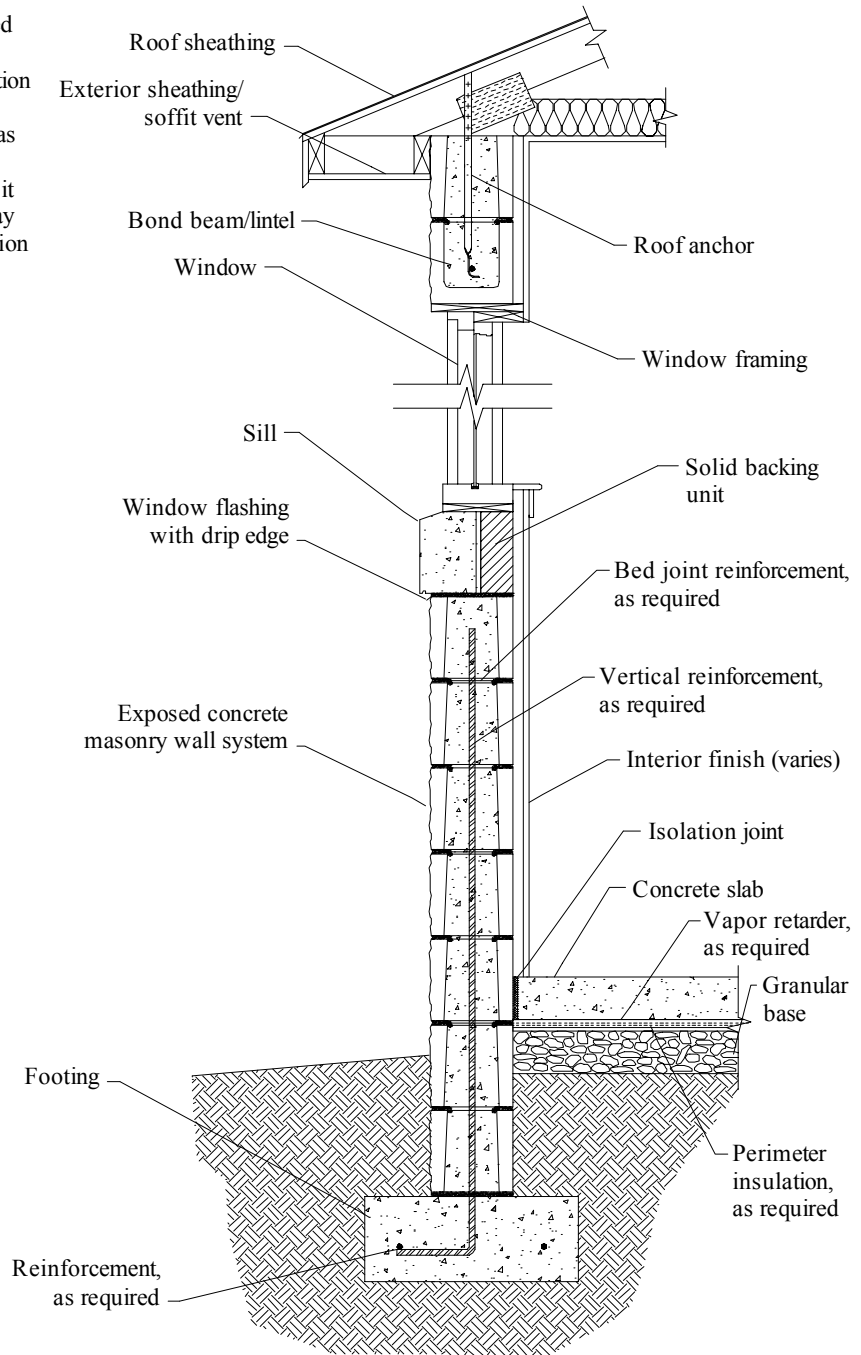


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Exposed Concrete Masonry Wall Section

One of the most prevalent forms of construction is exposed concrete masonry, often incorporating architecturally finished units such as split face, ground face, scored, and acid washed. The following detail illustrates a generic cross section of such a system. Specific details related to this type of construction can be found in subsequent sections and chapters.

As with other concrete masonry wall systems, insulation may be incorporated on the exterior, interior, or integrally within the wall. This type of construction can be used with both reinforced and unreinforced concrete masonry walls, as dictated by design. Where wood is in direct contact with masonry materials, it should be treated, isolated, or of a decay resistant species to prevent the absorption of moisture from the masonry.



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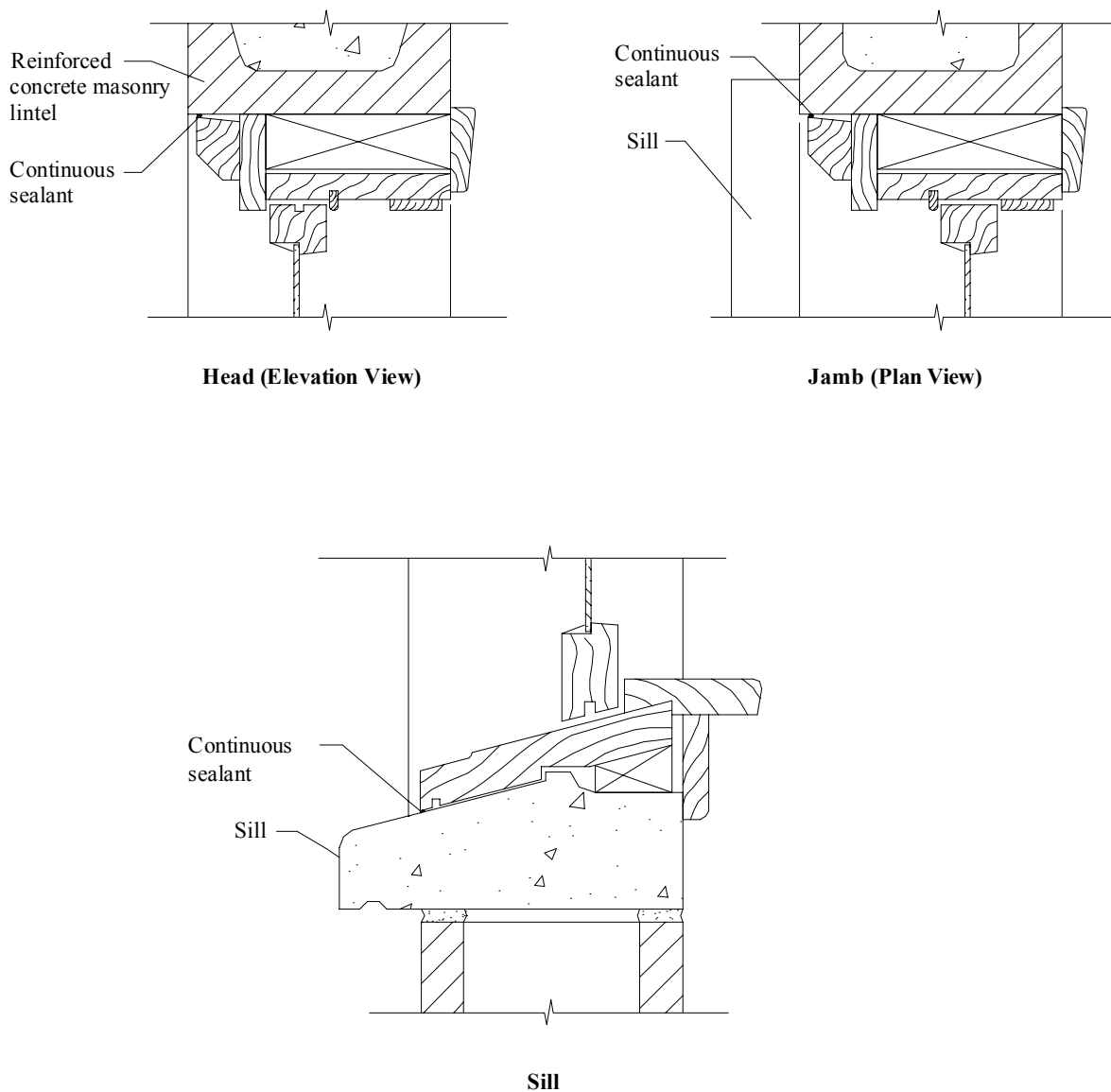
Wood Window Details

Aluminum, wood and vinyl sash windows are most commonly used. The sash is fitted in place and bolted or locked in with a snap closure piece. Consult the window manufacturer for specific details.

Caulking around the window frame is important to minimize water penetration.

Wood in direct contact with masonry materials should be pressure treated, be naturally decay resistant or should have a moisture barrier placed between the wood and the masonry.

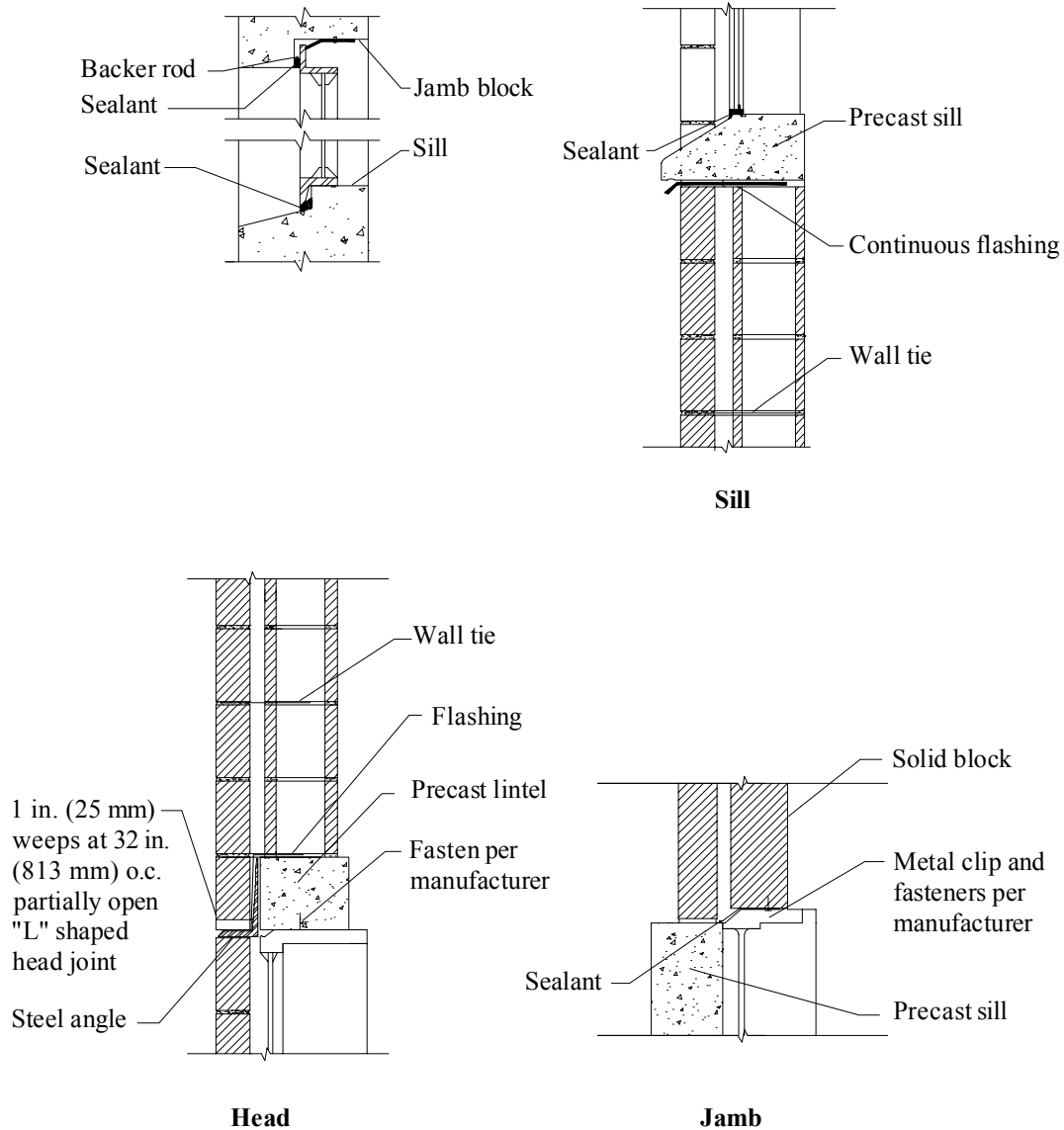
The details below are also applicable to vinyl windows.



Last Modified: December, 2002

Metal Window Details

As with other types of window construction, manufacturer's recommended installation should be followed.



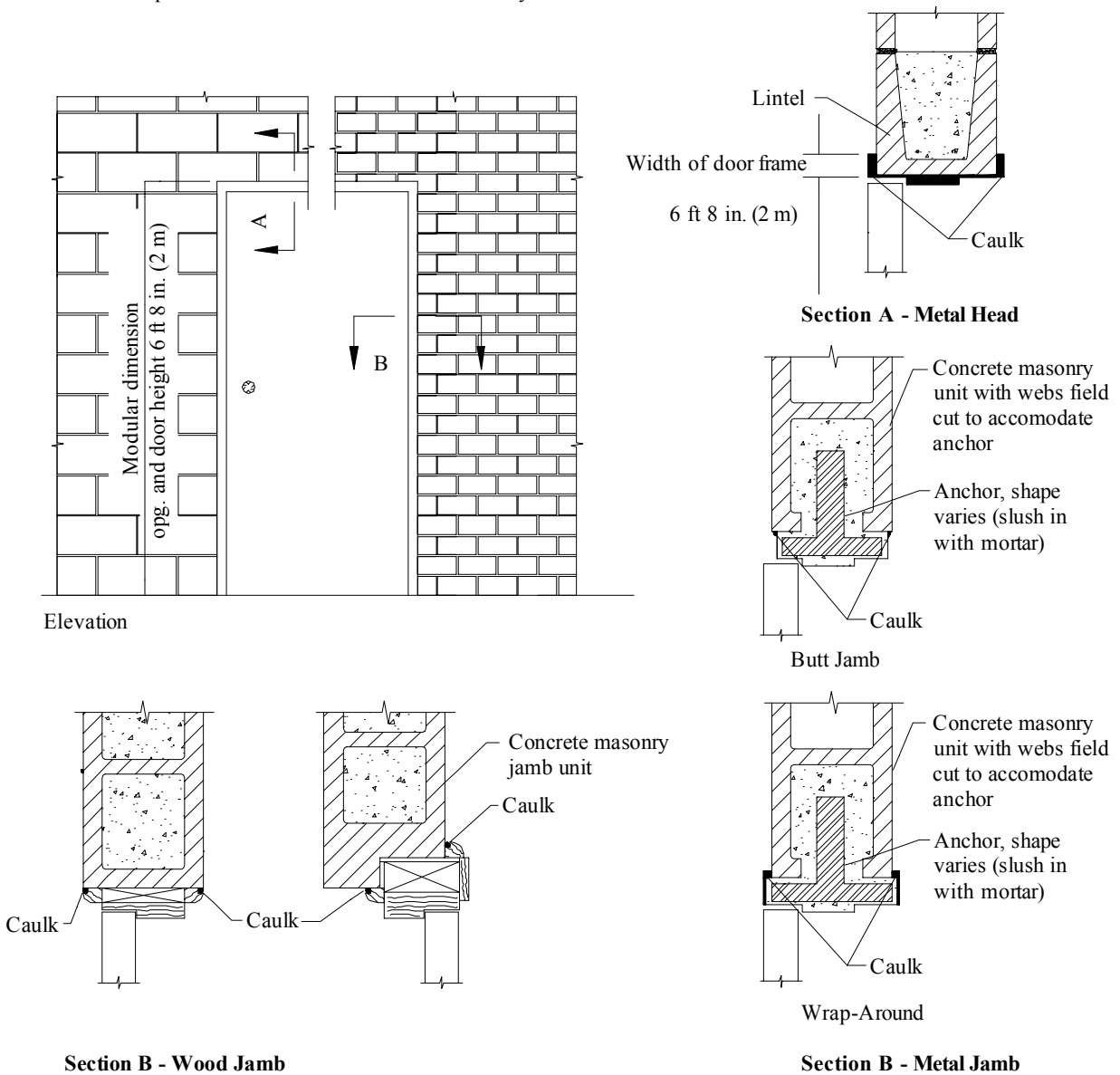
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Door Jamb Details

Wood door jamb anchors are typically installed approximately 8 inches (203 mm) from the top and bottom of the frames and near the mid-height of the frame. Avoid door hardware locations. For doors more than 3 ½ feet (1.1 m) wide, install head anchors similar to jamb anchorage. For metal jambs, if grouted frames are required, use bond beam concrete masonry units or cut ends of units at the jamb to allow grout to fill the void in the metal frame.

In some locations, products may be available to accommodate the framing above 6 feet 8 inches (2,000 mm) doors without the need to cut masonry units. These products include precast lintels with a 2 inch (51 mm) notch in them and doors with a 4 inch (102 mm) header.

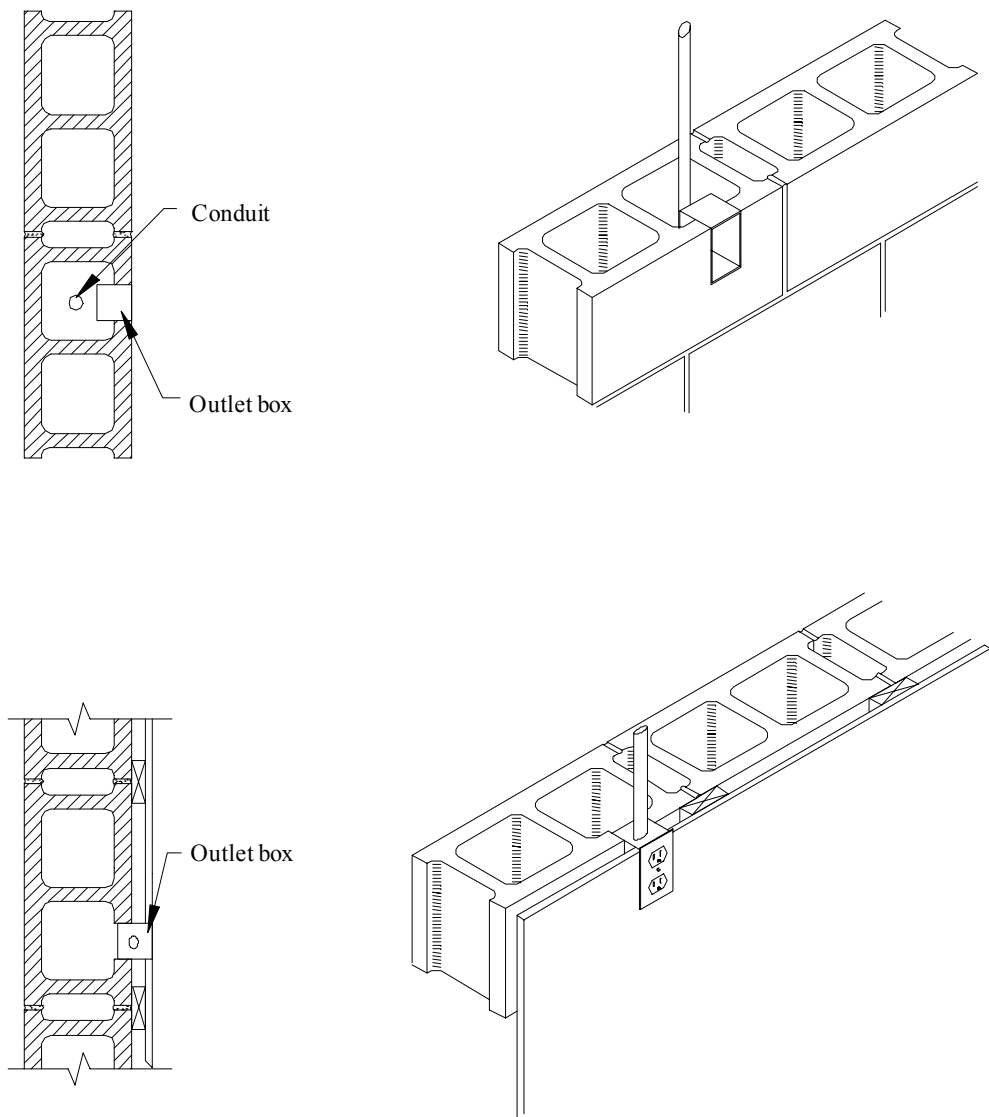
Wood in direct contact with masonry materials should be pressure treated, be naturally decay resistant or should have a moisture barrier placed between the wood and the masonry.



Last Modified: December, 2002

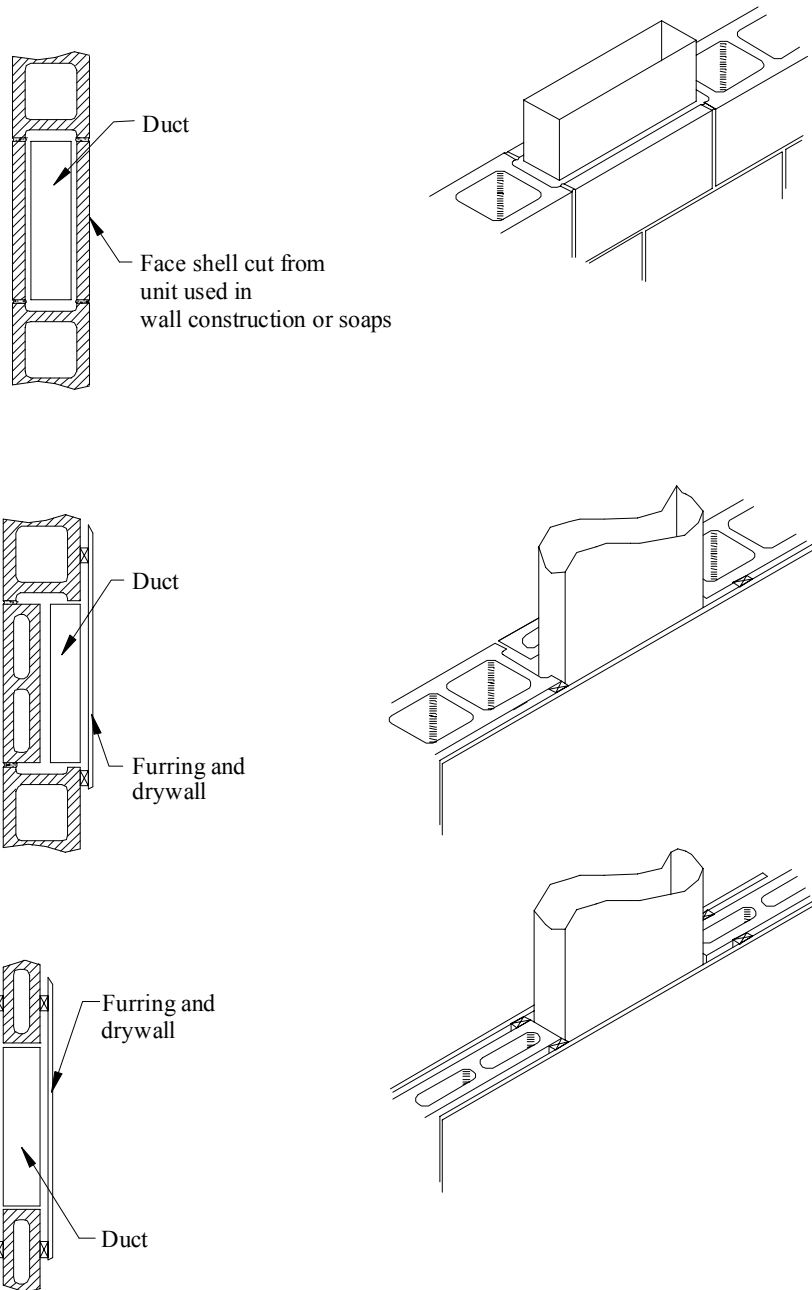
Outlet Box Utility Penetrations

When concrete masonry will be exposed, and when 1 inch (25 mm) nominal furring is used, cut a hole in the face shell to accommodate the outlet box. With 2 inch (51 mm) or larger nominal furring, the box can be mounted on the surface of the masonry. When interior concrete masonry will be exposed, stagger outlet boxes on each side of the wall to reduce noise transmission through the wall. Concrete masonry units with recessed webs can accommodate horizontal conduits. For single wythe exterior walls, it is preferable to surface mount utility boxes.



Duct Utility Penetrations

When concrete masonry will be exposed, vertical ducts can be placed in a gap left in the masonry, then covered by mortaring two face shells in place over the duct. Ensure the masonry is designed and properly supported to accommodate this gap. For single wythe exterior walls, it is preferable to place ducts on the interior of, rather than within, the concrete masonry wall.



Last Modified: December, 2002

3B-Curtain Walls

Nonloadbearing masonry curtain walls are used to enclose concrete or steel frame structures. Curtain walls are designed to resist lateral wind and seismic loads (if needed) and transfer these lateral loads to the structural frame. They typically do not carry any vertical loads other than their own weight. They are distinguished from masonry veneer walls in that curtain walls are supported at large intervals whereas anchored masonry veneer is continuously supported by a backup material.

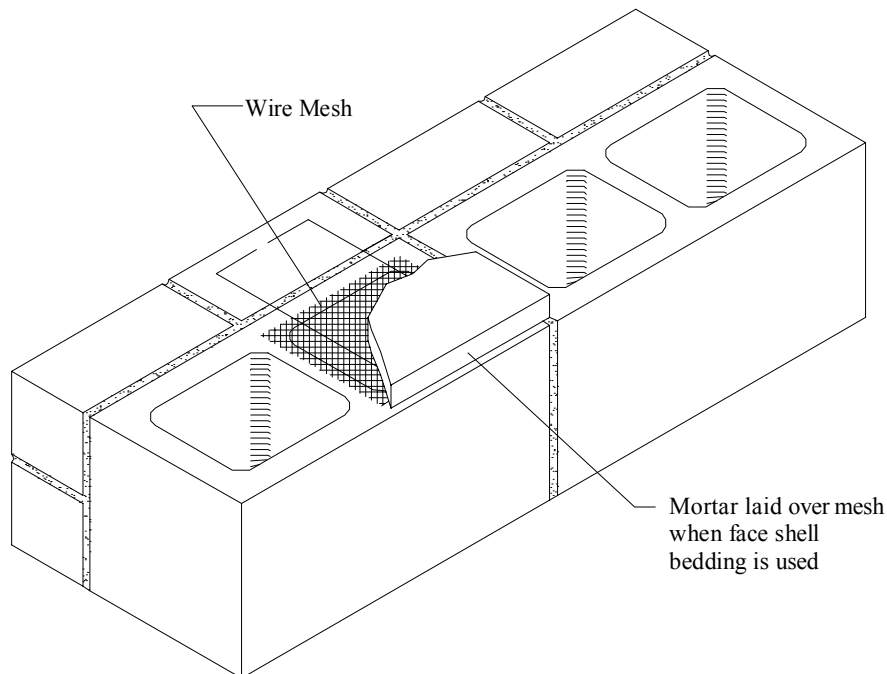
Curtain walls must be isolated from the frame to prevent the unintentional transfer of structural loads and to allow differential movement between the frame and the masonry. Anchorage between the concrete masonry and structural frame must also account for different construction tolerances for each building material. Concrete masonry curtain walls should incorporate flashing and weeps as for other concrete masonry wall construction (see Section 2D).

Concrete masonry curtain walls are vertically supported at the foundation and can be designed to resist lateral loads at beams, columns or floors. They can also incorporate reinforcement to increase the wall's lateral load resistance and the required distance between lateral supports.

Anchors used to provide lateral support must be sufficiently stiff in the out-of-plane direction to transfer lateral loads to the frame and be flexible enough in-plane to allow differential movement between the curtain wall and the frame. *Building Code Requirements for Masonry Structures* (Ref. 3.1) includes specific corrosion-resistance requirements to ensure long-term integrity of the anchors, consisting of AISI Type 304 stainless steel or galvanized or epoxy coatings.

Anchors are required to be embedded at least 1½ inches (38 mm) into the mortar bed when solid masonry units are used (Ref. 3.1) to prevent failure due to mortar pullout or pushout. Because of the magnitude of anchor loads, it is also recommended that they be embedded in grout filled cores when using hollow units. As an alternative to completely filling the masonry core, this can be accomplished by placing a grout stop material under the anchor and laying in 1 to 2 inches (25 to 51 mm) of mortar in the core of the block to surround and embed the anchor (see figure below).

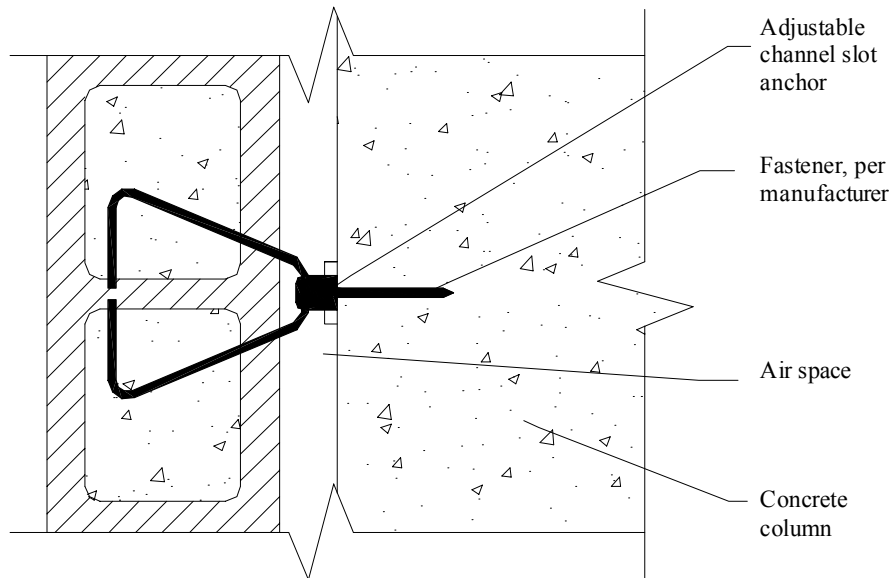
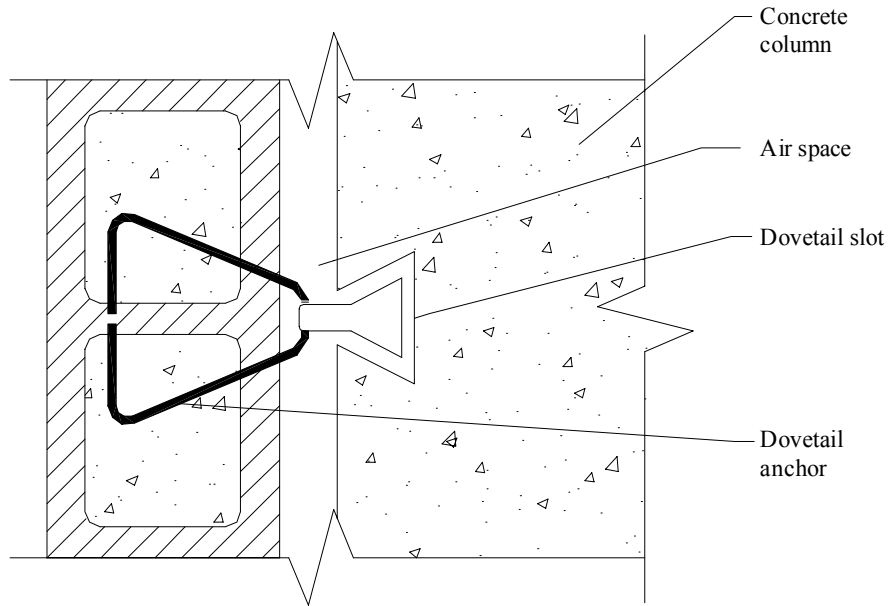
For both concrete and steel frames, the space between the structural frame and the masonry should be kept clear of mortar to avoid rigidly bonding the two elements.



Last Modified: December, 2002

Curtain Wall Connections to Concrete Columns

Keep the space between the frame and the masonry clear of mortar to avoid rigidly bonding the two elements together.



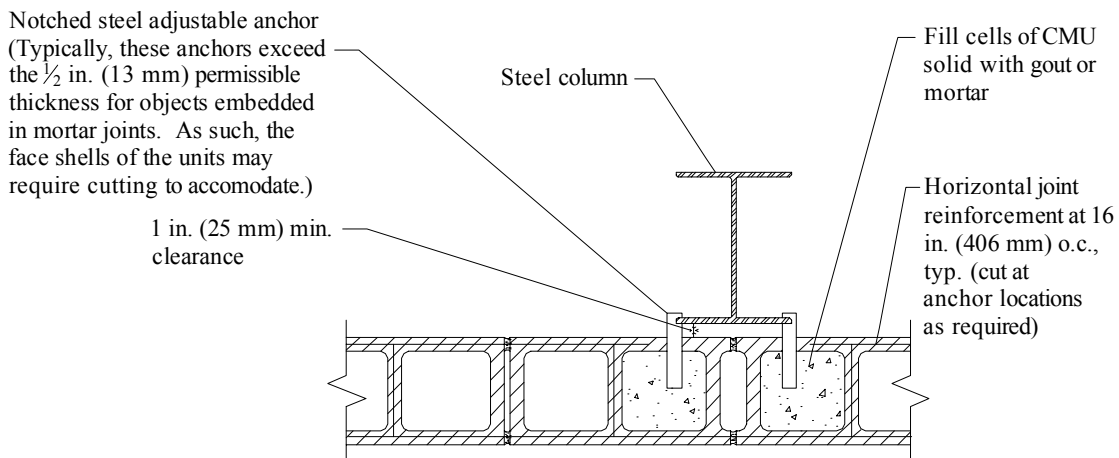
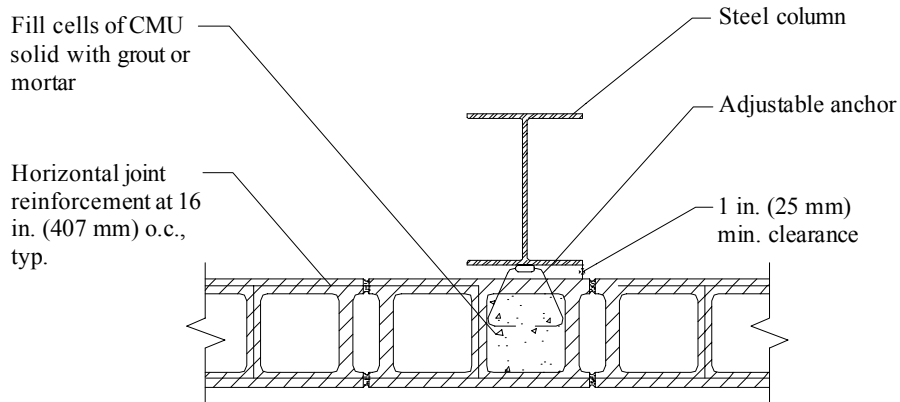
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Connections to Steel Columns

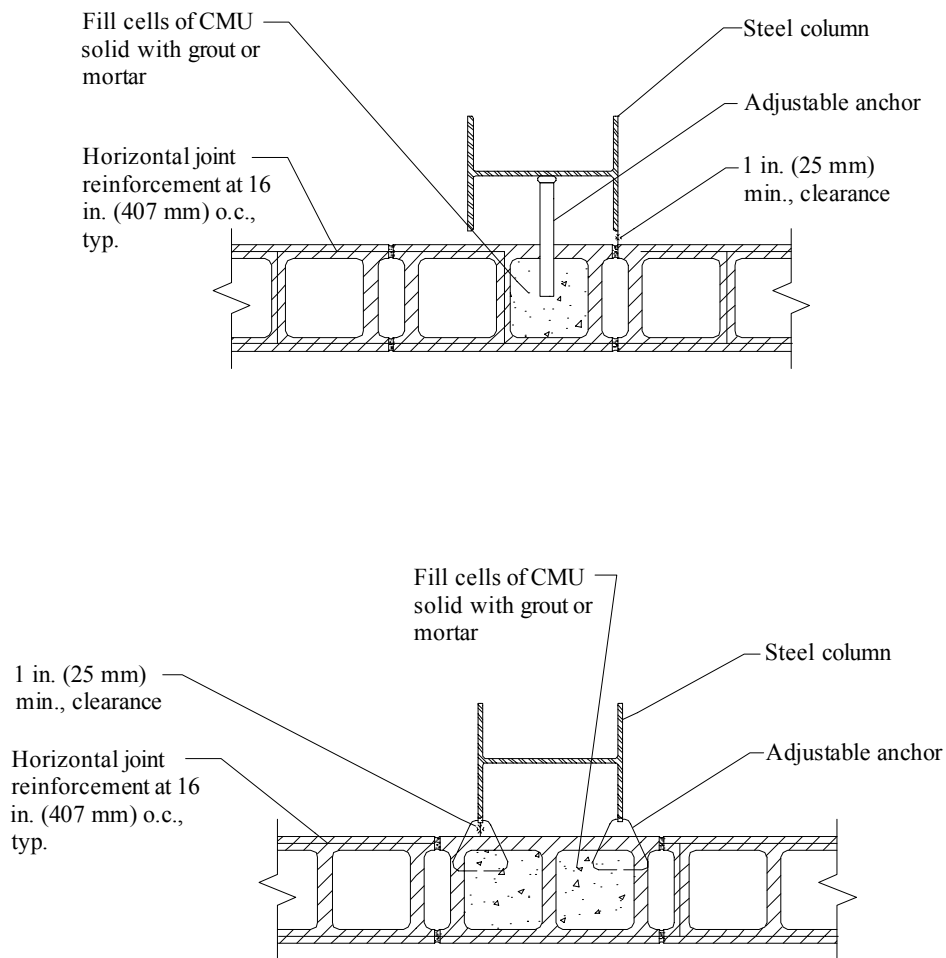
Keep the space between the frame and the masonry clear of mortar to avoid rigidly bonding the two elements together.

Using two anchors increases load capacity and hence vertical spacing requirements. Adjustable strip anchors engage the steel column flange through a slotted metal channel and have a 90° bend at the other end, which must be embedded into a fully grouted masonry core above and below the anchor.

Horizontal joint reinforcement should be discontinued at control joints.



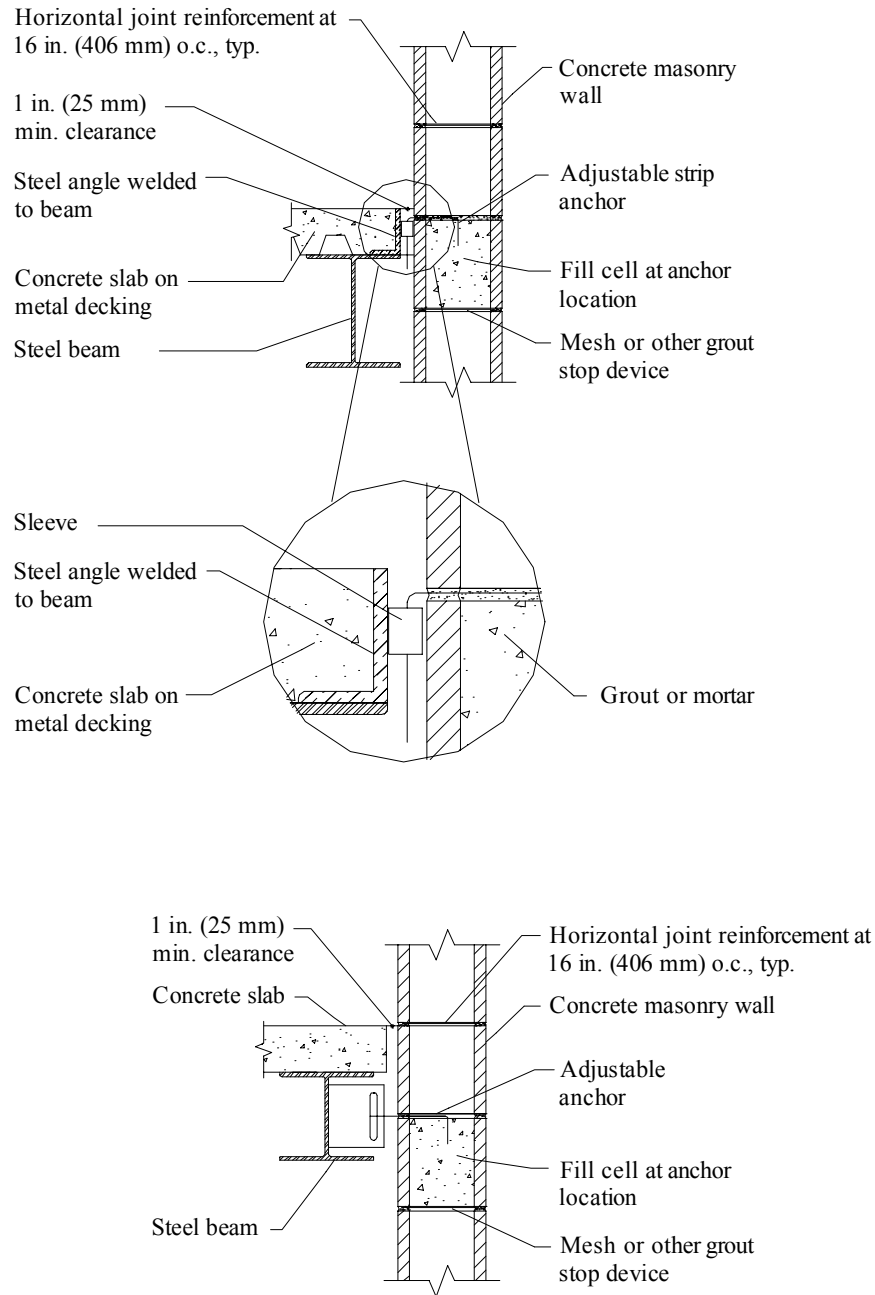
Connections to Steel Columns

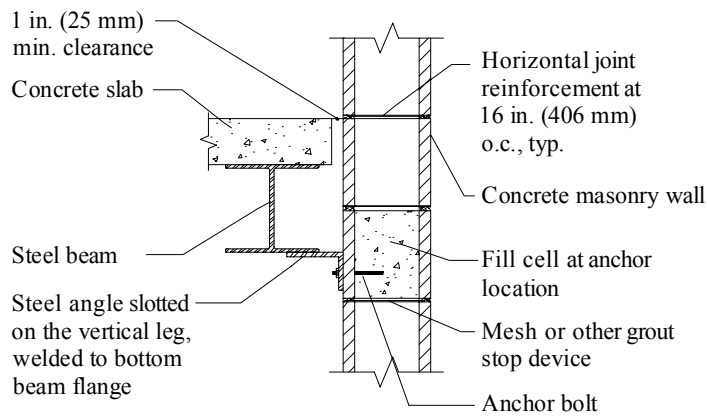
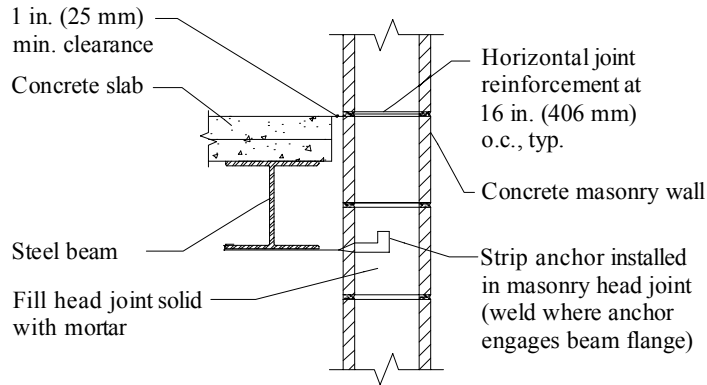


Last Modified: December, 2002

Curtain Wall Connections to Steel Beams

Keep the space between the frame and the masonry clear of mortar to avoid rigidly bonding the wall and frame. The strip anchor must be fully embedded in the mortar of the masonry head joint. This anchor is most effective where beam deflections are minimal.

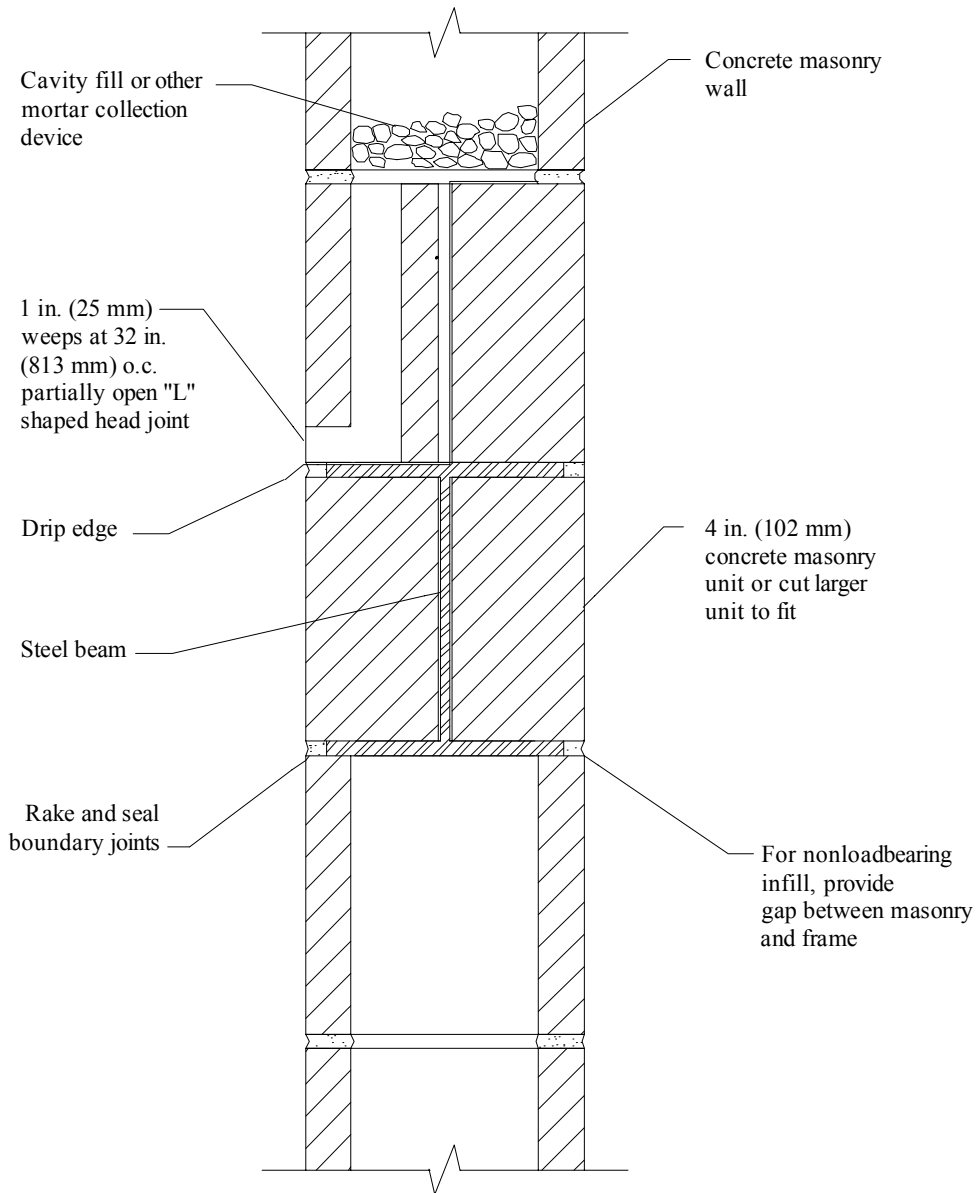




3C — Infill Walls

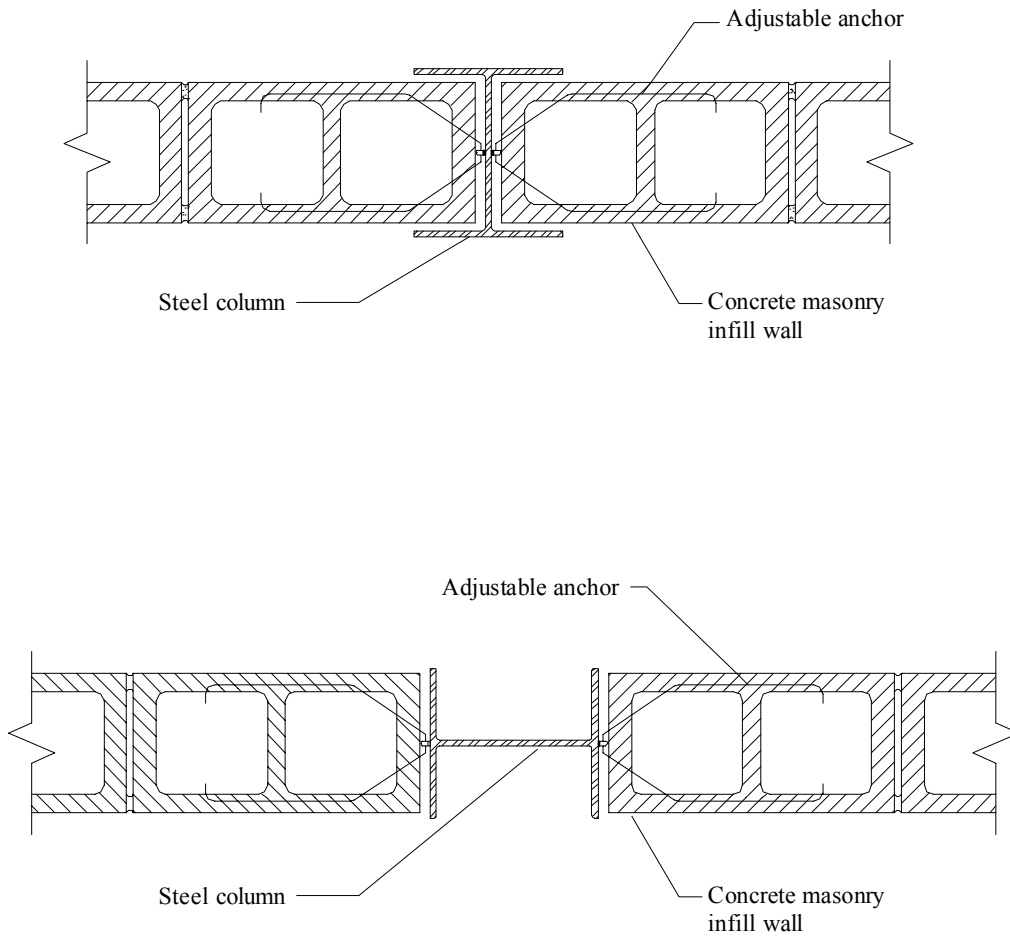
Infill walls are nonloadbearing panels enclosed in a frame of adjacent beams and columns. Flexible connections at columns and open spaces or compressible fillers at the beams prevent the infill wall from being inadvertently subjected to the building frame loads. Gapped infill walls have an airspace between the ends of the wall and the structural column. Flexible anchors provide lateral support to the infill walls. Ungapped infill walls are laid flush with the structural column, a construction method that allows the infill walls to function as shear walls.

Masonry Cover Over Steel Beam

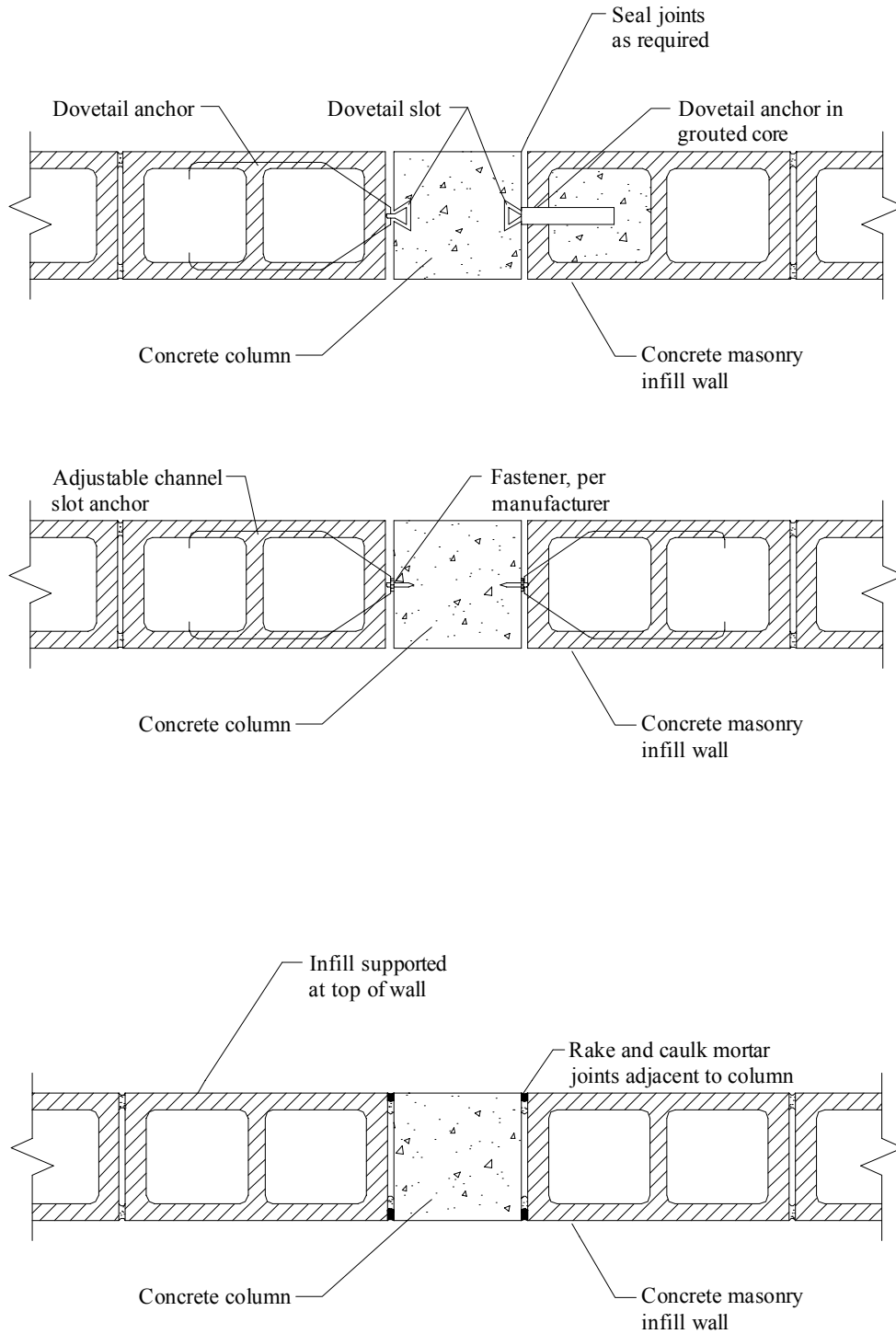


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Masonry at Steel Column



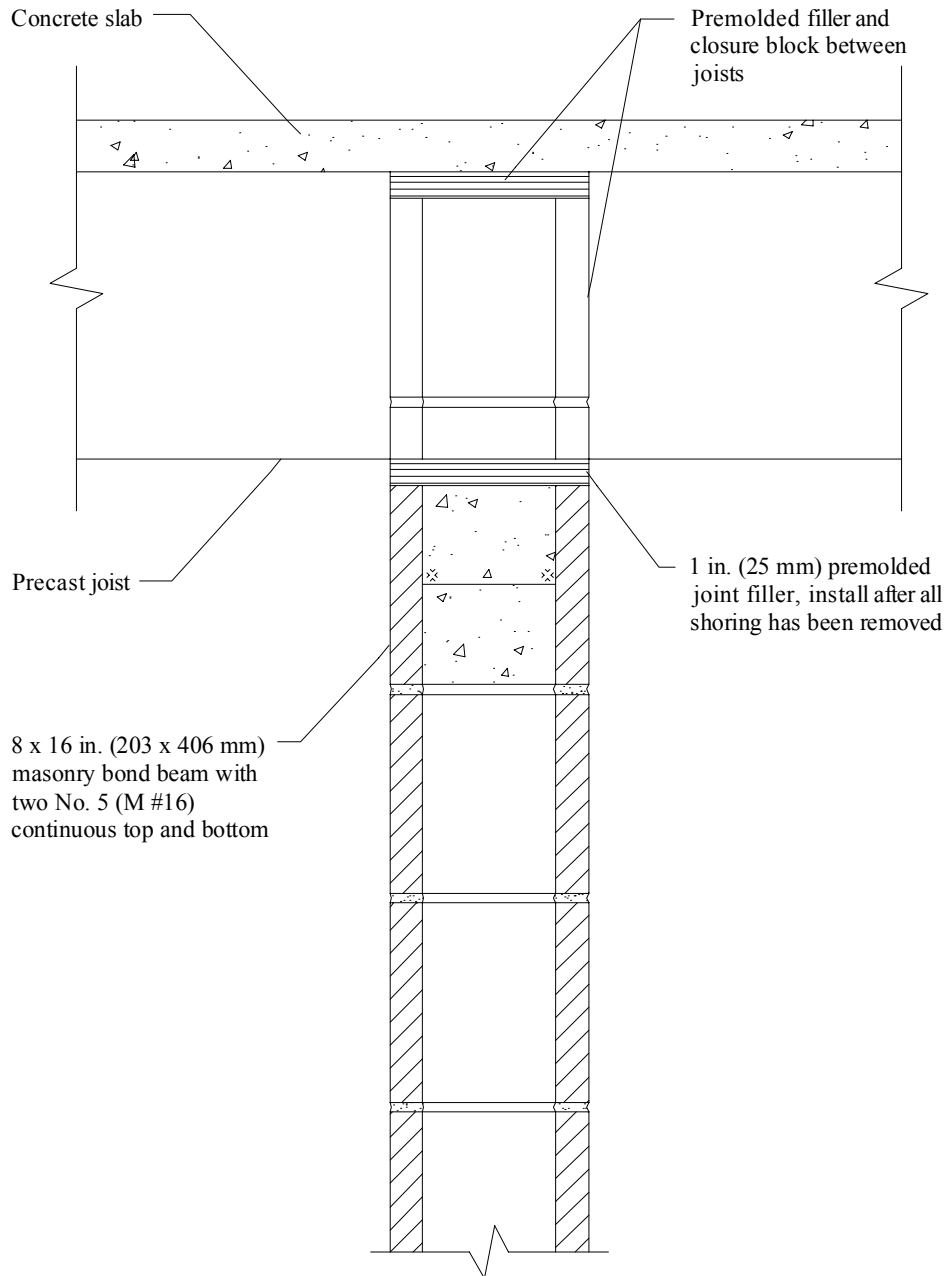
Masonry at Concrete Column



Last Modified: December, 2002

Masonry at Precast Joist

As an alternate to the detail illustrated below, form and pour a 8 x 12 inch (203 x 305 mm) minimum, concrete tie beam with two No. 5 (M #16) bars continuous top and bottom.



3D-Prestressed Masonry

Prestressing is the general term used when a structural element is compressed prior to being subjected to loads. This initial state of compression offsets tensile stresses from applied loads. Post-tensioning is a specific method of prestressing where tendons are stressed after the wall has been placed. The other type of prestressing, called pre-tensioning, involves tensioning the tendon prior to construction of the masonry. Because virtually all prestressed masonry built to date has been post-tensioned, the two terms are often used interchangeably as they apply to this form of masonry design and construction.

Post-tensioned concrete masonry walls have been built for schools, retail, manufacturing, highway sound barriers, warehouses and other types of structures. In addition, post-tensioning has been used to strengthen and repair existing masonry walls.

Prestressing has the potential to increase the flexural strength, shear strength and stiffness of a masonry element. In addition to increasing the strength of an element, prestressing forces can also close or minimize the formation of some cracks.

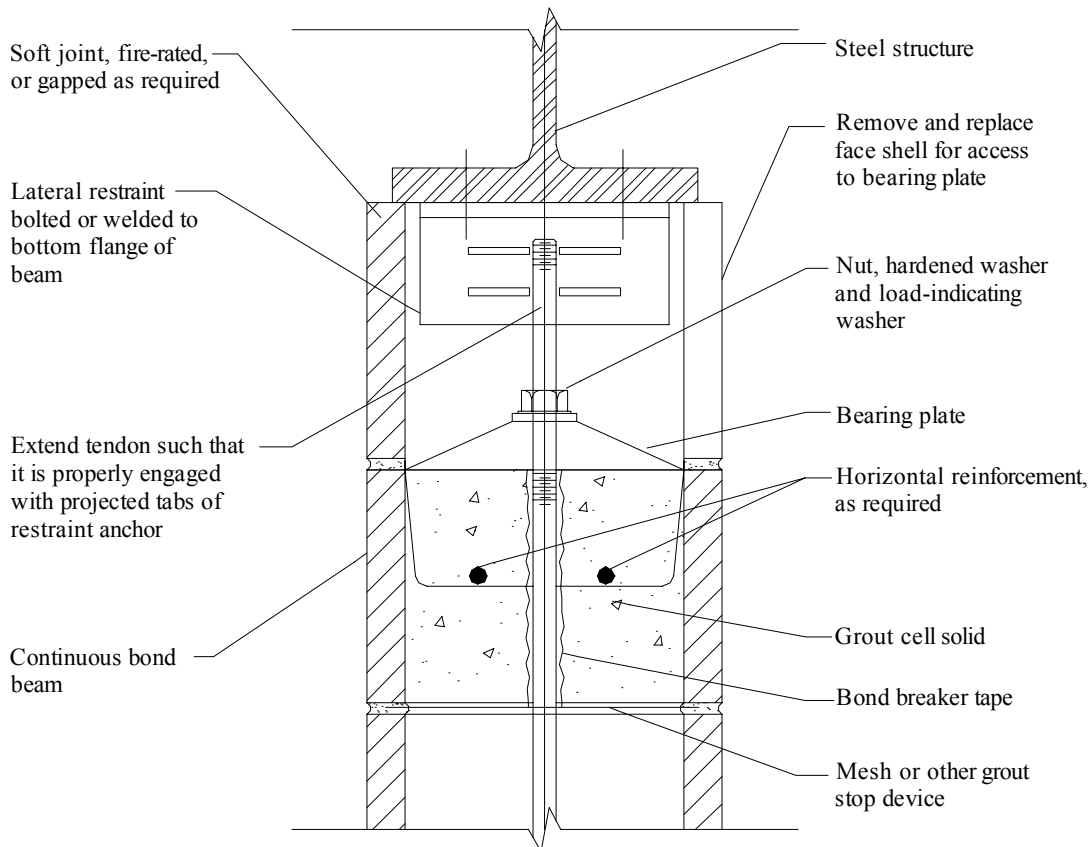
In the United States, tendons are usually high-strength bars joined by couplers, although *Building Code Requirements for Masonry Structures* (Ref. 3.1) also allows steel strands or wires to be used. As with conventionally reinforced masonry structures, *Building Code Requirements for Masonry Structures* (Ref. 3.1) mandates that prestressing tendons for post-tensioned masonry structures be protected against corrosion.

The key steps of constructing post-tensioned concrete masonry walls include: selecting and setting the bottom anchorages, installing the tendons, selecting and setting the top anchorages, and tensioning the tendons.

The following details apply to new concrete masonry walls laid in running bond and built with unbonded vertical post-tensioning tendons. Because the tendons are unbonded, the grout shown is conventional grout (i.e., conforming to ASTM C 476), not prestressing grout. Prestressing grout is only used with bonded tendons. Encasing tendons in conventional grout restrains the tendons, but they are still considered unbonded because a bond breaker material is placed around the tendon.

Prestressing Anchorage at Top of Wall

Shown is a means for supporting the top of an interior partition when the top anchor is placed on a bond beam in a lower course. *Building Code Requirements for Masonry Structures* (Ref. 3.1) requires that tendons be anchored by mechanical embedments or bearing devices or by bond development in concrete. Tendons cannot be anchored by bond development into the masonry. The top anchor must be placed on solid masonry, a grouted bond beam or a precast concrete unit. The anchor should not be supported by mortar.



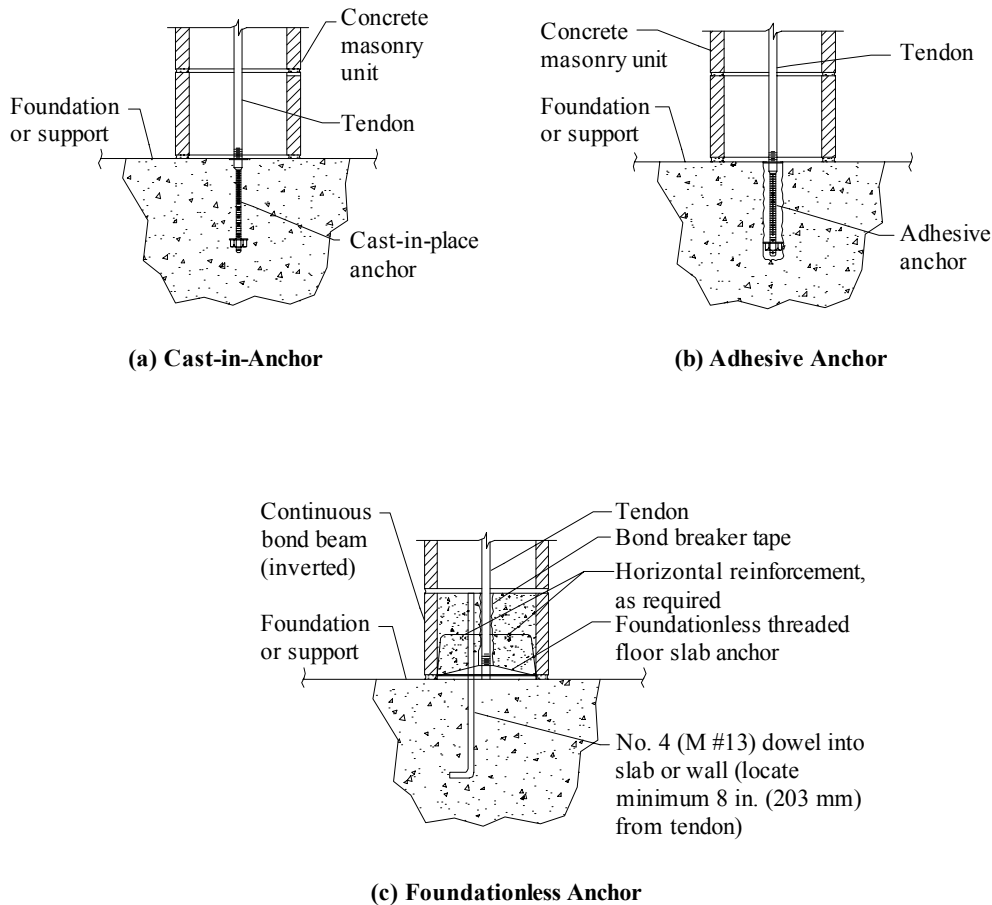
Prestressing Anchorage at Bottom of Wall

Bottom anchors are most critical to the proper construction of post-tensioned walls. Alignment is essential to ensure that the tendons are placed exactly as intended. *Building Code Requirements for Masonry Structures* (Ref. 3.1) requires that tendons be anchored by mechanical embedments, by bearing devices or by bond development in concrete. Tendons cannot be anchored by bond development into the masonry.

Unless the design documents call out specific bottom anchors, the contractor must select the anchor appropriate to the conditions. The cast-in-place bottom anchor (a) is preferred for shear walls and for fire walls. While they are the best anchors for capacity, cast-in-place anchors are the most difficult to align. Cast-in-place anchors are often set by the foundation contractor, not the mason. Thus, quality control and coordination is a concern with these anchors.

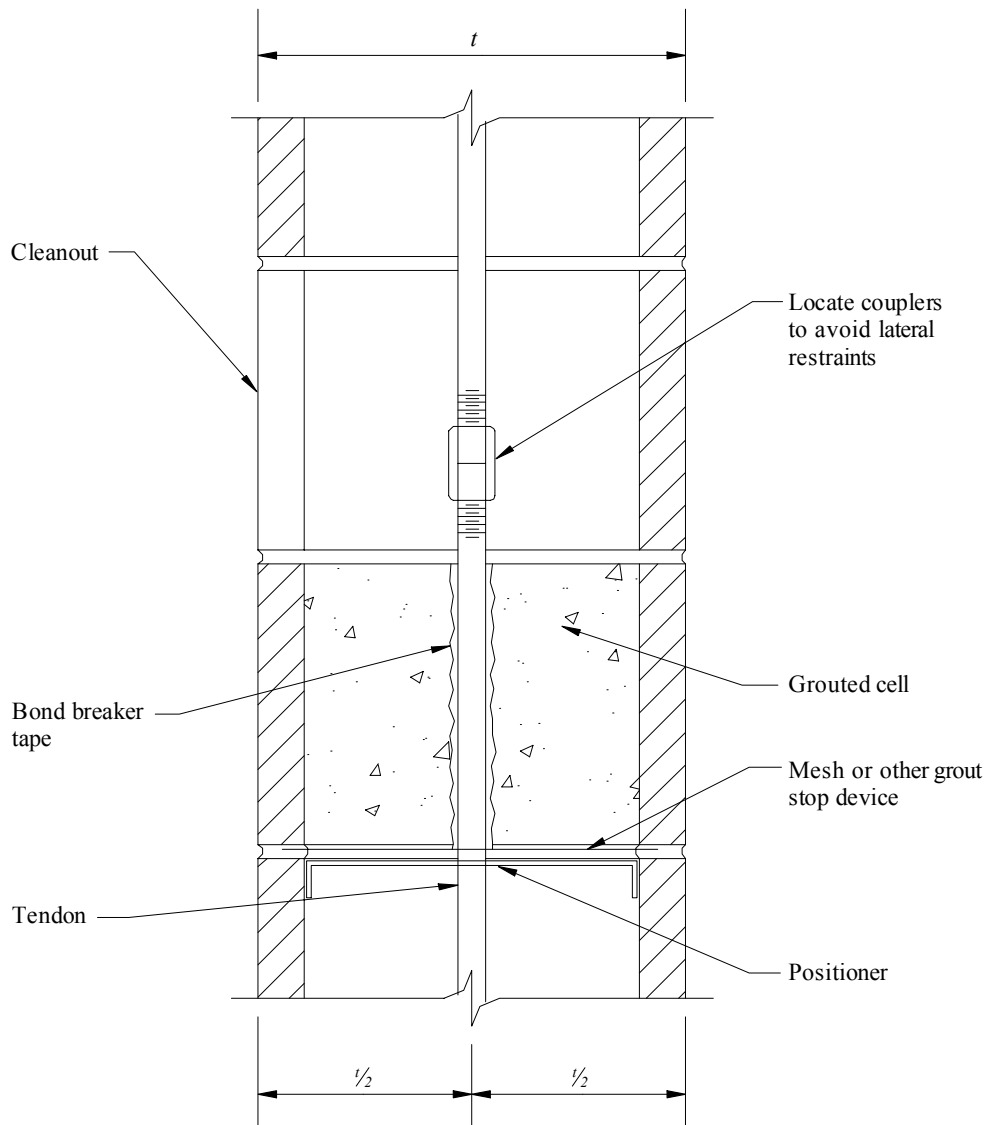
The mason has complete control over the placement of the bottom anchors when either adhesive anchors are post-installed in the foundation (b), or an anchor is used which does not rely on the foundation for support (c). If the anchor in (c) is used, foundation dowels are grouted to the wall to lock it in place and provide shear resistance. Tendons can also begin at an upper floor and not at the foundation. In this case, the foundationless anchor is used at a bond beam.

Adhesive anchors should not be used for fire walls.



Prestressing Tendon Coupler

Couplers allow the use of shorter tendons, which minimizes the height of lifting concrete masonry units over the tendons or the need to use "A" or "H" shaped concrete masonry units. Tendons must be able to slip freely, hence the bond breaker, such as poly tape, at the grouted cell. Tendon positioners are useful to maintain the tendon location within the wall during construction of the masonry. Positioners may also function as restraints if their capacity is determined by testing.



3E - Foundation Walls

Concrete masonry can be used to construct various foundation wall types—full basement walls, crawlspace walls, stem walls or piers. In addition to carrying structural loads to the underlying foundation soil, design considerations focus on minimizing water penetration, providing protection from soil gas entry and from insect damage.

Specific recommendations for water penetration resistance are outlined below for the different foundation types. However, for all foundations, finished grade should slope away from the wall. In addition, water from downspouts should be directed away from the wall and preferably directed away from the building.

Footings

Footings lie under the basement, crawlspace, or stem wall and transfer structural loads from the building to the supporting soil. Footings are typically poured concrete, placed beneath the frost depth to prevent damage and heaving caused by freezing of water in the soil.

Footings should be placed on undisturbed native soil, unless this soil is unsuitable, weak or soft. In this case, the unsuitable soil should be removed and replaced with compacted soil, gravel or concrete. Similarly, tree roots, construction debris and ice should be removed prior to placing footings.

Footings should be carefully aligned so that the concrete masonry wall will be near the center line of the footing. Although the top surface of poured concrete footings should be relatively level, it should generally not be troweled smooth, as a slightly roughened surface enhances the bond between the mortar and concrete. Footing design is governed by *Building Code Requirements for Structural Concrete*, ACI 318 (Ref. 3.3).

Construction

Concrete masonry should be laid on a relatively clean footing. Mud, oil, dirt, ice or other materials which reduce bond should be removed prior to wall construction. To make up for surface irregularities in the footing, the first course of masonry is set on a mortar bed joint which can range in thickness from $\frac{1}{4}$ to $\frac{3}{4}$ inches (6.3 to 19 mm). This initial bed joint should fully bed the first course of masonry units (including webs), although mortar should not excessively protrude into masonry cells that will be grouted. Note that many building codes require Type M or S mortar for foundation wall construction.

For reinforced construction, reinforcing bars must be properly located to be fully functional. In most cases, vertical reinforcement is positioned towards the interior face of below grade walls to provide the greatest resistance to soil pressures.

A solid top course on the below grade concrete masonry wall spreads loads from the building above and also improves the soil gas and termite resistance. Where only the top course is to be grouted, wire mesh or other equivalent grout stop material can be used to contain the grout.

Connection details for different floor diaphragm types are shown in Section 6B. For residential construction, anchor bolts are typically embedded 7 inches (180 mm) into the masonry, are $\frac{1}{2}$ inch (13 mm) in diameter and are spaced at a maximum of 6 feet (1800mm) on center to attach the home to the foundation. Wood in direct contact with masonry materials should be pressure treated, be naturally decay resistant or should have a moisture barrier placed between the wood and the masonry.

When a concrete slab is used, a vapor retarder (typically 6-mil (0.15 mm) polyethylene, PVC or equivalent) reduces rising dampness and helps prevent soil gas entry through the bottom of the slab. Placing the vapor retarder directly under the slab is the recommended location, however it may result in delayed finishing of the concrete.

Commentary - Basement Walls:

Basements are typically constructed as conditioned space so that they can be used for storage, work or living space. Because of this, water penetration resistance is of paramount importance to basement wall design and construction. Below grade walls are protected from water entry by installing an impervious barrier on the exterior wall surface. The barrier is part of a comprehensive system to prevent water penetration, which includes proper wall construction and the installation of drains, gutters and proper grading. Building codes typically require that basement walls be dampproofed for conditions where hydrostatic pressure will not occur, and waterproofed where hydrostatic pressures may exist. Dampproofing is appropriate where groundwater drainage is good, for example where granular backfill and a subsoil drainage system are present. Hydrostatic pressure may exist due to a high water table or to poorly draining backfill. Waterproofing materials are generally elastic, allowing them to span small cracks and accommodate minor wall movements.

Considerations for choosing a waterproof or dampproof system include resistance to hydrostatic water pressure, absorption characteristics, elasticity, stability in moist soil, resistance to mildew and algae, impact or puncture resistance and abrasion resistance. Below grade masonry walls should be damp-proofed in areas where hydrostatic pressure will not occur. Where ground water levels are high, soil drainage is slow or where soil gas levels are high, consideration of waterproof membranes such as rubberized asphalt, polymer-modified asphalt or butyl rubber should be considered. Drainage boards can also be used to drain water quickly and to reduce backfill pressure. A complete discussion of waterproofing, dampproofing, and drainage systems is included in *Preventing Water Penetration in Below-Grade Concrete Masonry and Basement Manual* (Refs. 3.4 and 3.7). All dampproofing and waterproofing systems should be applied to walls that are clean and free from dirt, mud and other materials which may reduce bond between the coating and the concrete masonry wall.

Draining water away from basement walls significantly reduces water pressure on the wall and reduces the possibility of water infiltration into the basement if the waterproofing (or dampproofing) system fails. Perforated pipe has historically proven satisfactory when properly installed to channel and drain subsurface water. Drainage pipes can also be placed beneath the slab and connected into a sump. Pipes through the footing or the wall drain water from the exterior side of the basement wall.

The drainage and waterproofing systems should always be inspected prior to backfilling to ensure they are properly placed. Any questionable workmanship or materials should be repaired at this stage since repairs are difficult and expensive after backfilling.

Following recommended backfill procedures will help prevent basement wall failures such as cracking during this operation. Walls should always be properly braced to resist backfill soil loads or have the first floor diaphragm in place prior to backfilling. Otherwise, a wall designed to be supported at the top may crack or even fail from the large soil pressures.

The backfill material should preferably be drainable soil free from large stones, construction debris, organic materials and frozen earth. Saturated soils, especially saturated clays, should not be used since wet materials significantly increase the hydrostatic pressure on the walls. Backfill should be placed in several lifts and each layer should be lightly compacted. Care should be taken during backfilling to ensure the drainage, waterproofing, and any exterior insulation are not damaged. Heavy equipment should not be operated within about 3 feet (0.9 m) of the wall.

The top 4 to 8 inches (102 to 203 mm) of backfill should be low permeability soil so rain water is absorbed into the backfill slowly. Finished grade should be sloped away from the building.

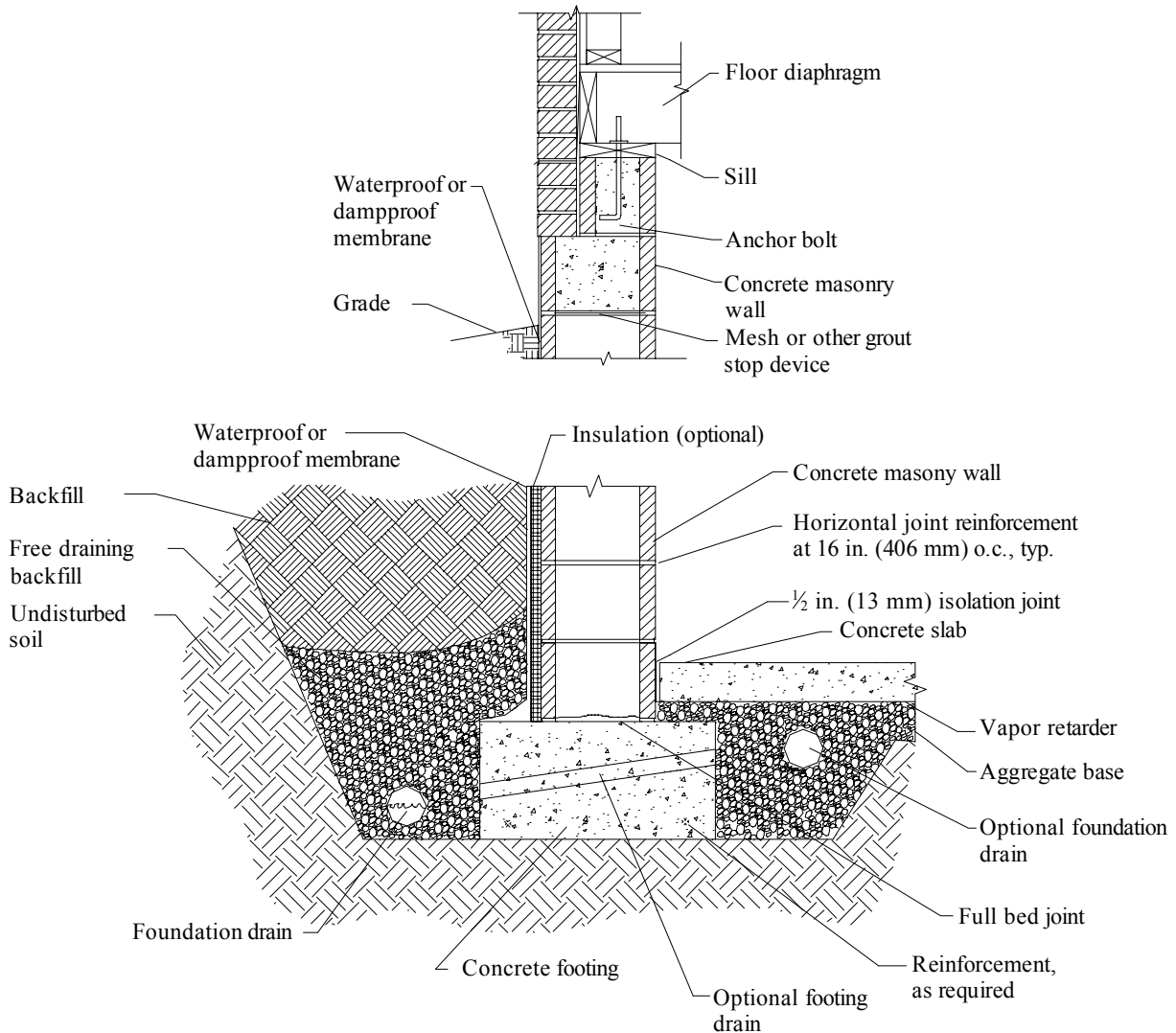
Control joints are not typically used in foundation walls due to concerns with waterproofing the joint and the fact that shrinkage is less significant in below grade walls due to relatively constant temperature and moisture conditions. Horizontal joint reinforcement is usually installed to hold any cracks that may form tightly together.

Plain (Unreinforced) Residential Basement Wall

Foundation drain can also be located on the exterior side of the footing, or on both sides if necessary. The drain should be placed below the top of the footing.

Optional footing drain, such as 2 inch (51 mm) PVC pipe at 8 feet (2,400 mm) on center, allows water on the exterior to drain to the under-slab foundation drain. These can be cast into the footing or constructed using plastic pipes through the bottom of the first course of concrete masonry, directly on top of the footing.

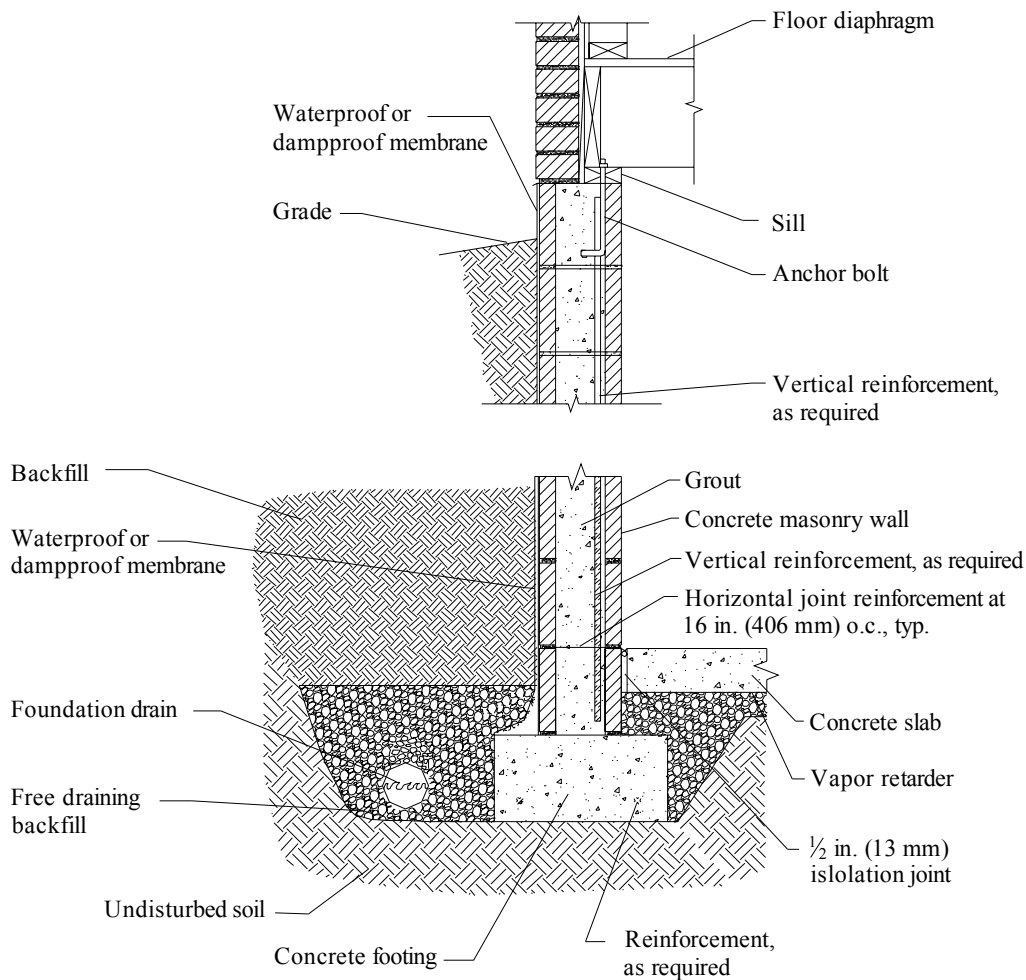
Local codes may restrict the use of foam plastic insulation below grade in area where the hazard of termite damage is high.



Last Modified: December, 2002

Reinforced Residential Basement Wall

Foundation drain can be located on either side of the footing, or on both sides if necessary. The drain should be placed below the top of the footing. A footing drain can also be used. Cells containing reinforcement must be grouted solid. In addition, a solid grouted top course or bond beam spreads loads from the building above into the basement walls and also increases the soil gas and termite resistance. Where only the top course is to be grouted, wire mesh can be used to contain the grout. Vertical reinforcement should generally be placed in cores adjacent to openings, in all corners, and at the spacing required for structural capacity. Rebar positioners can be used to hold the bars in proper position during grouting.

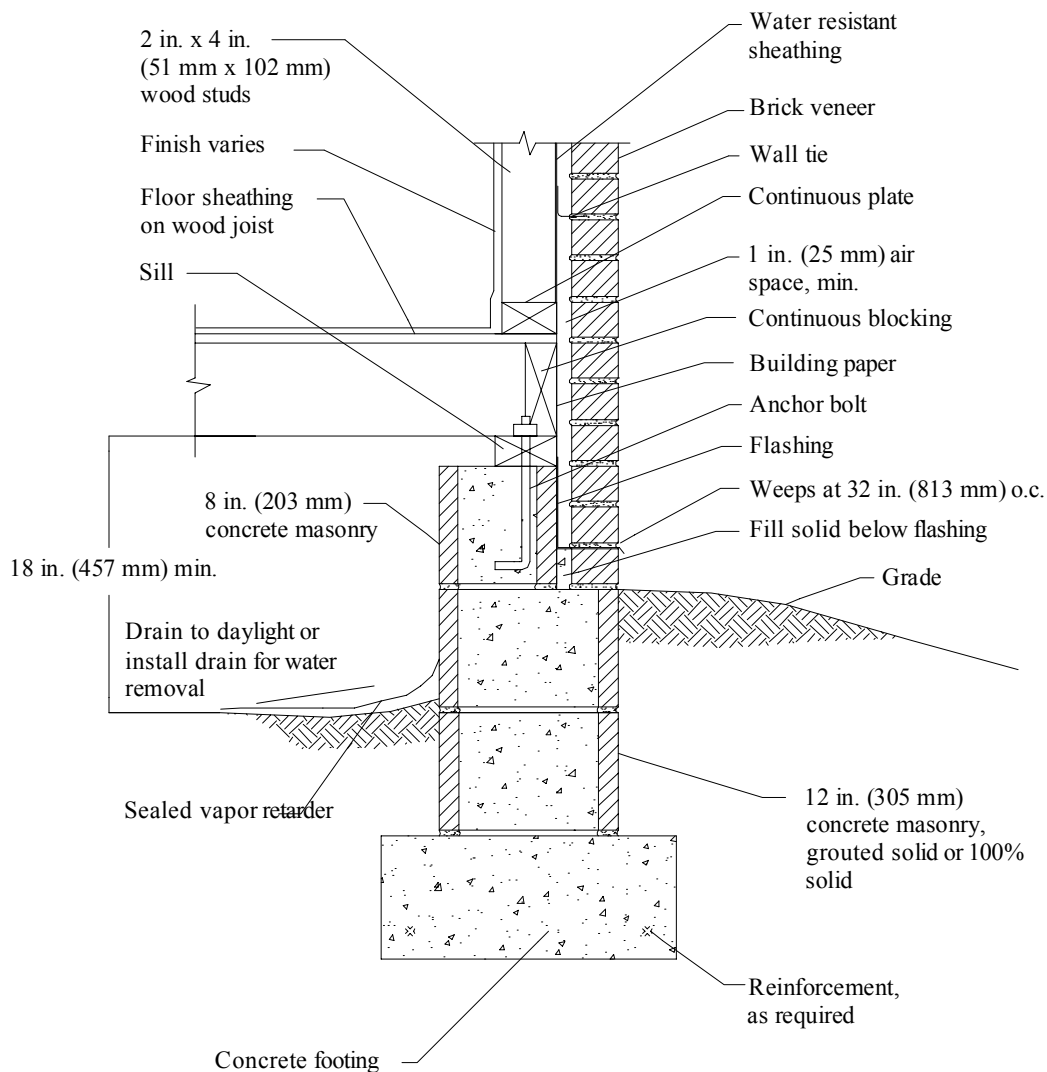


Last Modified: December, 2002

Commentary — Crawspace Walls:

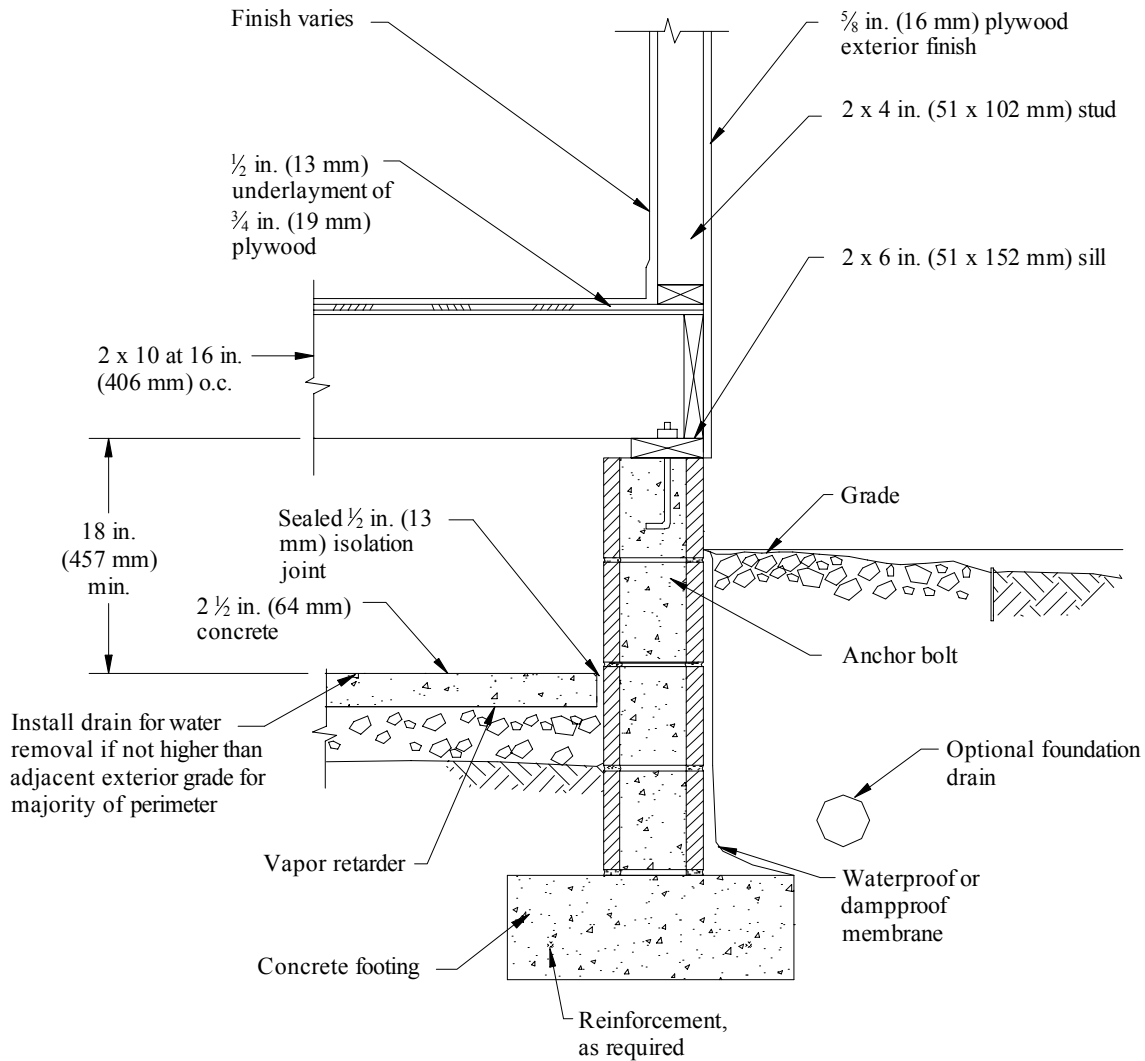
Unlike basements, crawlspaces are typically designed as unconditioned spaces, either vented or unvented. Although most codes require operable louvered vents near each corner of a crawl space to reduce moisture buildup in the space, research has shown that the use of a moisture retardant ground cover eliminates the need for vents in many locations (Ref. 3.5). If the crawspace is vented, the floor joists of the floor above are insulated and exposed pipes and ducts must also typically be insulated. If unvented, the walls or the floor above may be insulated. Unvented crawlspaces must have a floor covering to minimize moisture and, where applicable, radon gas entry. Exposed soil floors should be covered with vapor retarder membranes. A dampproof coating on the exterior crawspace wall will also help prevent water entry.

A vapor retarder (typically 6-mil (0.15 mm) polyethylene, PVC or equivalent) is good practice to minimize water migration and soil gas infiltration. If the crawspace will be used for storage or access to utilities, a concrete floor is more durable than a plastic membrane.



Last Modified: December, 2002

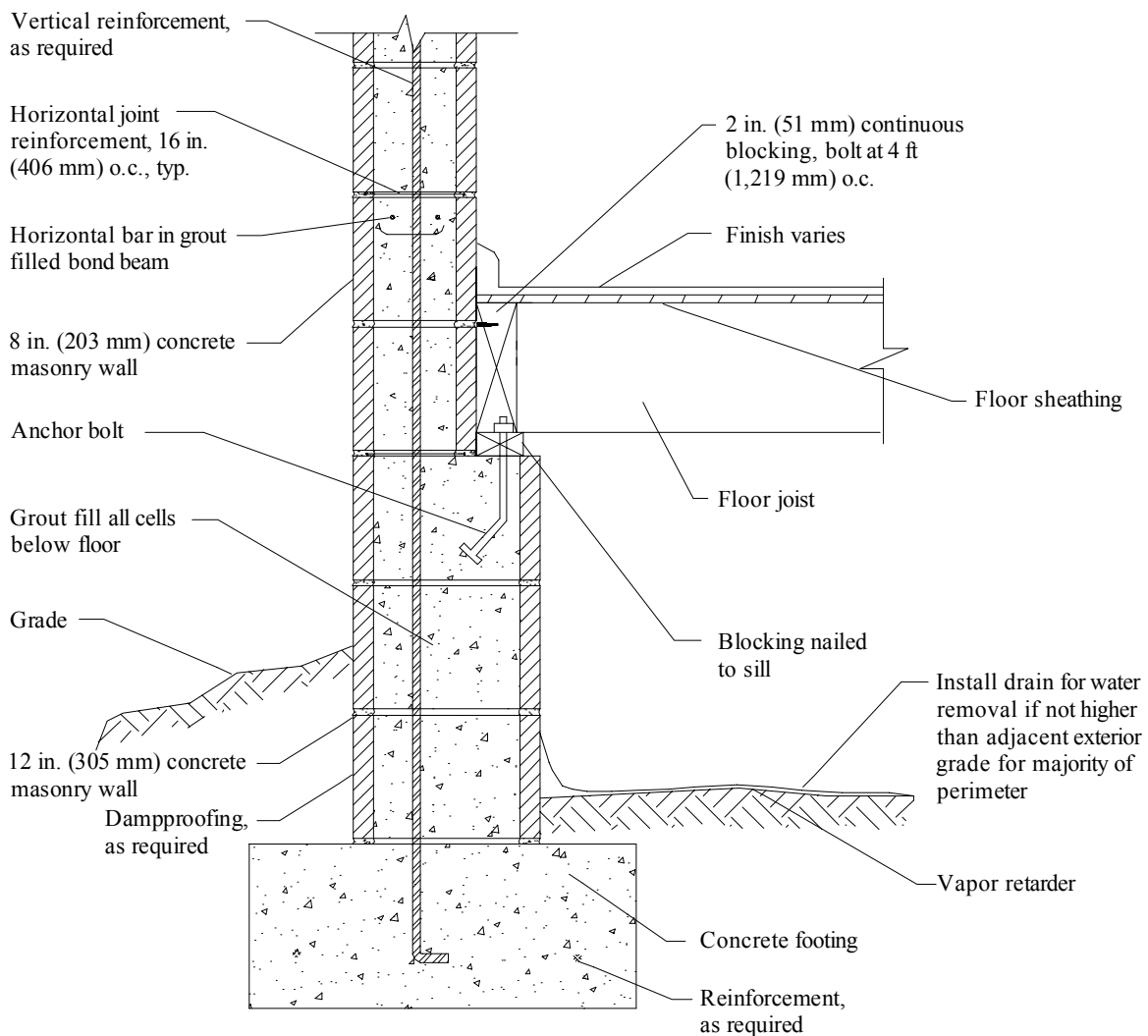
Crawlspace with Finished Floor



Last Modified: December, 2002

Crawlspace with Above Grade Masonry

A thicker crawlspace wall supports the above grade concrete masonry wall and allows anchor bolt attachment. The top course of the crawlspace wall should be grouted solid to provide a solid bearing area and increase the soil gas and termite resistance. Where only the top course is to be grouted, wire mesh can be used to contain the grout.



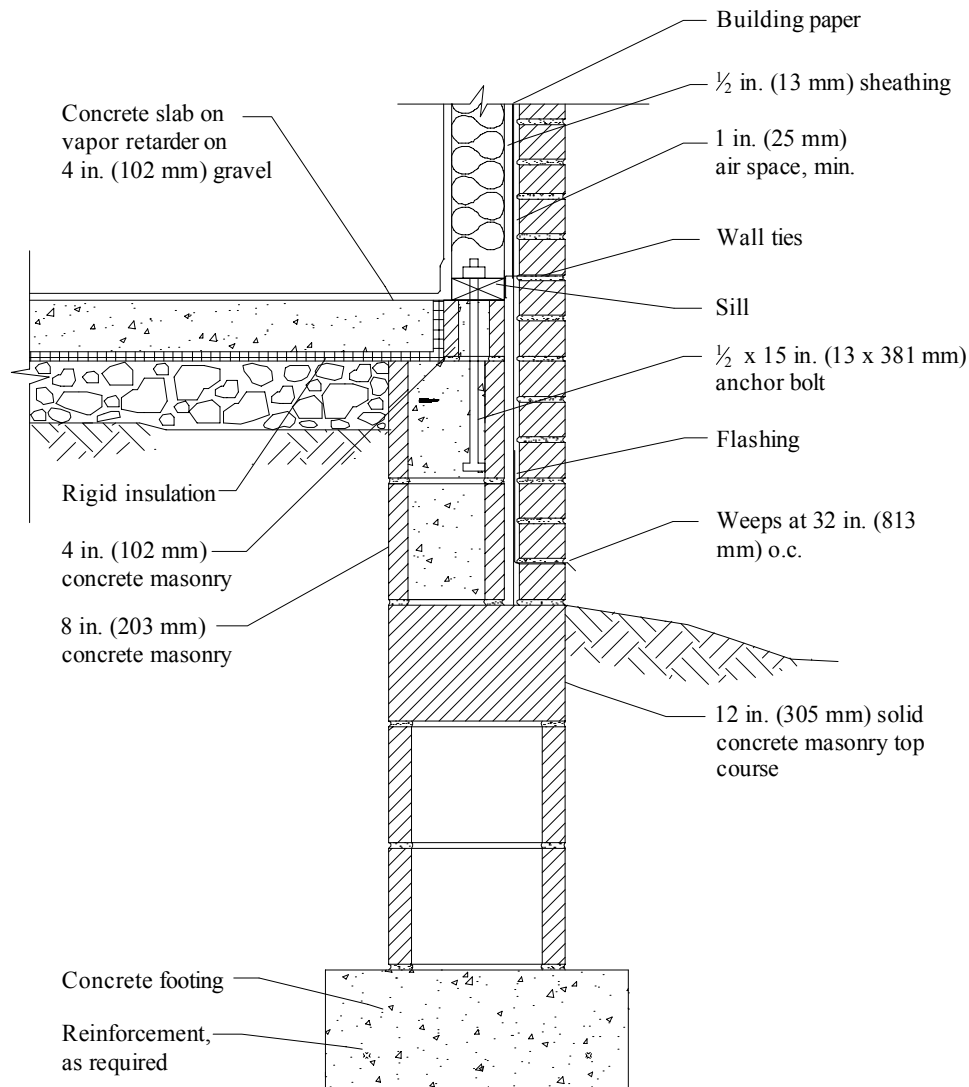
Last Modified: December, 2002

Commentary — Stemwall/Slab on Grade

A stemwall supports a slab on grade and often provides a brick ledge as well to support an exterior masonry veneer. Because the wall is exposed to soil on both sides, waterproofing or dampproofing coatings are typically not required.

Stemwall with Brick Ledge

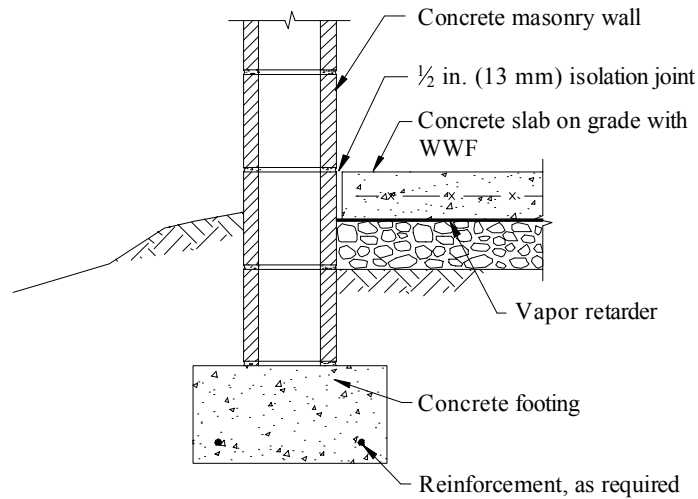
Stem walls are typically insulated on the exterior of the masonry wall. If insulated on the interior as shown (on the wall or under the slab), it is important to place insulation in the joint between the slab edge and the foundation wall to avoid thermal bridging, although this insulation typically does not need to be greater than $R5^{\circ}\text{F} \cdot \text{ft}^2 \cdot \text{h}/\text{Btu}$ ($0.88 \text{ m}^2 \cdot \text{K}/\text{W}$). Masonry design codes typically require a nominal 1 inch (25 mm) clear airspace between the masonry veneer and backup to ensure an open drainage cavity. See Section 5 for more detailed information on masonry veneers on wood or steel stud backup.



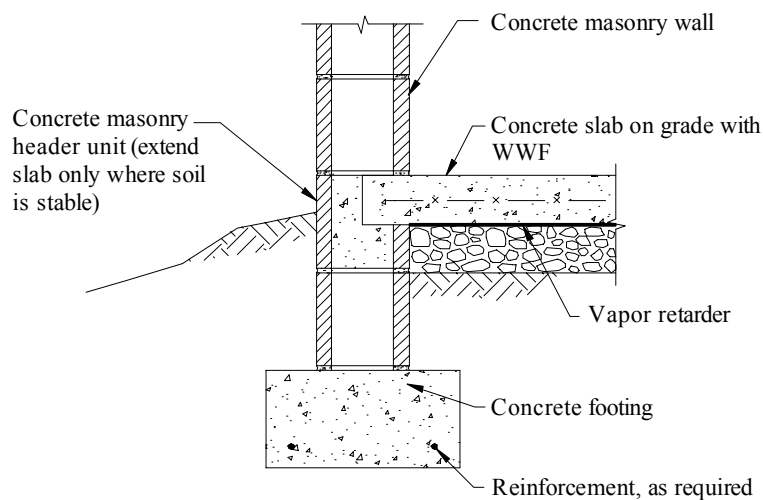
Last Modified: December, 2002

Stemwall without Brick Ledge

Stem walls are typically insulated on the exterior of the masonry wall. If insulated on the interior (on the wall or under the slab), it is important to place insulation in the joint between the slab edge and the foundation wall to avoid thermal bridging, although this insulation typically does not need to be greater than $R5^{\circ}\text{F} \cdot \text{ft}^2 \cdot \text{h}/\text{Btu}$ ($0.88 \text{ m}^2 \cdot \text{K}/\text{W}$).

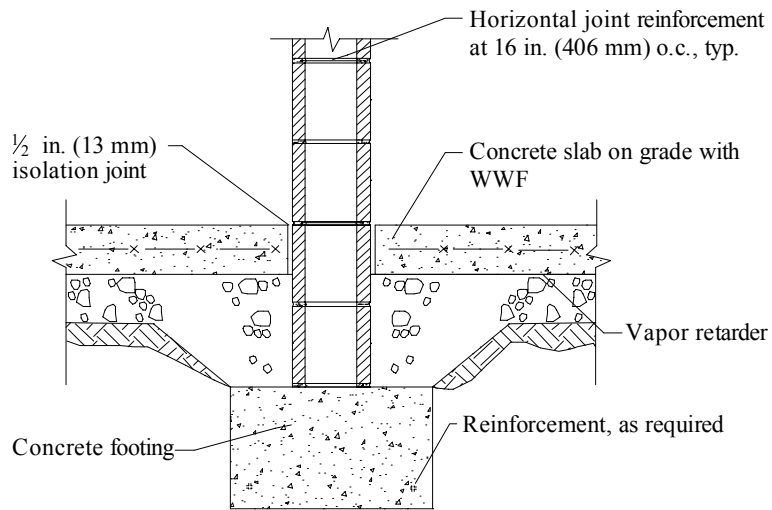


(a) Floating Slab



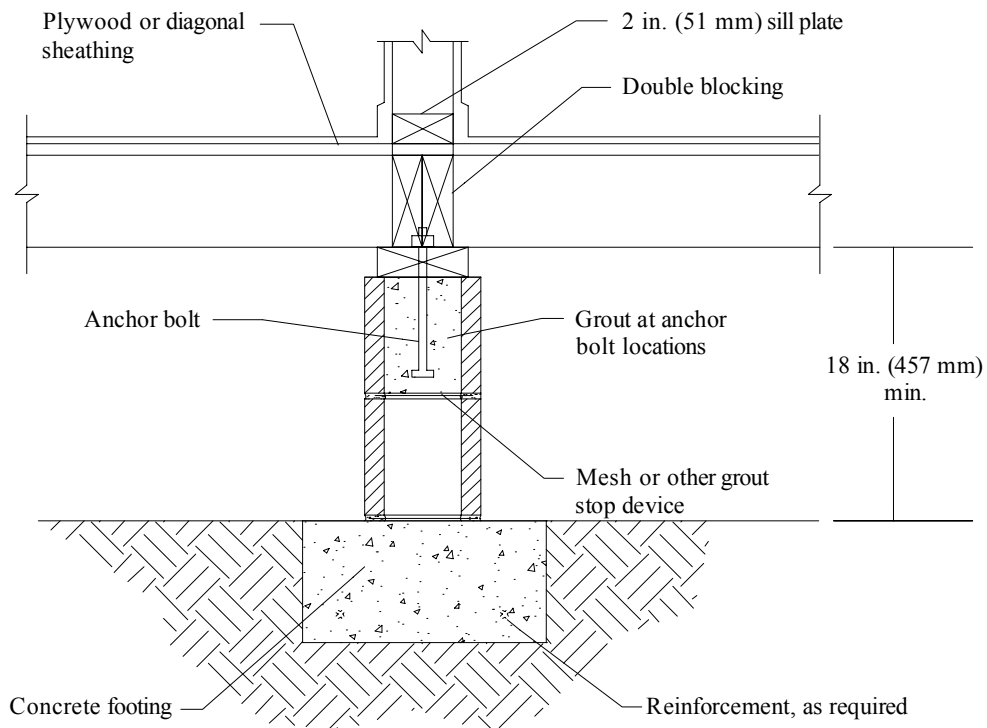
(b) Slab Supported on Header Block

Interior Stemwalls



Piers

Piers are isolated structural elements used to support the building above. Structural design ensures the piers are sized and spaced to carry the necessary building loads to the foundation. Piers typically enclose a crawlspace below, so recommendations for moisture and soil gas resistance for crawlspaces should be followed. *Building Code Requirements for Masonry Structures* (Ref. 3.1) requires foundation piers to be at least 8 inches (203 mm) thick, with a height not exceeding four times their thickness and a length not exceeding three times the thickness.



CHAPTER 3 REFERENCES

- 3.1 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02, Reported by the Masonry Standards Joint Committee, 2002.
- 3.2 *Specification for Masonry Structures*, ACI 530.1-02/ASCE 6-02/TMS 602-02, Reported by the Masonry Standards Joint Committee, 2002.
- 3.3 *Building Code Requirements for Structural Concrete*, ACI 318-99, American Concrete Institute, 1999.
- 3.4 *Preventing Water Penetration in Below-Grade Concrete Masonry*, TEK 19-3A, National Concrete Masonry Association, 1994.
- 3.5 *2001 ASHRAE Handbook, Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2001.
- 3.6 *Concrete Masonry Walls for Metal Buildings*, TR 149, National Concrete Masonry Association, 1996.
- 3.7 *Basement Manual Design and Construction using Concrete Masonry*, TR 68B, National Concrete Masonry Association, 2001.
- 3.8 *Plaster and Stucco for Concrete Masonry*, TEK 9-3A, National Concrete Masonry Association, 2002.

CHAPTER 4 - MULTIWYTHE CONSTRUCTION

A wall constructed with two or more wythes of masonry can technically be classified in one of three ways, depending on how each individual wythe is designed and detailed. These three wall systems are composite, noncomposite or veneer walls. Composite and noncomposite walls are covered in this chapter while veneers are covered in Chapter 5.

Each wythe of a noncomposite wall (Section 4A) is connected to the adjacent wythe with metal wall ties, but they are designed such that each wythe individually resists the loads imposed on it. Bending moments (flexure) due to wind or gravity loads are distributed to each wythe in proportion to its relative stiffness.

Conversely, composite walls (section 4B) are designed so that the wythes act together as a single member to resist structural loads. This requires that the two masonry wythes be connected by masonry headers or by a mortar or grout filled collar joint and wall ties to help ensure adequate load transference between each wythe.

Although *Building Code Requirements for Masonry Structures* (Ref. 4.1) includes design provisions for noncomposite and composite masonry walls, these design approaches are rarely taken with masonry walls as it requires two structural walls to be constructed adjacent to one another. (In other words, if structural design dictates the use of a 12 inch (305 mm) wall thickness, it is often easier and more cost effective to use a single 12 inch (305 mm) wythe rather than a composite system consisting of 4 inch (102 mm) and 8 inch (203 mm) units.) The primary advantage of using composite and noncomposite construction is in applications where different architectural features are desired on each side of a fully exposed concrete masonry wall.

Typically for concrete masonry, if composite action is not desired, the wall is designed and detailed as a veneer wall (covered under Section 5C) rather than as a noncomposite wall. In a veneer wall, the backup wythe is designed as the loadbearing system while the veneer provides the architectural wall finish transferring loads to the backup through wall ties. Note that although *Building Code Requirements for Masonry Structures* (Ref. 4.1) defines a cavity wall as a noncomposite masonry wall, the term cavity wall is also commonly used to describe a veneer wall with a masonry backup.

SECTION 4A - NONCOMPOSITE WALLS

In noncomposite construction, the wythes are connected by wall ties (as opposed to being rigidly bonded with grout or masonry headers, as in composite construction). The collar joints of noncomposite walls are not permitted to contain headers, grout, or mortar. Noncomposite walls are designed as follows: imposed vertical loads are carried by the wythe closest to the center of span of the supported member; bending moments are distributed to each wythe in proportion to its relative stiffness; and loads acting parallel to the plane of the wall (shear) are carried only by the wythe affected.

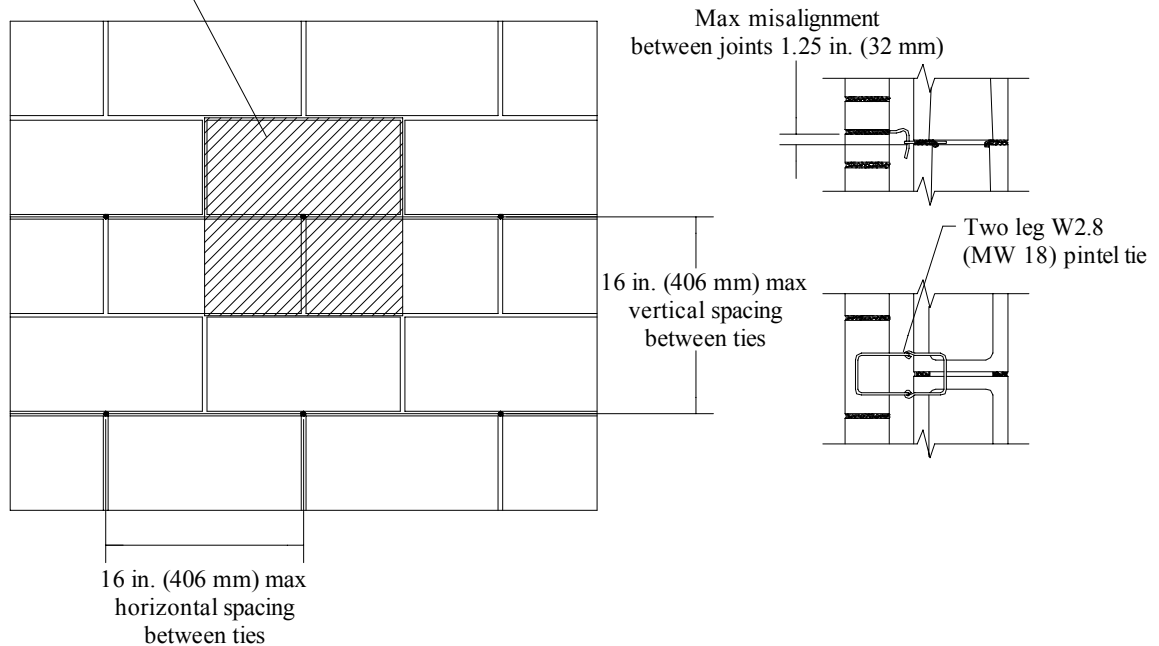
Building Code Requirements for Masonry Structures (Ref. 4.1) includes prescriptive wall tie spacing requirements to aid compatible lateral deflection between the wythes. Wire wall ties, including cross wires of joint reinforcement, are used to tie wythes in noncomposite masonry walls. When joint reinforcement is used for this purpose, ladder-type or tab-type joint reinforcement must be used, as the truss-type restricts in-plane differential movement between the two masonry wythes. Wall ties with drips intended to prevent moisture migration across the cavity may not be used due to their lower load carrying capacity.

Adjustable ties for noncomposite masonry construction must meet the following prescriptive requirements (Ref. 4.1):

- provide one tie for each 1.77 ft² (0.16 m²) of wall area,
- maximum vertical and horizontal spacing between wall ties is 16 inches (406 mm),
- maximum clearance between connecting parts of the wall tie is 1/16 inch (1.6 mm), and
- pintle ties must have at least two pintle legs of wire size W2.8 (MW 18).

With the exception of structural load paths and as noted above, architectural details for noncomposite masonry walls are nearly indistinguishable from those for masonry veneer on masonry backup. The user is referred to Section 5C for such details.

Provide one tie
 per 1.77 ft (0.16 m)
 wall surface area



Composite Walls

Composite walls are multiwythe walls where both wythes act structurally as one unit. They depend on sufficient shear transfer across the joint between the wythes for composite action. *Building Code Requirements for Masonry Structures* (Ref. 4.1) contains prescriptive requirements for bonding the wythes of composite walls, as well as allowable shear stresses for the collar joint.

Composite walls are most often designed with the axial load from floor slabs or the roof carried by the inner wythe of masonry. The collar joint thickness ranges from $\frac{3}{8}$ to 4 inches (10 to 102 mm). The joint may contain either vertical or horizontal reinforcement, or reinforcement may be placed in either wythe. The collar joint may be filled with either mortar or grout. Stresses in each wythe due to axial load and moment are calculated using the modular ratio, n , to transform sections using elastic analysis and assuming no slip at the collar joint.

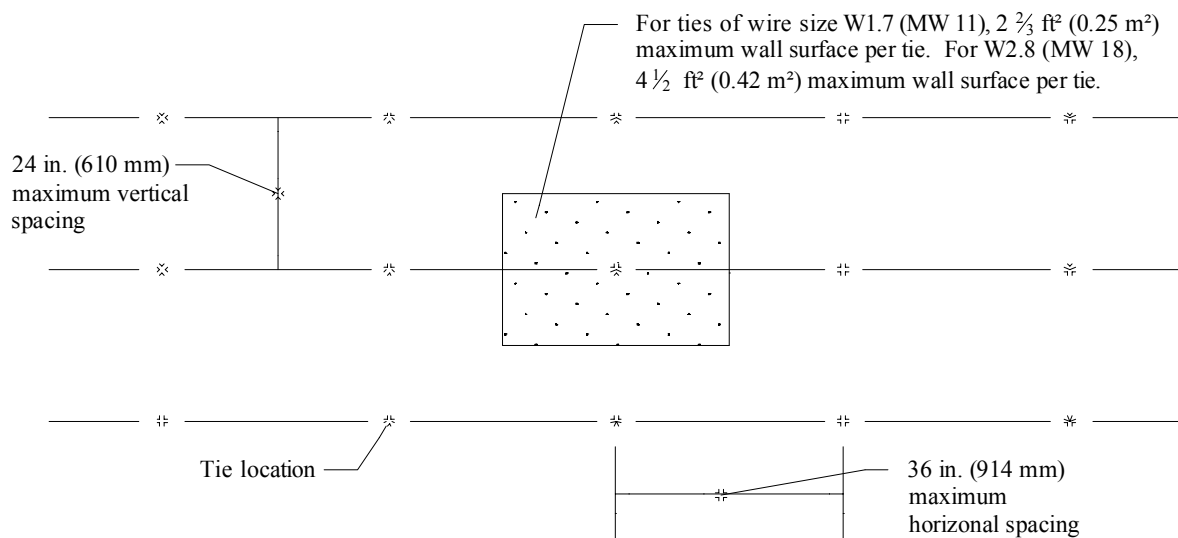
To ensure shear transfer, the *Code* allows the collar joint to either be crossed by connecting masonry headers or be filled with mortar or grout and connected by wall ties. Permissible wall ties include cross wires of horizontal joint reinforcement, rectangular wall ties, and with solid masonry units only Z wall ties.

Wall ties used to bond wythes of composite masonry must meet the following prescriptive spacing requirements:

- for ties of wire size W1.7 (MW 11), use a minimum of one tie per $2 \frac{2}{3}$ ft² (0.25 m²) of wall,
- for ties of wire size W2.8 (MW 18), use a minimum of one tie per $4 \frac{1}{2}$ ft² (0.42 m²) of wall,
- maximum horizontal spacing between ties of 36 inches (914 mm), and
- maximum vertical spacing between ties of 24 inches (610 mm)

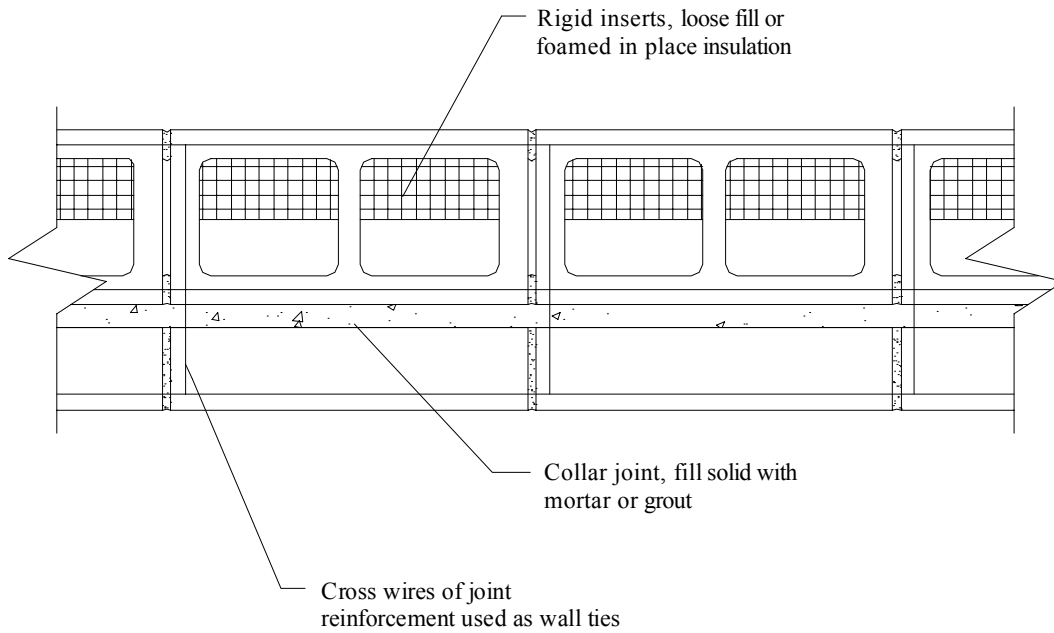
Although allowed by the Code, the use of headers is an outdated method and is not recommended for several reasons. Headers are less ductile than metal wall ties, making accommodation for differential movement a critical issue. Differential movement can shear the headers, effectively eliminating the composite action, particularly with a combination of concrete and clay masonry. When bonded with wall ties, the ties would still be able to transfer shear should bond at the collar joint be broken. Walls bonded by headers are also more susceptible to water penetration.

As opposed to cavity wall construction, where the space between wythes may contain insulation and a vapor retarder if required by local conditions, these elements must be located elsewhere with composite walls to avoid breaking the bond between the wythes. Insulation can be located either in the cores of the inner masonry wythe or on the wall interior. Two wythes of a composite wall act as one structural unit, therefore vertical movement joints should extend through both wythes at the same location across the collar joint.



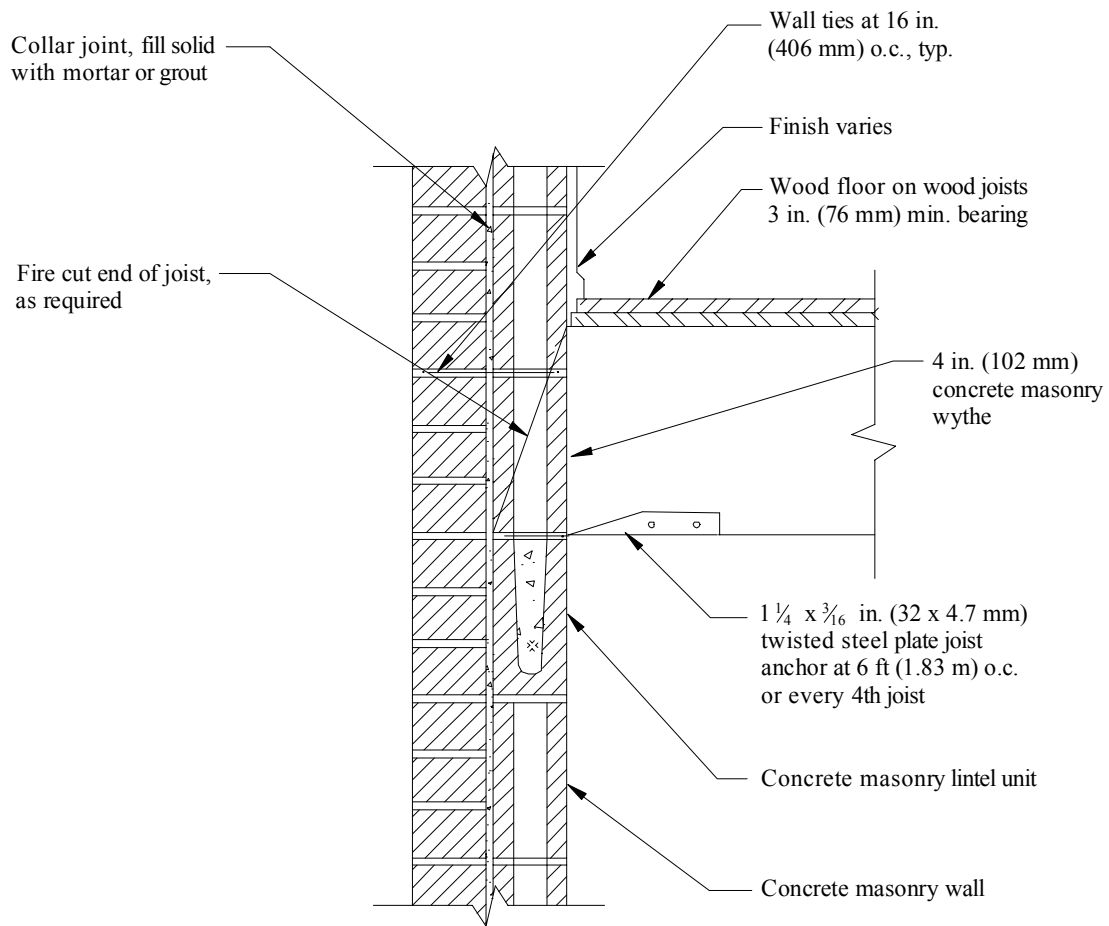
Typical Wall Section

Ensure the longitudinal wires of the horizontal joint reinforcement are encased in the mortar bed joint.



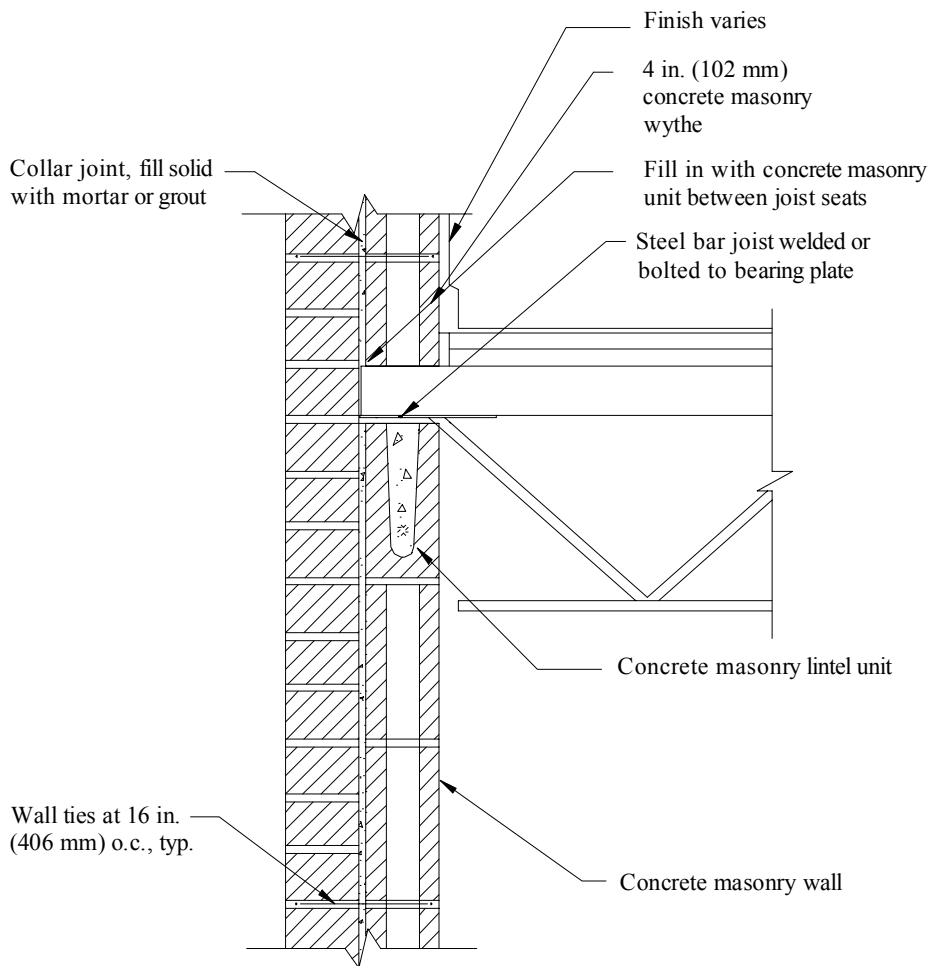
Floor Connections

See Chapter 6, Section 6B for examples of other types of connections.



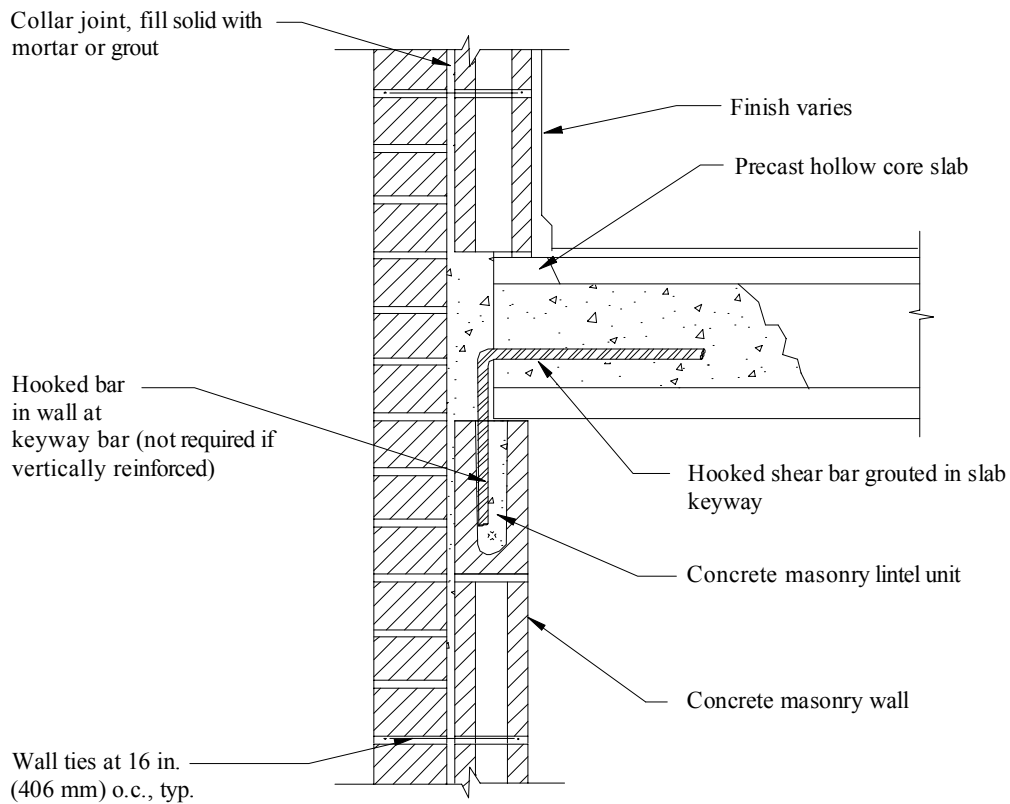
(a) Wood Floor

Floor Connections



(b) Steel Joist Floor

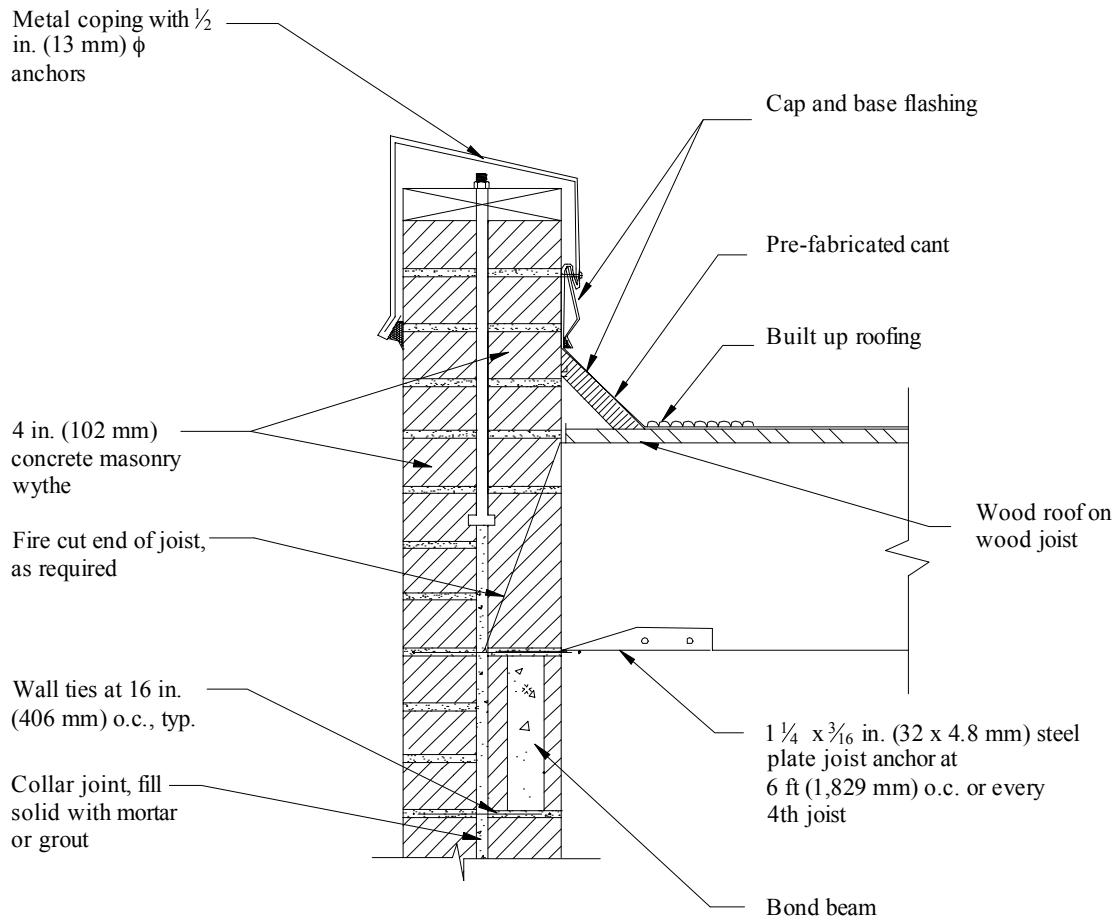
Floor Connections



(c) Precast Hollow Core Floor

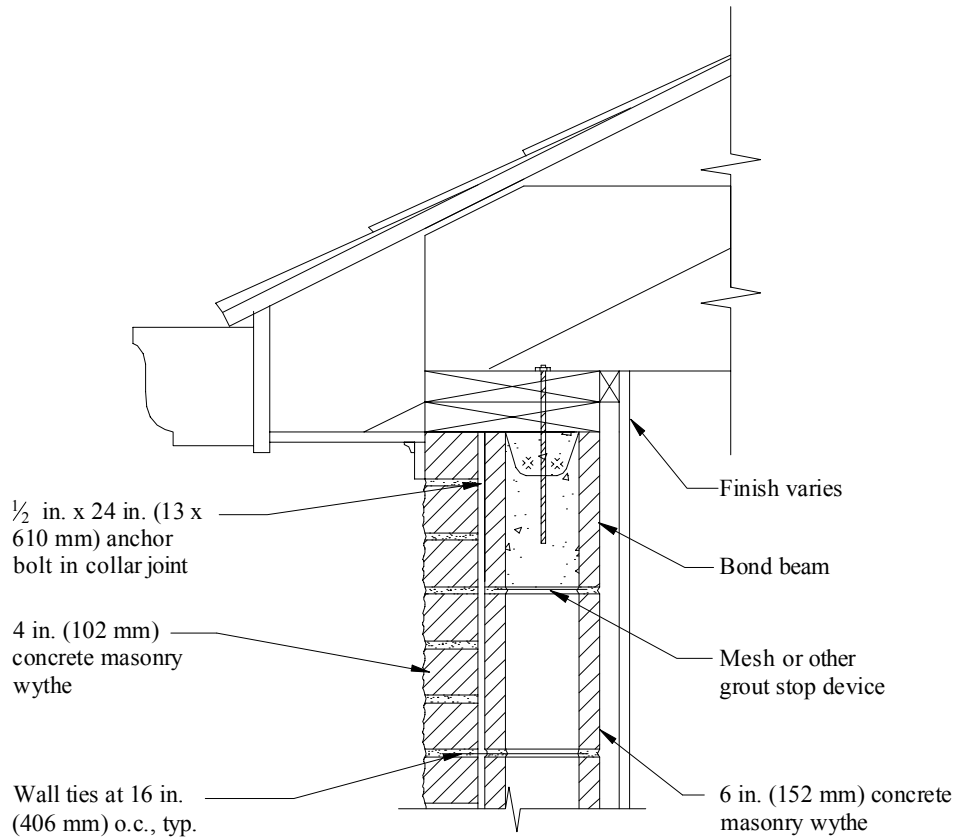
Roof Detail

See Chapter 6, Section 6A for examples of other types of connections.



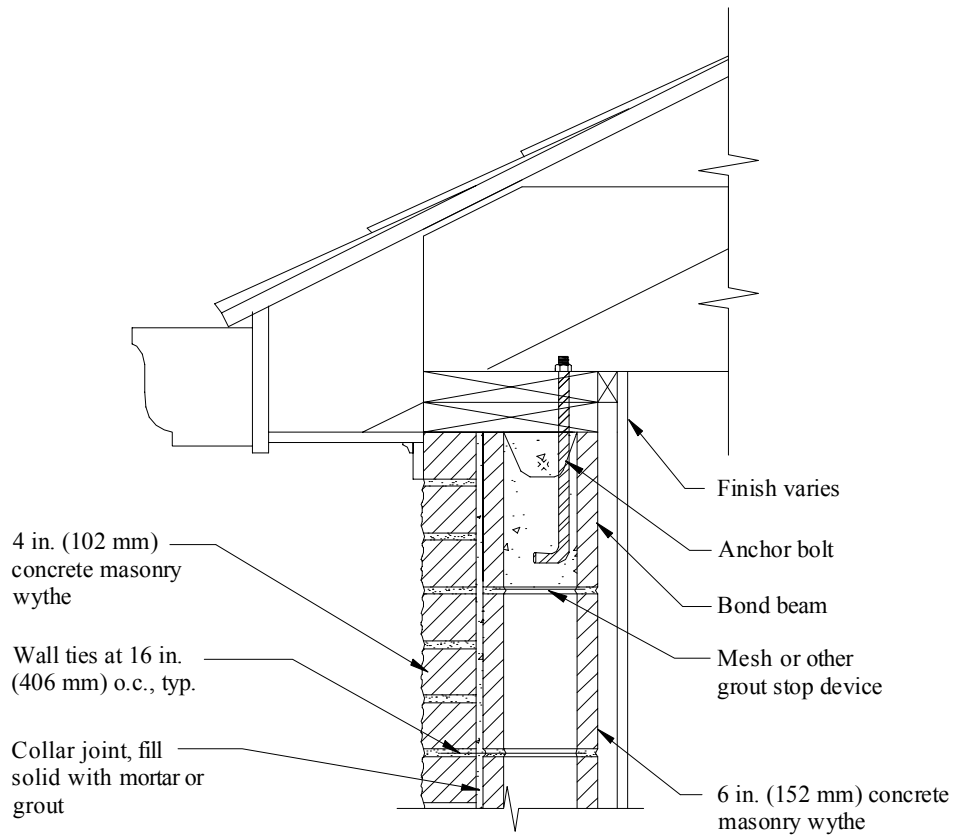
(a) Parapet

Roof Detail



(b) Sloped Roof

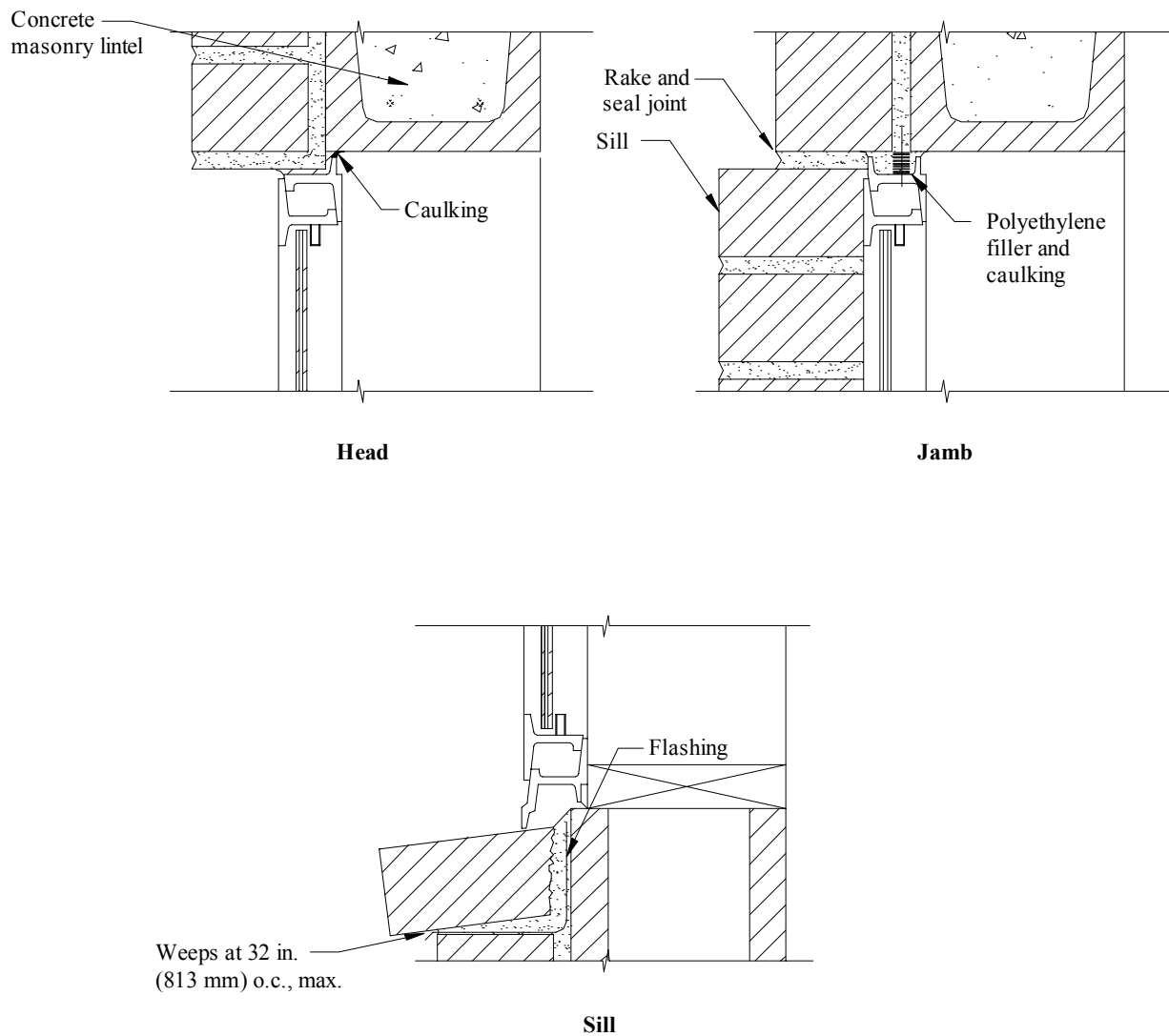
Roof Detail



(c) Sloped Roof, Alternate

Composite Wall Steel Window Details

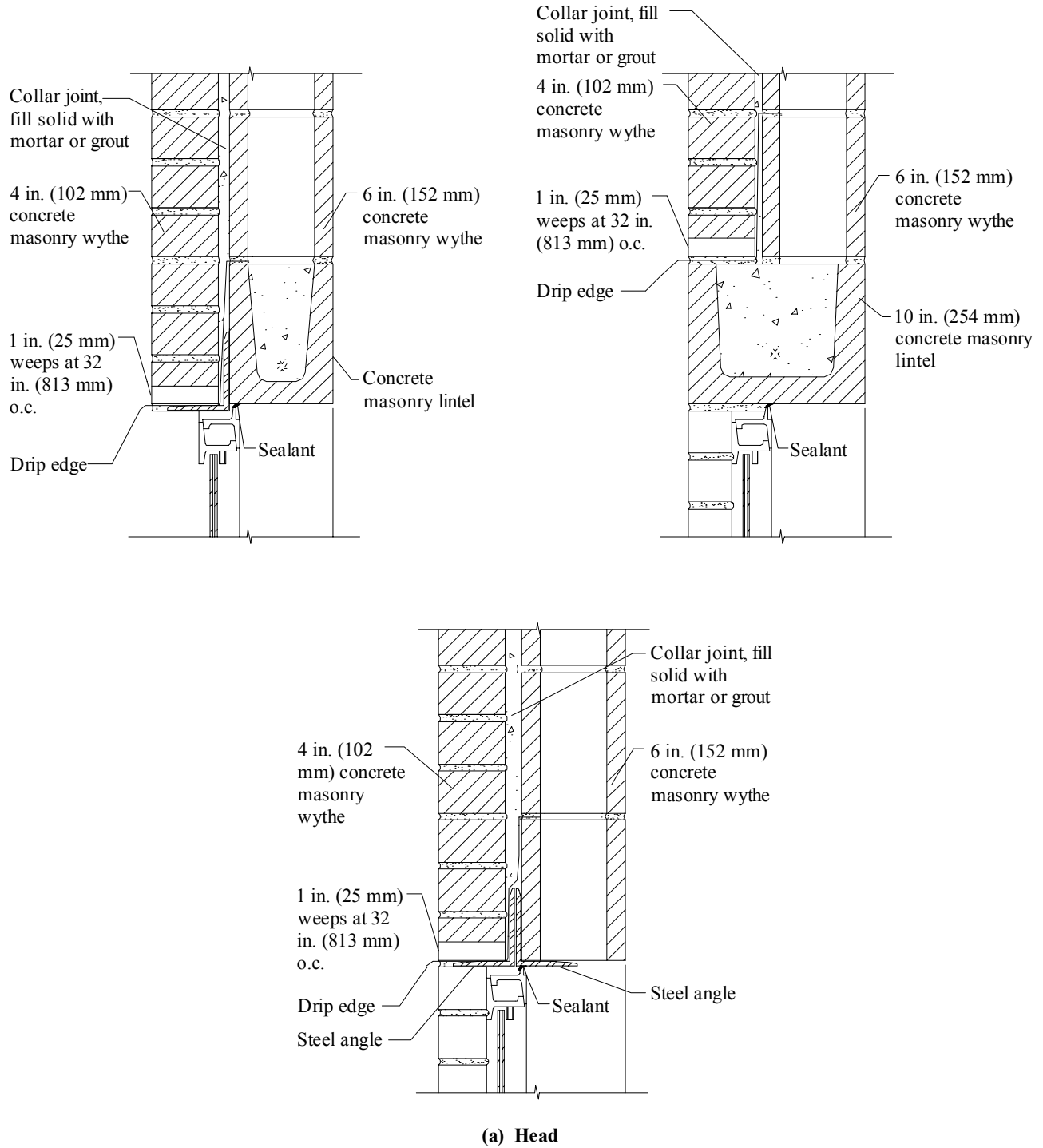
The collar joint is typically $\frac{3}{8}$ to $\frac{3}{4}$ in. (10 to 20 mm) wide. Caulking around the window frame is important to minimize water penetration.



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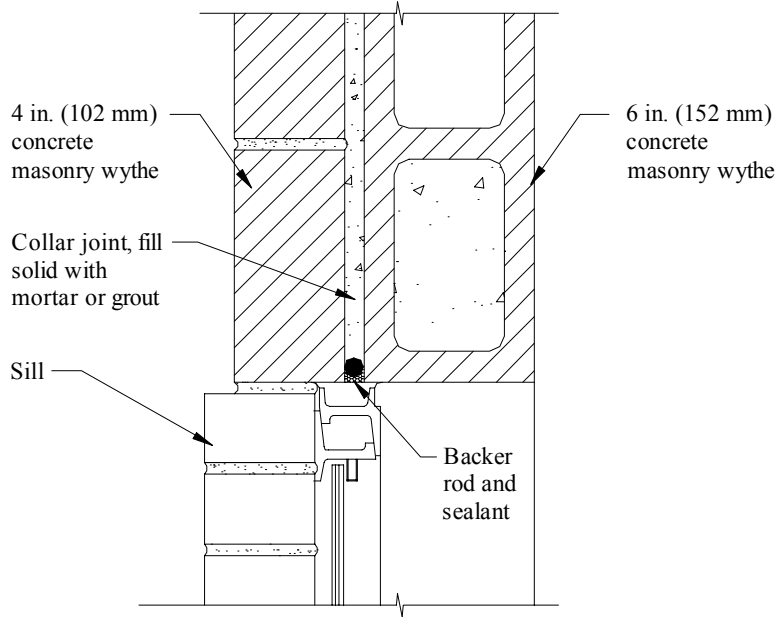
Metal Window Details

Caulking around the window frame is important to minimize water penetration.

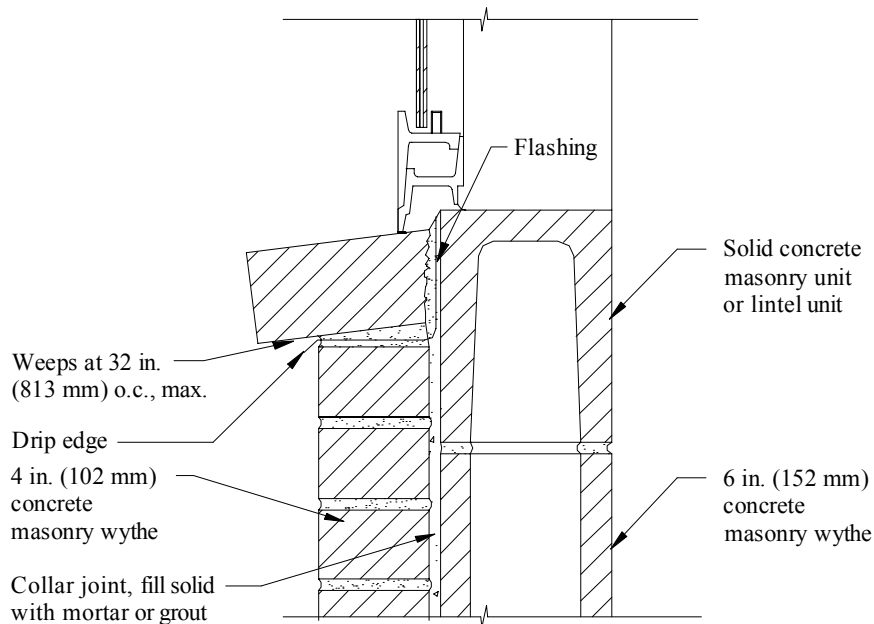


Last Modified: December, 2002

Metal Window Details



(b) Jamb



(c) Sill

CHAPTER 4 REFERENCES

4.1 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.

CHAPTER-5 - CONCRETE MASONRY VENEERS

Building Code Requirements for Masonry Structures (Ref. 5.1) defines veneer as a masonry wythe which provides the exterior finish of a wall system and transfers out-of-plane loads directly to the backing, but is not considered to add load resisting capacity to the wall system. Masonry veneers are typically composed of architectural units such as concrete or clay facing brick or split, fluted, glazed, ground face or scored block. Most commonly, anchored masonry veneers have a nominal thickness of 4 inches (102 mm), although 3 inch (76 mm) veneer units may be available as well.

The primary function of anchored veneers is to provide an architectural facade and to prevent water penetration into the building. As such, the structural properties of veneers are neglected in veneer design. The veneer is assumed to transfer out-of-plane loads through the anchors to the backup system. *Building Code Requirements for Masonry Structures* Chapter 6 (Ref. 5.1) includes requirements for design and detailing anchored masonry veneer. The *Code* provides two alternative approaches: a set of prescriptive requirements or a rational design. Prescriptive requirements for veneers and veneer anchors are shown in this publication in Chapter 1, Figures 1E.12 through 1E.14.

Although structural requirements for veneers are minimal, the following design considerations should be accounted for: crack control in the veneer, including deflection of the backup and any horizontal supports; adequate anchor strength to transfer applied loads; differential movement between the veneer and backup; and water penetration resistance.

The continuous airspace behind the veneer, along with flashing and weeps must be detailed to collect any moisture that may penetrate the veneer and direct it to the outside so that water cannot penetrate through the backup wall. A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity). Otherwise, a 2 inch (51 mm) air space is preferred. As an alternative, proprietary insulating drainage products can be used.

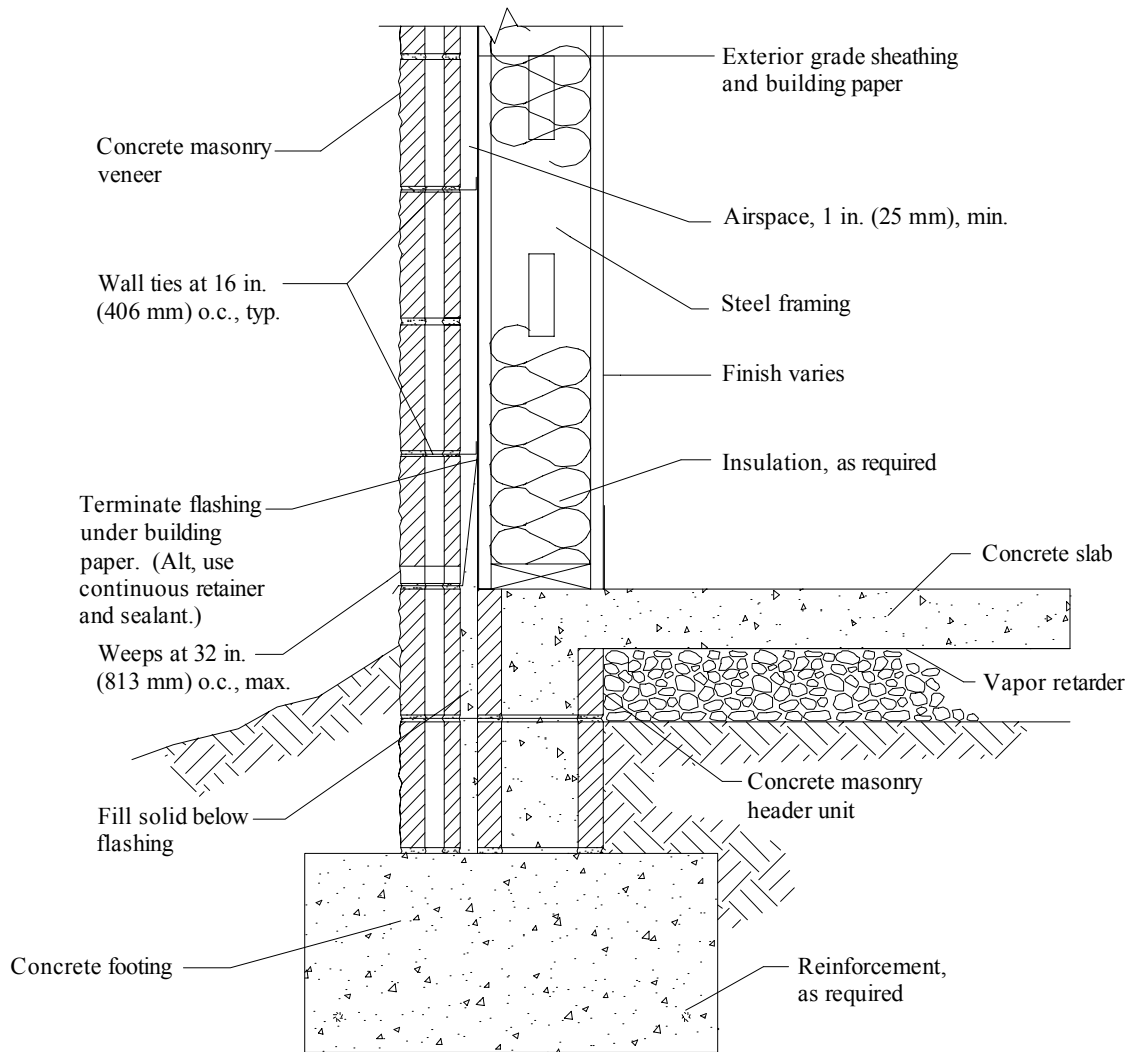
Although veneer crack control measures are similar to those for other concrete masonry wall constructions, specific crack control recommendations have been developed for concrete masonry veneers. These include: locating control joints to achieve a maximum panel length to height ratio of $1\frac{1}{2}$ and a maximum spacing of 20 feet (6.1 m), as well as where stress concentrations occur (see Ref. 5.2); incorporating joint reinforcement at 16 inches (406 mm) on center; and using Type N mortar for maximum flexibility. It is important to note that, because veneers rely on the backup for support, wall ties must be placed within 12 inches (305 mm) of control joints and wall openings to ensure the free ends of the veneer are adequately supported.

5A — Steel Framing Backup

For masonry veneer over steel stud backup, prescriptive *Code* provisions require the weight of the veneer to be supported by steel shelf angles (or other noncombustible construction) for each story above the first 30 feet (9,144 mm) (height at plate) or 38 feet (11,600 mm) (height at gable). This support does not necessarily have to occur at the floor height — it can be provided at a window head or other convenient location. Shelf angles are most commonly used. Another alternative is to support the veneer directly on the floor. Be aware, however, that supporting veneer on floors allows the exposed floor slab edges to act as thermal bridges and may be more susceptible to water entry at the floor/wall interface.

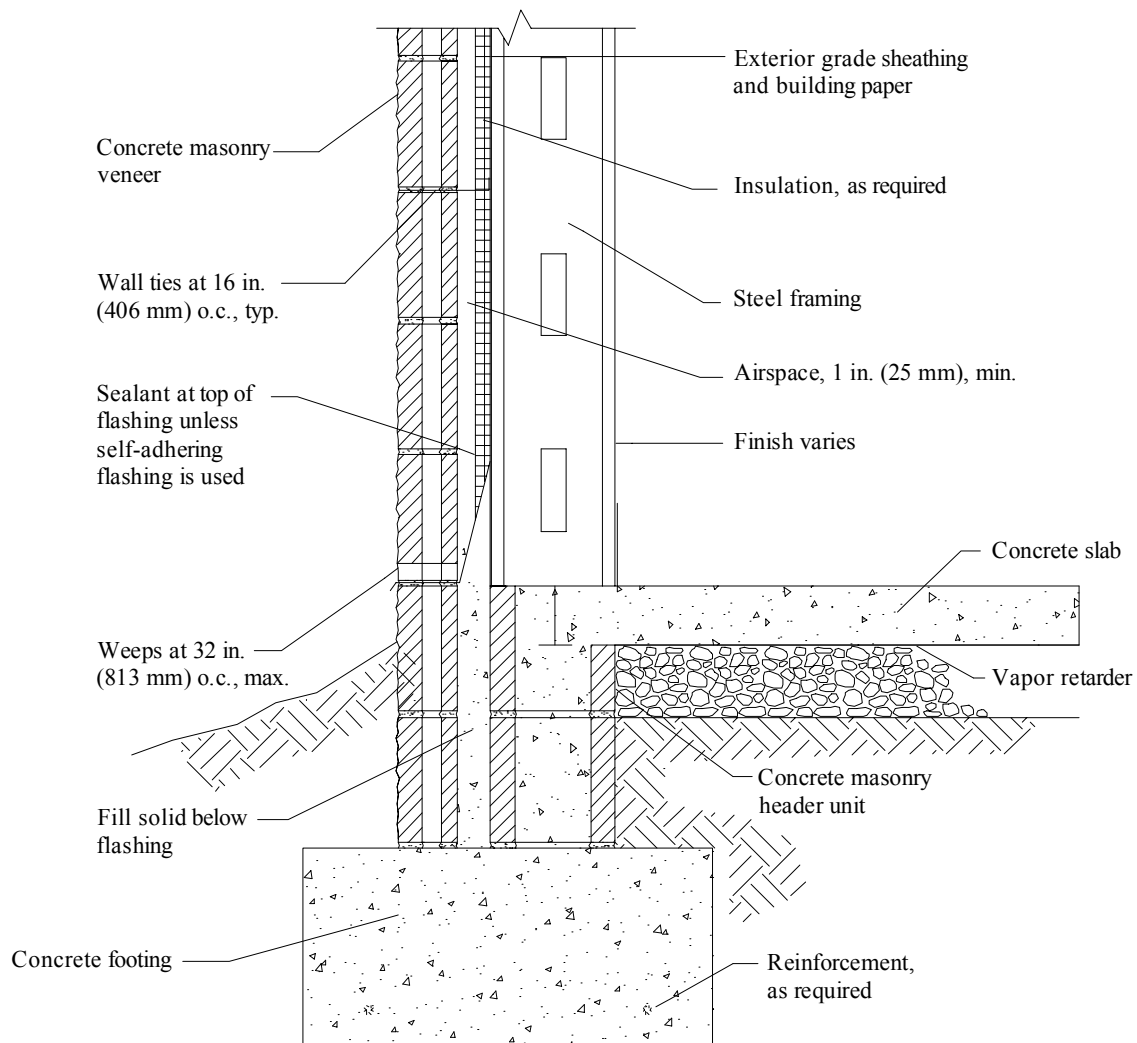
Building paper should be applied on the exterior side of the sheathing, and should be ship lapped a minimum of 6 in. (152 mm) at seams. Veneer must be attached to the steel framing with adjustable anchors using corrosion-resistant screws with a minimum nominal shank diameter of 0.190 inches (4.8 mm). In addition, the framing must be corrosion-resistant with a minimum base metal thickness of 0.043 inches (1.1 mm) to provide sufficient pull-out resistance of screws. The distance between the inside face of the veneer and the steel framing is limited to 1 inch (25 mm) minimum and 4 ½ inches (114 mm) maximum. When veneer is laid in a bond pattern other than running bond, it must have joint reinforcement, at least one wire, W1.7 (MW 11) at a maximum of 18 inches (457 mm) on center vertically, to increase the flexural strength of the veneer in the horizontal span. See section 2D for more detailed information on flashing and weeps.

Concrete Masonry Stem Wall, Batt Insulation



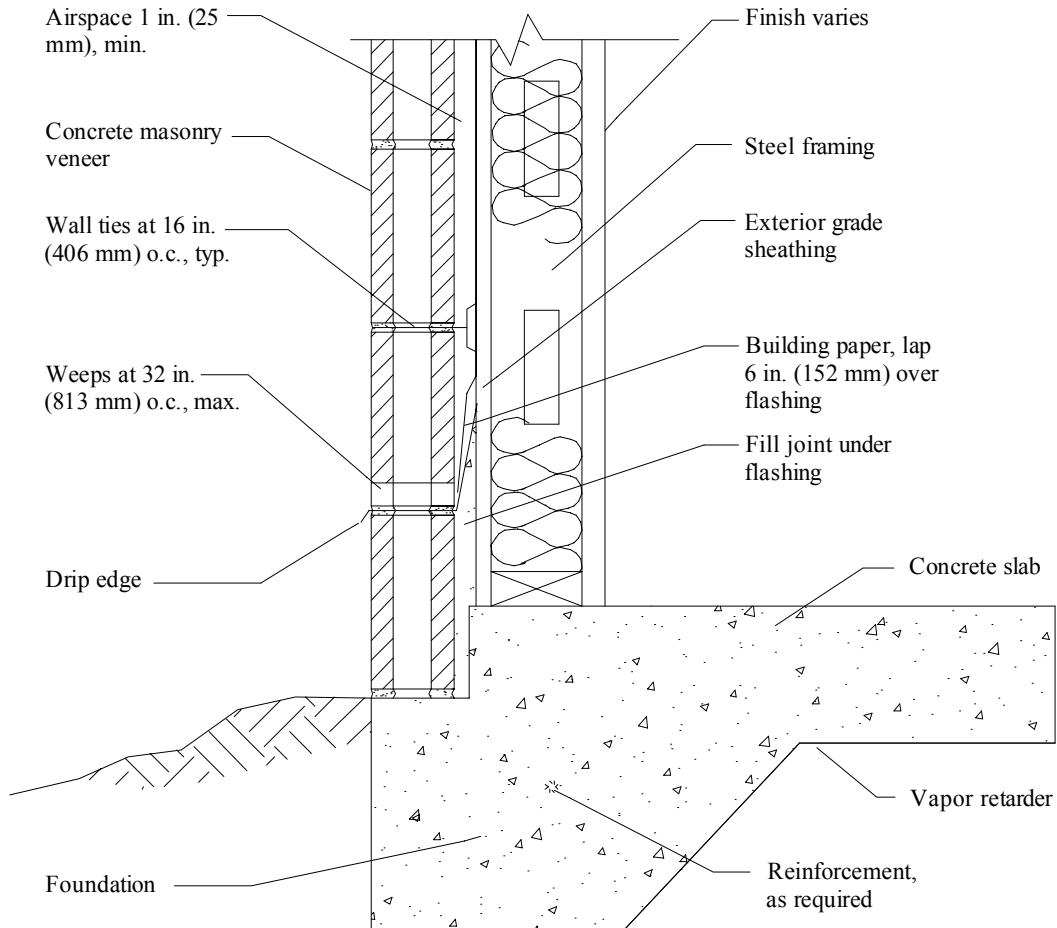
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Concrete Masonry Stem Wall, Rigid Insulation

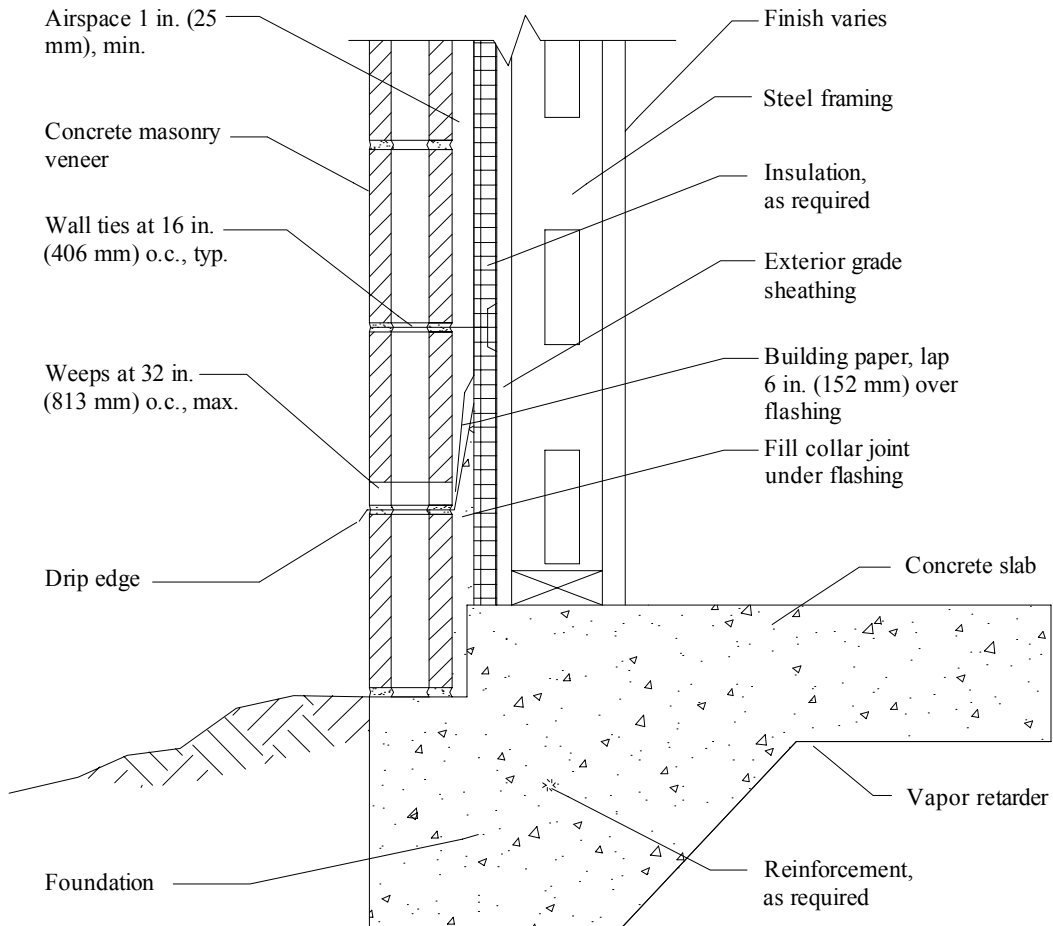


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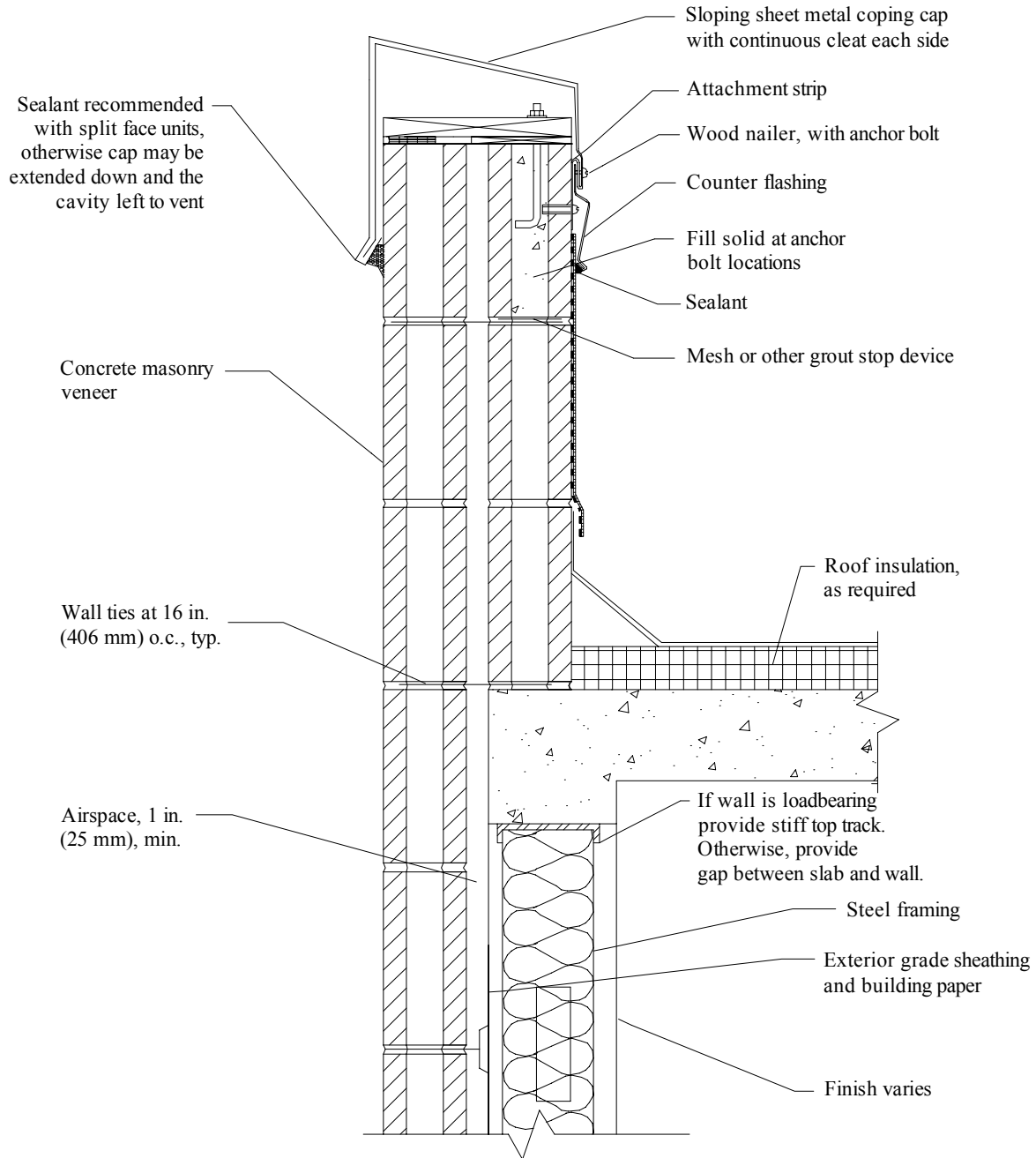
Slab, Batt Insulation



Slab, Rigid Insulation



Parapet



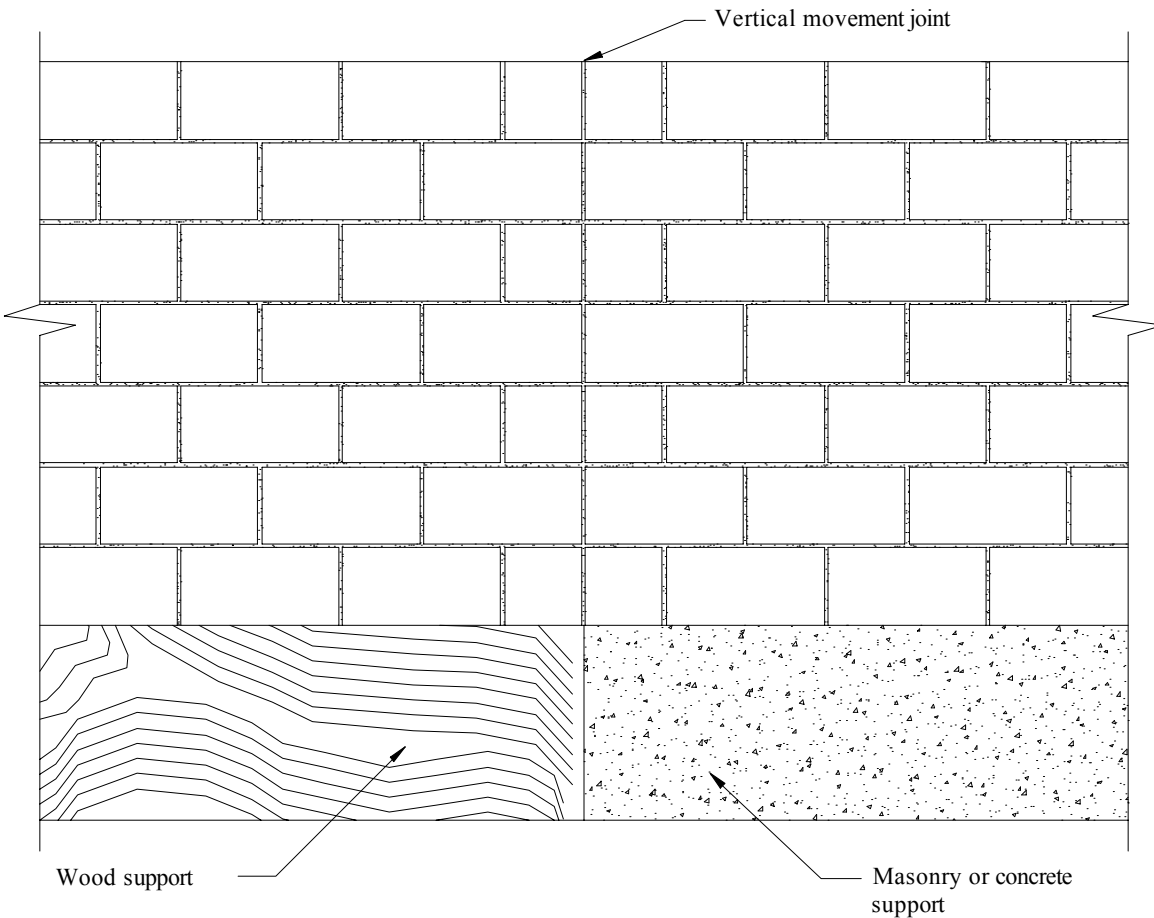
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5B — Wood Stud Backup

Prescriptive requirements in the Code limit the height of masonry veneer with wood frame backing to 30 feet (9,144 mm) (height at plate) or 38 feet (11,582 mm) (height at gable). Appropriate wall ties for masonry veneer on wood backing include corrugated sheet metal anchors, sheet metal anchors, wire anchors, joint reinforcement and adjustable anchors.

When veneer is supported by wood construction, a vertical movement joint must be provided to isolate the veneer supported by the wood construction from the veneer supported by the noncombustible foundation (see below). According to the *Code*, up to 12 feet (3,658 mm) of veneer may be supported by wood provided that it weighs no more than 40 psf (195 kg/m²). In addition, the masonry veneer may not be in direct contact with untreated or nondurable wood species.

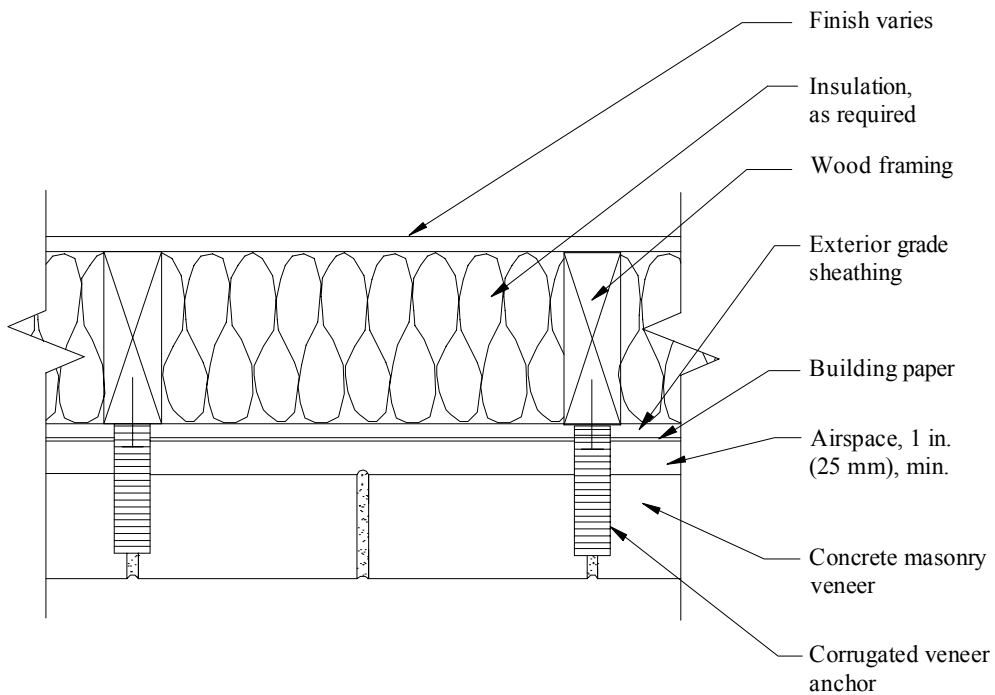
Anchors must be attached to wood framing with corrosion-resistant 8d common nails or fasteners with equal or greater pullout strength. For corrugated sheet metal anchors, the nail must be located within ½ inch (13 mm) of the 90° bend in the anchor. The distance between the inside face of the veneer and the wood framing is limited to 1 inch (25 mm) minimum and 4 ½ inches (114 mm) maximum. However, when corrugated anchors are used, the *Code*-required 4 ½ inches (114 mm) maximum distance between the veneer and backing is reduced to a 1 inch (25 mm) maximum between the inside face of the veneer and the outside face of the solid sheathing. When veneer is laid in a bond pattern other than running bond, it must have joint reinforcement (at least one wire, W1.7 (MW 11) at a maximum of 18 inches (457 mm) on center vertically) to increase the flexural strength of the veneer in the horizontal span. See section 2D for more detailed information on flashing and weeps.



Vertical Movement Joint at Foundation Change

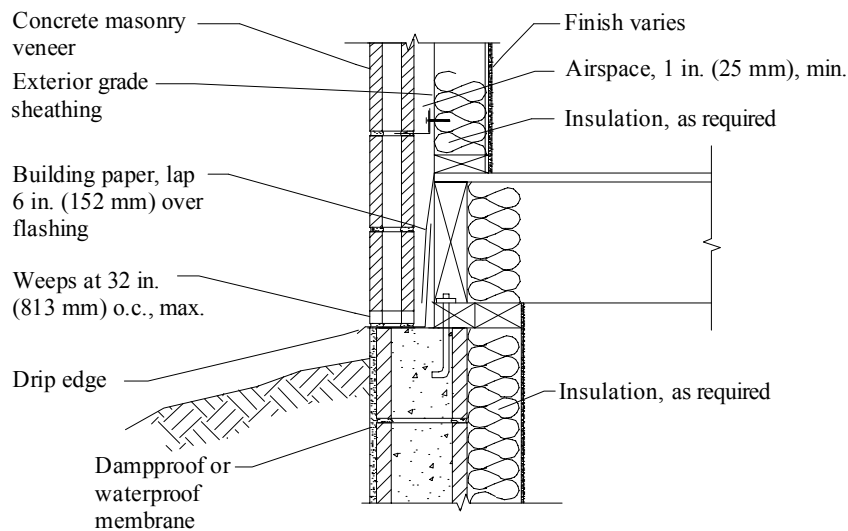
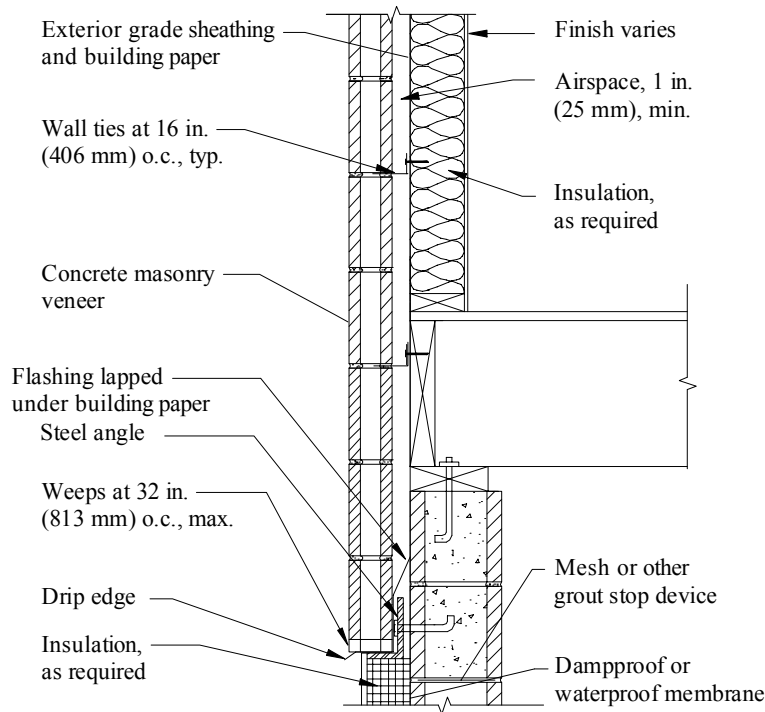
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Typical Wall Section



Foundation, Batt Insulation

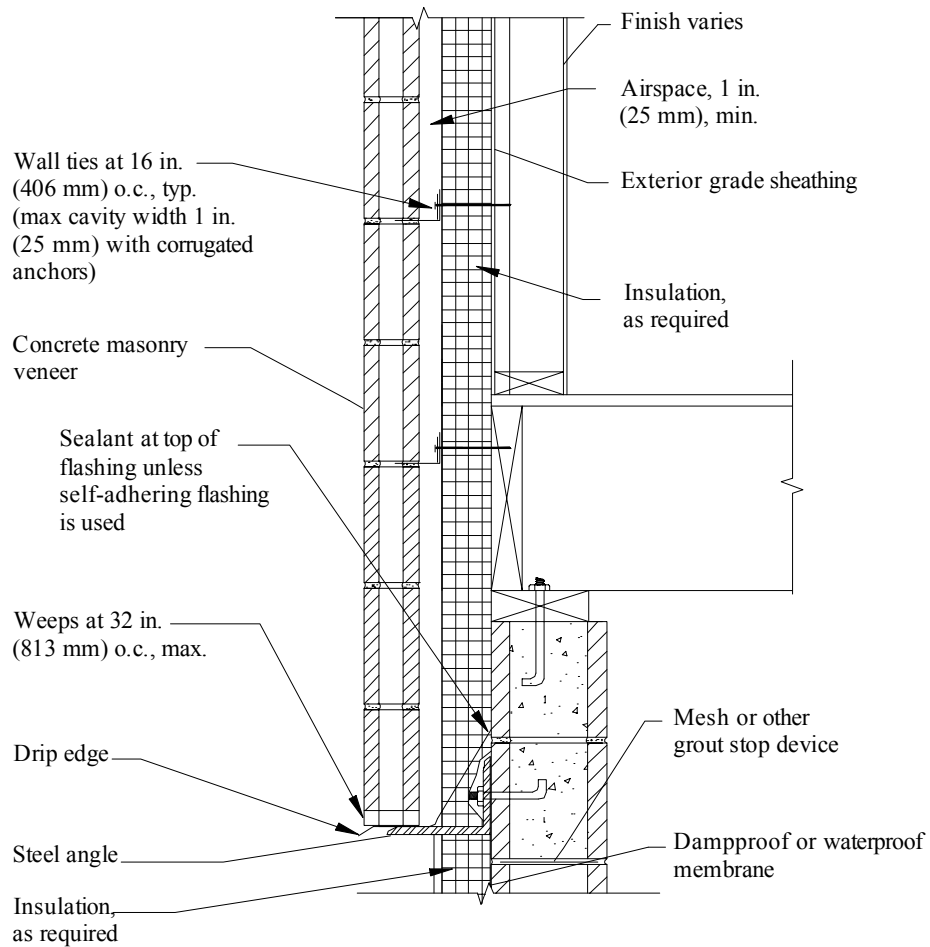
At the foundation, the veneer may be supported by foundation block or a shelf angle.



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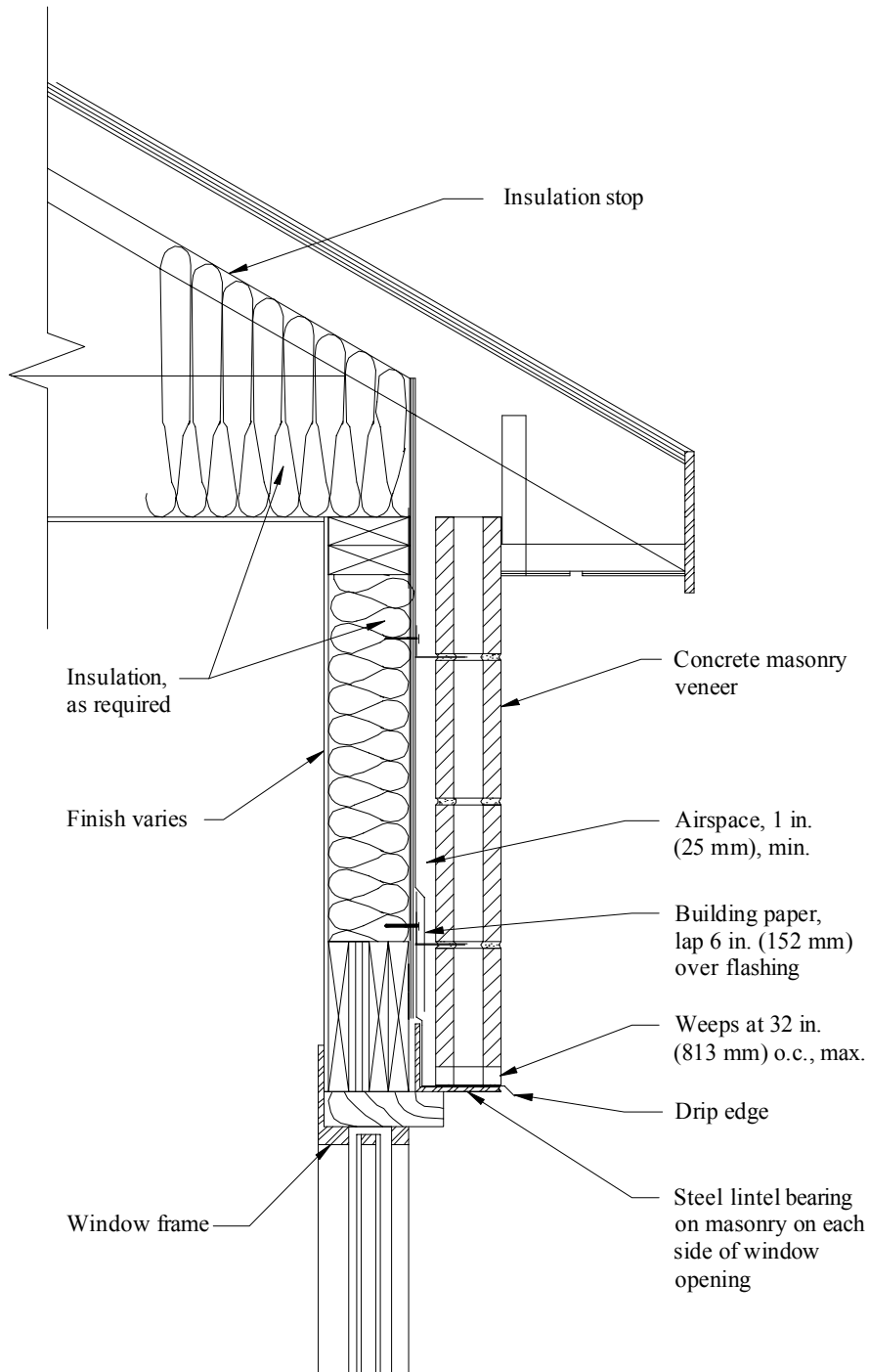
Foundation, Rigid Insulation

At the foundation, the veneer may be supported by foundation block or shelf angle.



Last Modified: December, 2002

Window Opening



Last Modified: December, 2002

5C — Concrete Masonry Backup

A masonry veneer with masonry backup with an air space between the masonry wythes is commonly referred to as a cavity wall. The continuous air space, or cavity, provides the wall with excellent resistance to moisture penetration and wind driven rain as well as a convenient location for insulation.

A true veneer is nonstructural — any contribution of the veneer to add to the wall's out-of-plane load resistance is neglected. If the exterior wythe of masonry is considered to add to the wall's load resistance, the wall is considered a multi-wythe noncomposite wall, rather than a veneer (see Chapter 4).

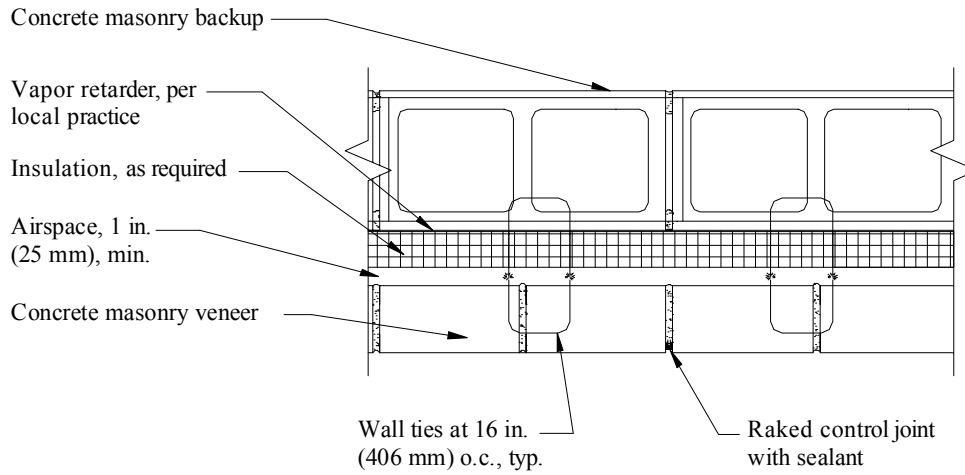
Wall ties may be joint reinforcement or wire wall ties. Wall ties for cavity walls transfer lateral loads to the structural wythe and also allow differential in-plane movement between wythes. This second feature is particularly important when the two wythes are of materials with different thermal and moisture expansion characteristics (such as concrete masonry and clay brick), or in an insulated cavity wall which tends to have differential thermal movement between the wythes. When horizontal joint reinforcement is used to tie the two wythes together, hot-dipped ladder type reinforcement is preferred over truss type, because the ladder shape accommodates differential in-plane movement.

Because the two wythes in a cavity wall are designed to be relatively independent, crack control measures should be employed as required for each wythe. It is generally not necessary for the vertical movement joints in the veneer wythe to exactly align with those in the backup wythe, provided that the ties allow differential in-plane lateral movement.

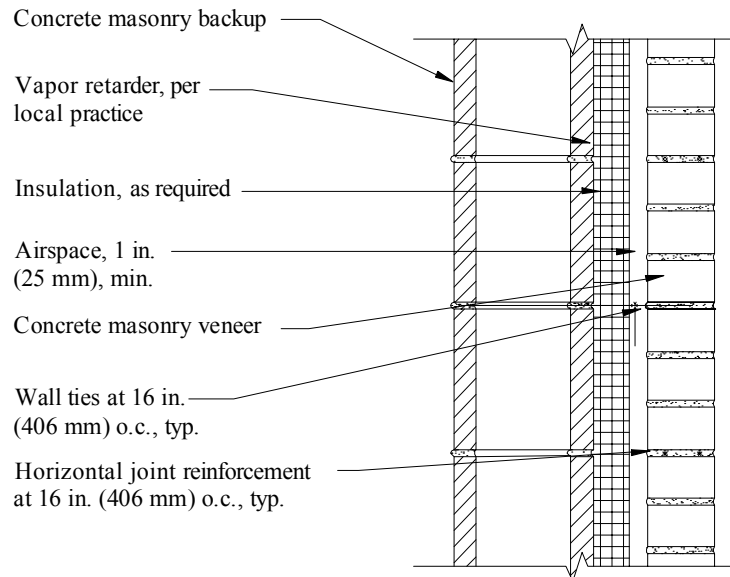
The distance between the inside face of the veneer and the outside face of the masonry backup must be a minimum of 1 inch (25 mm) and a maximum of 4 ½ inches (114 mm). With glazed masonry veneer, a 2 inch (51 mm) wide airspace is recommended with air vents at the top and bottom of the wall to enhance drainage and preclude a pressure differential between the cavity and the exterior of the wall. This is due to the impermeable nature of glazed masonry units. Vents can also be installed at the top of other masonry veneer walls to provide natural convective air flow within the cavity to facilitate drying.

Typical Wall Section

Concrete masonry veneer is shown. For clay brick veneer, the vertical raked control joint shown should be replaced with an expansion joint.



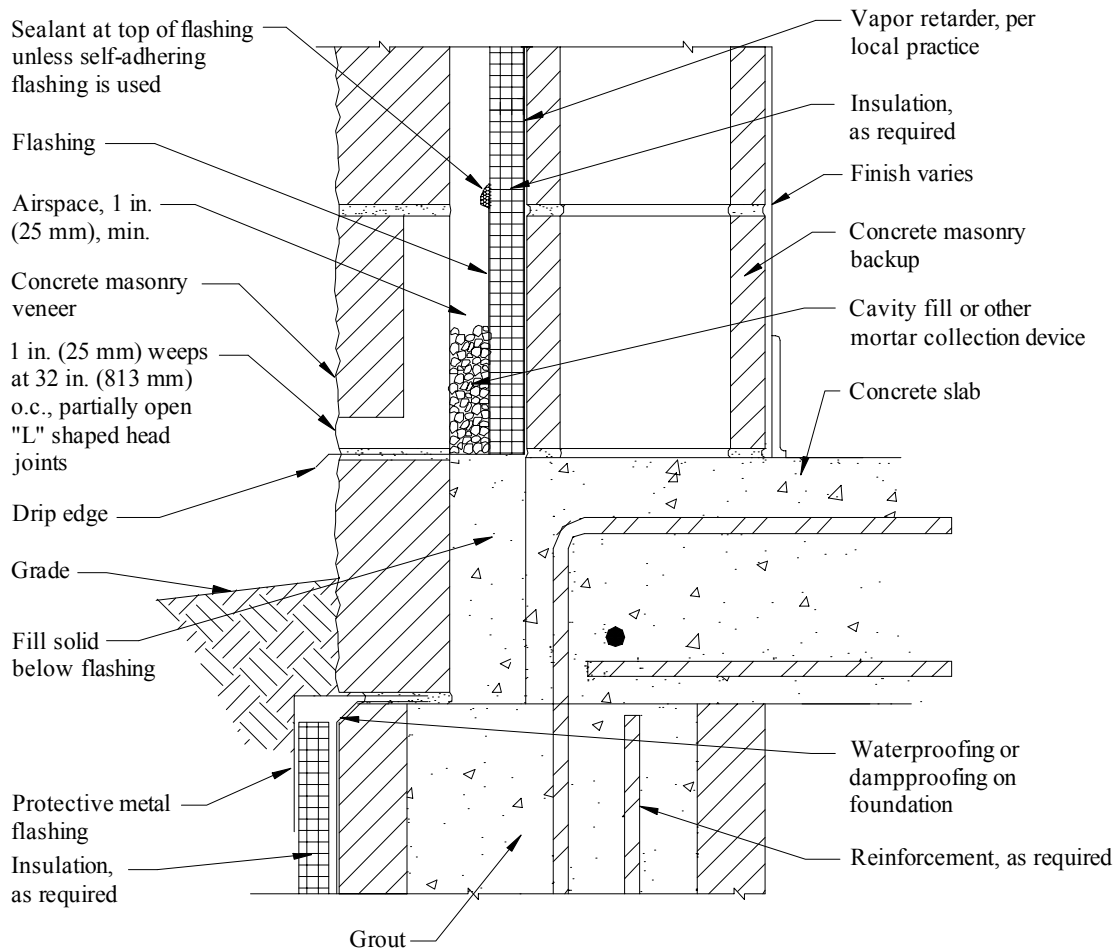
Plan View



Section

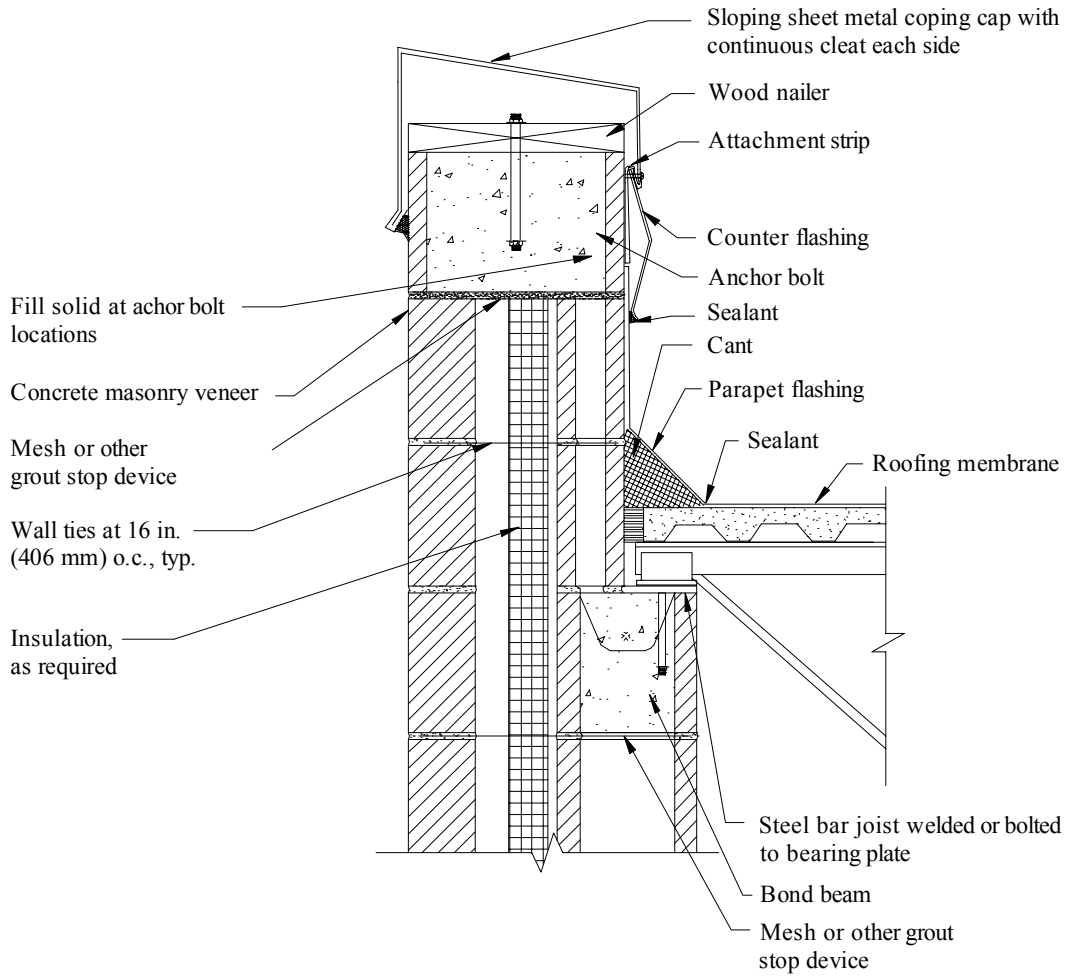
Foundation

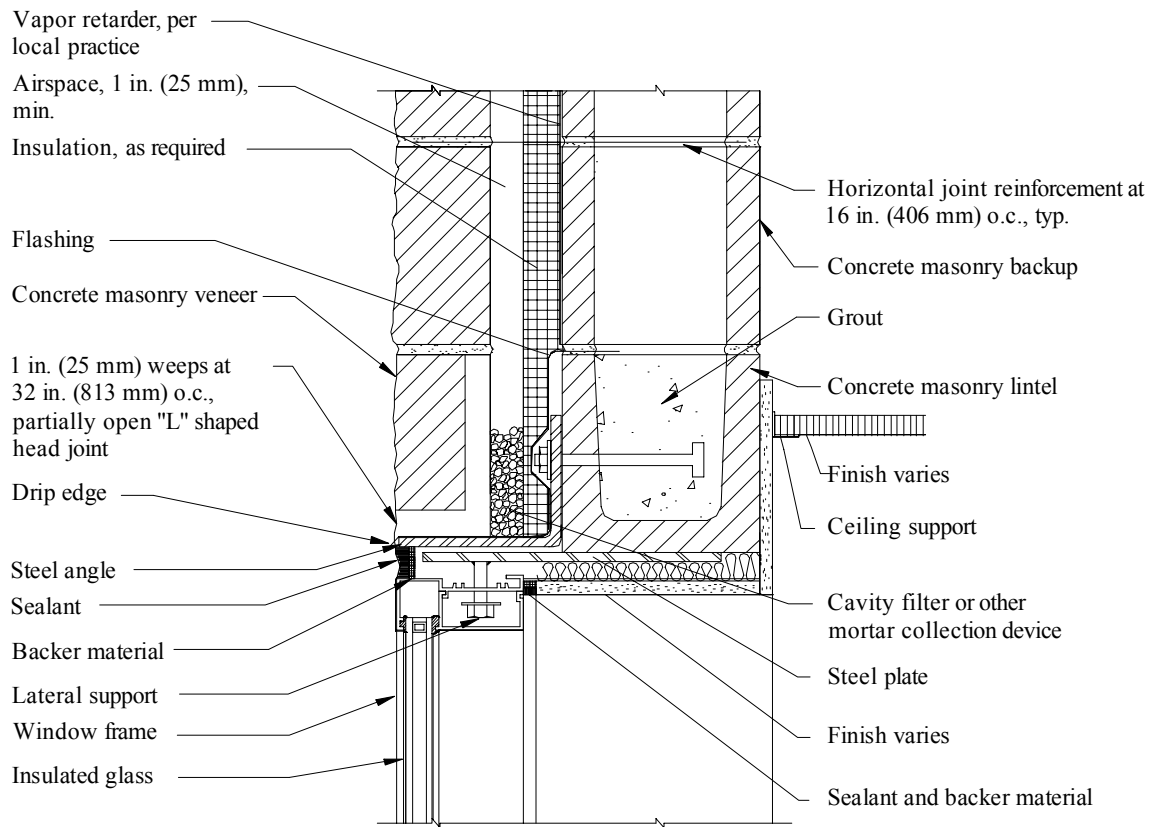
Local codes may restrict the use of foam plastic insulation below grade in areas where the hazard of termite damage is very heavy.



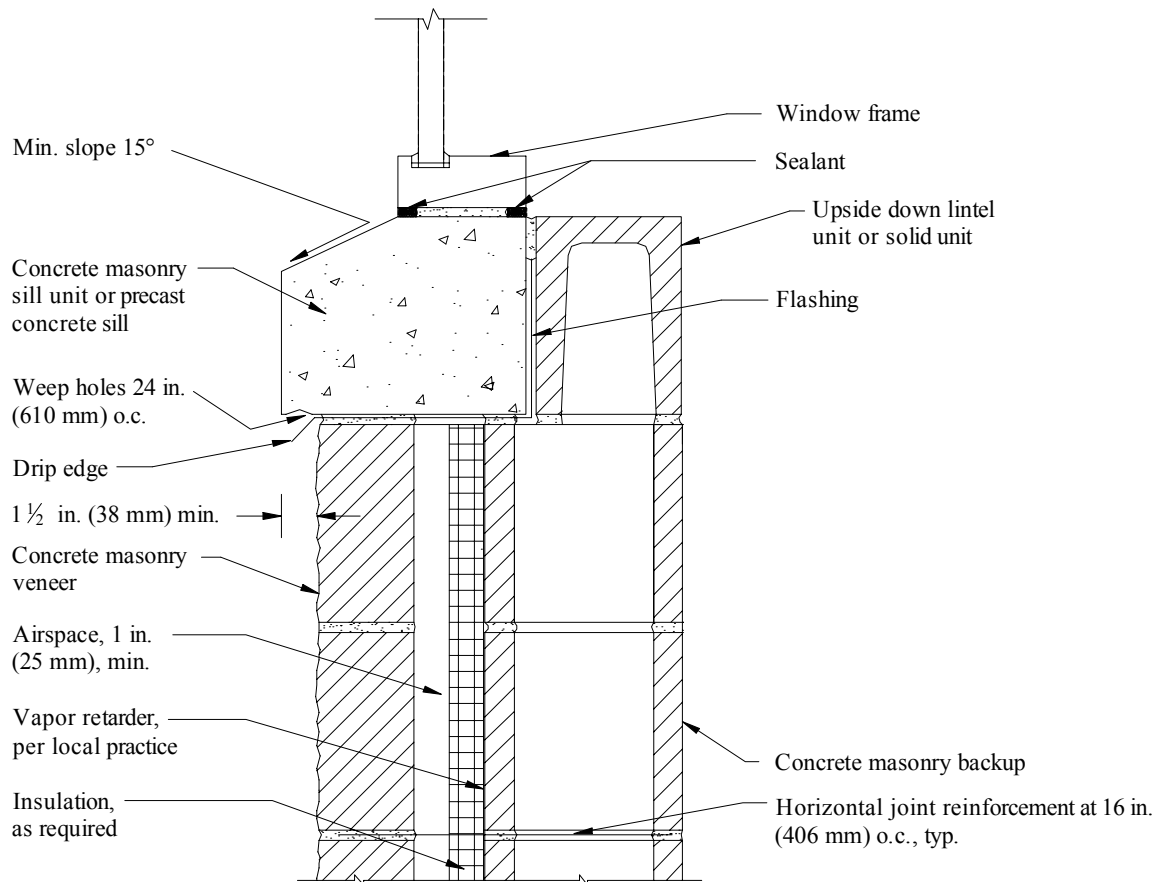
Parapet

Extending insulation up the full height of the parapet helps prevent thermal losses through the parapet.





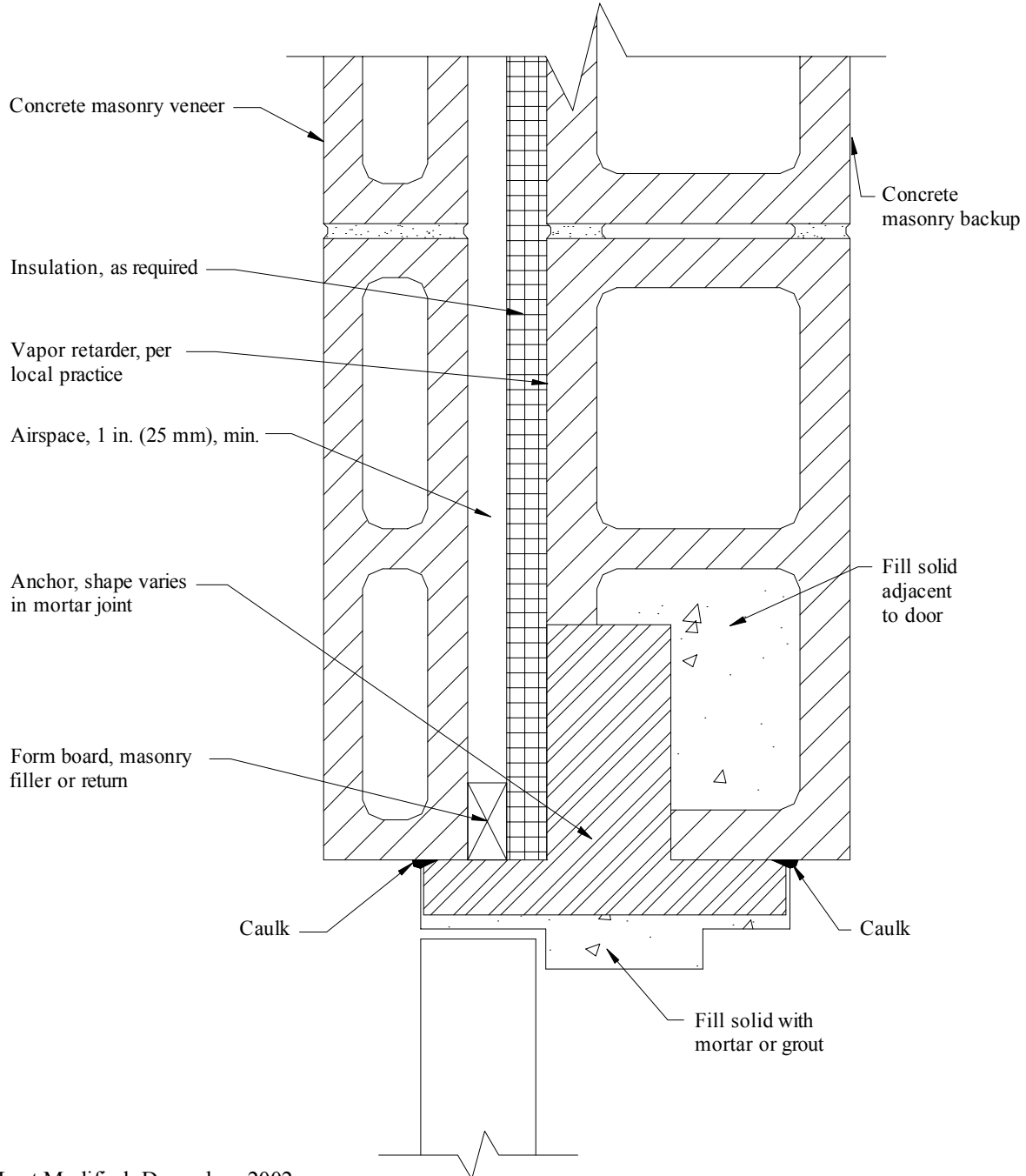
(a) Head



(b) Sill

Metal Door Jamb

In the backup wythe, the cell adjacent to the door should be filled solid. This is typically accomplished by slushing mortar into the cell as the wall is erected. A form board, or similar, is used to confine the mortar or grout fill to the buck. For larger cavities where part of the cavity will not be covered by the door jamb, masonry units may be cut and mortared into place to provide a solid backing for the door jamb.



Last Modified: December, 2002

References:

- 5.1 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
- 5.2 *Crack Control for Concrete Brick and Other Concrete Masonry Veneers*, TEK 10-4. National Concrete Masonry Association, 2001.

Chapter 6 — Anchorage and Connections

Connections between building elements transfer load or permit movement between elements. Connections between loadbearing walls and diaphragms, for example, must be strong and stiff enough to distribute design loads. When the element is not designed to carry building loads, the connection must accommodate or otherwise limit load transfer. Load transfer between diaphragms and walls requires proper design and detailing of the connections linking these elements. Connections are critical to the structural integrity of a building. The connections detailed below address minimal requirements. Additional requirements may be necessary in some locales, particularly where earthquake and high wind forces are to be resisted.

Appropriate connections for seismic and high wind applications are shown in Chapter 8.

Connections between concrete masonry buildings and metal buildings are shown in Section 3C.

Connections between concrete and steel beams/columns and concrete masonry walls are shown in Section 3B.

Connections between walls and foundations are shown in Section 3F.

Each of the following primary roof and floor connections are addressed in this chapter:

- Direct bearing connection - Often the simplest type of connection. This connection is used at the top of concrete masonry walls or when a change in wall thickness provides a ledge with sufficient bearing area.
- Pocket connection - Consists of framing the floor or roof system into a void in the masonry wall. This detail is used when masonry continues above the connection location (either as part of the wall or as a parapet) and eccentricity is to be minimized. Care must be taken to insure that the use of a pocket does not interfere with the continuity of vertical reinforcement in the wall.
- Hanger connection - When wall continuity must be maintained for structural, aesthetic or construction reasons, a wall hanger can be used to suspend the roof or floor system. Hangers are generally anchored to a wall through a joint and into a bond beam. However, hangers approved for direct attachment to the surface of a masonry wall are also available.
- * Ledger connection - As with hangers, ledger connections minimize the impact on the continuity of a masonry wall. A ledger connection reduces the necessary pre-planning and does not unduly impact the mason's work (as opposed to a pocket connection); thereby reducing the number of field modifications.

The following details show flashing and weep holes for water penetration resistance, which should be used in all exterior walls. Normally, flashing and weeps are not provided in interior walls. Additional design issues such as eccentrically applied loads, induced torsion, induced moment, and movements and deflections must be accounted for in each design.

6A — Wall to Roof

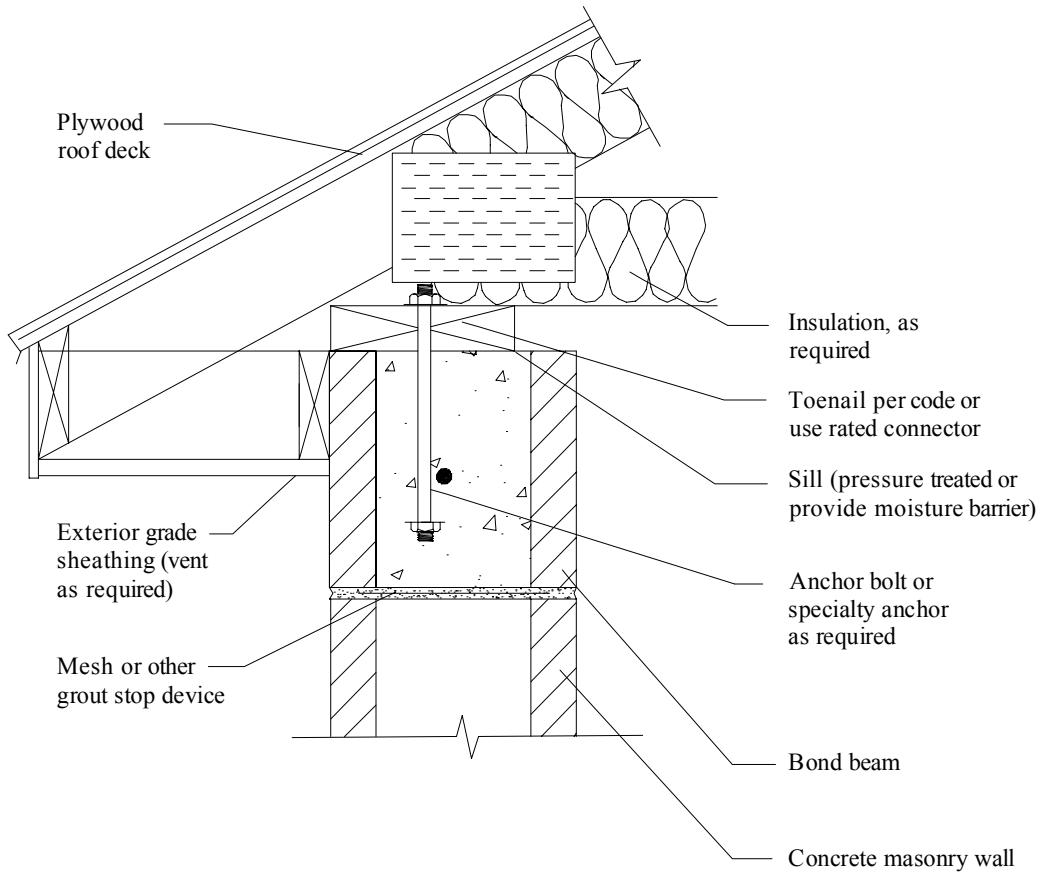
Roof systems distribute wind and/or seismic forces to the building's shear walls, gravity loads to loadbearing walls, and provide lateral support for walls. Two main types of roofs are used with masonry buildings: flat roofs and lightweight truss or joist roofs. A flat roof acts as a diaphragm and distributes loads to shear walls below according to the rigidity of the roof and the relative stiffness of the shear walls. Lightweight roofs are typically subject to net uplift forces due to wind, and so must be adequately tied down. A roof is also typically used to provide lateral support to the masonry walls below.

The enclosed details are based on an engineered design. Note that when buildings are designed using the empirical design method of *Building Code Requirements for Masonry Structures* Chapter 5 (Ref. 6.1), the following requirements apply. Where roofs provide lateral support to masonry walls, roof diaphragms must be anchored to masonry walls with $\frac{1}{2}$ inch (13 mm) diameter anchor bolts at 6 feet (1.8 m) on center, or their equivalent. Bolts must extend and be embedded at least 15 inches (381 mm) into the masonry, or be hooked or welded to not less than 0.2 in.² (129 mm²) of bond beam reinforcement placed not less than 6 inches (152 mm) from the top of the wall. In addition, where net roof uplift occurs, the uplift must be resisted entirely by an anchorage system which is designed by engineering methods in accordance with the *Code*. Roofs also must be designed so that the roof gravity load does not impart out-of-plane thrust to the walls.

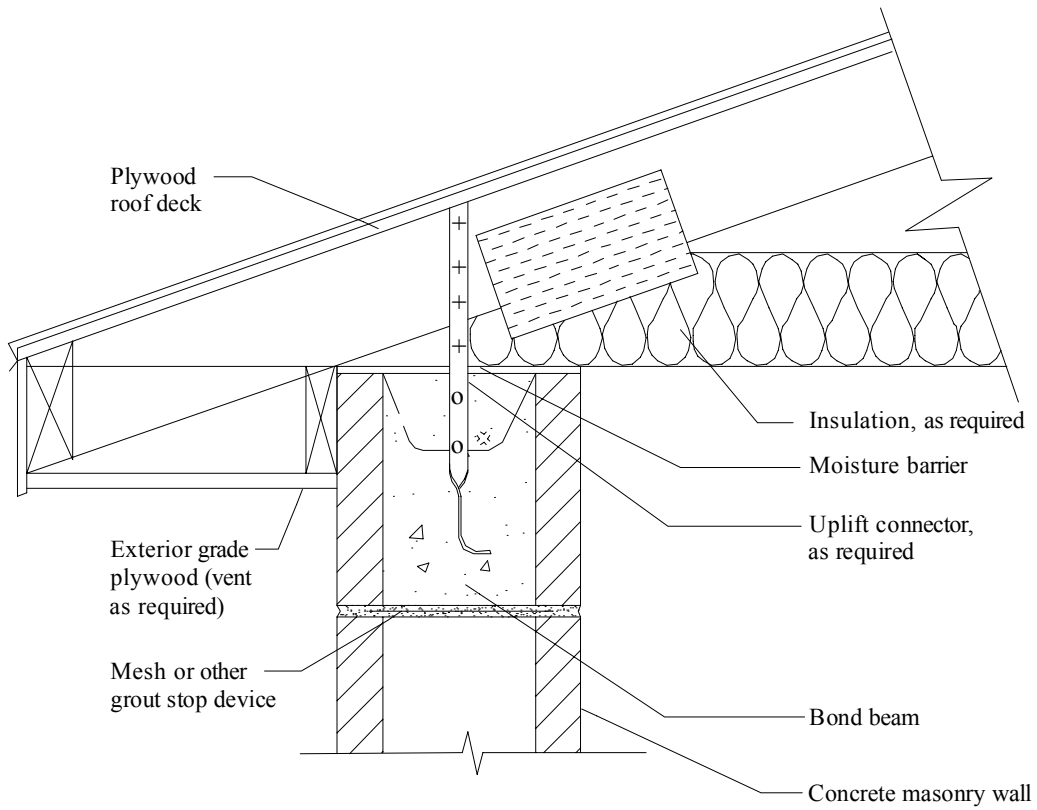
Note that additional prescriptive roof/wall anchorage requirements may apply in seismic or high wind designs. These are covered in Chapter 8.

Steel-framed roofs using steel bar joints are very common in commercial structures because they are capable of spanning long distances. Steel bar joists typically use pocketed or ledger connections to concrete masonry walls. Proprietary floor systems that use concrete masonry units as a filler between the steel joists are also available.

Wood Roof Truss with Top Plate



Wood Roof Truss with Embedded Strap Anchor

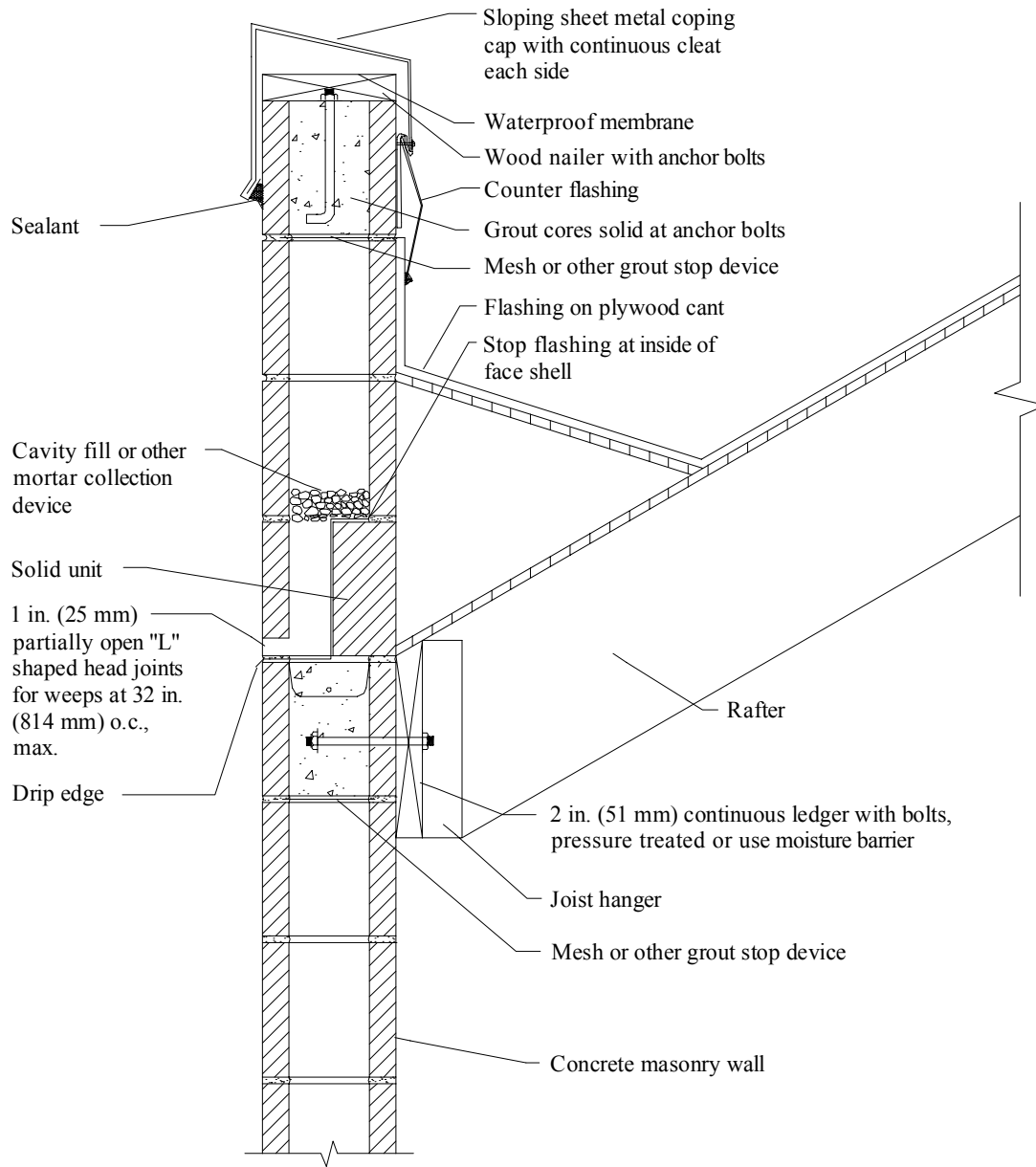


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Wood Roof Joist with Masonry Parapet

As an alternate, the joist hanger can be directly embedded into the masonry, eliminating the need for the ledger board. Note that this requires careful placement of the joist hangers at the time of masonry erection.

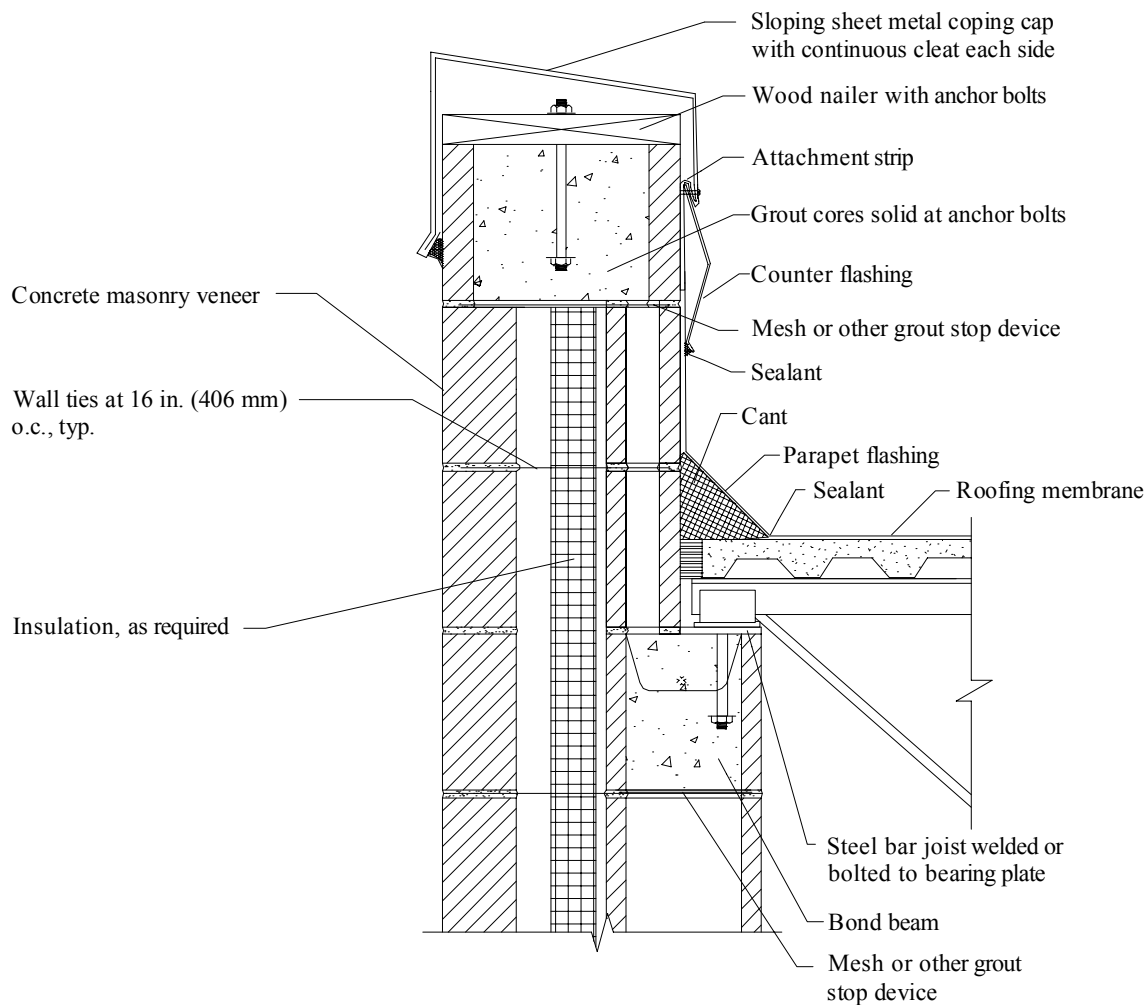
A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



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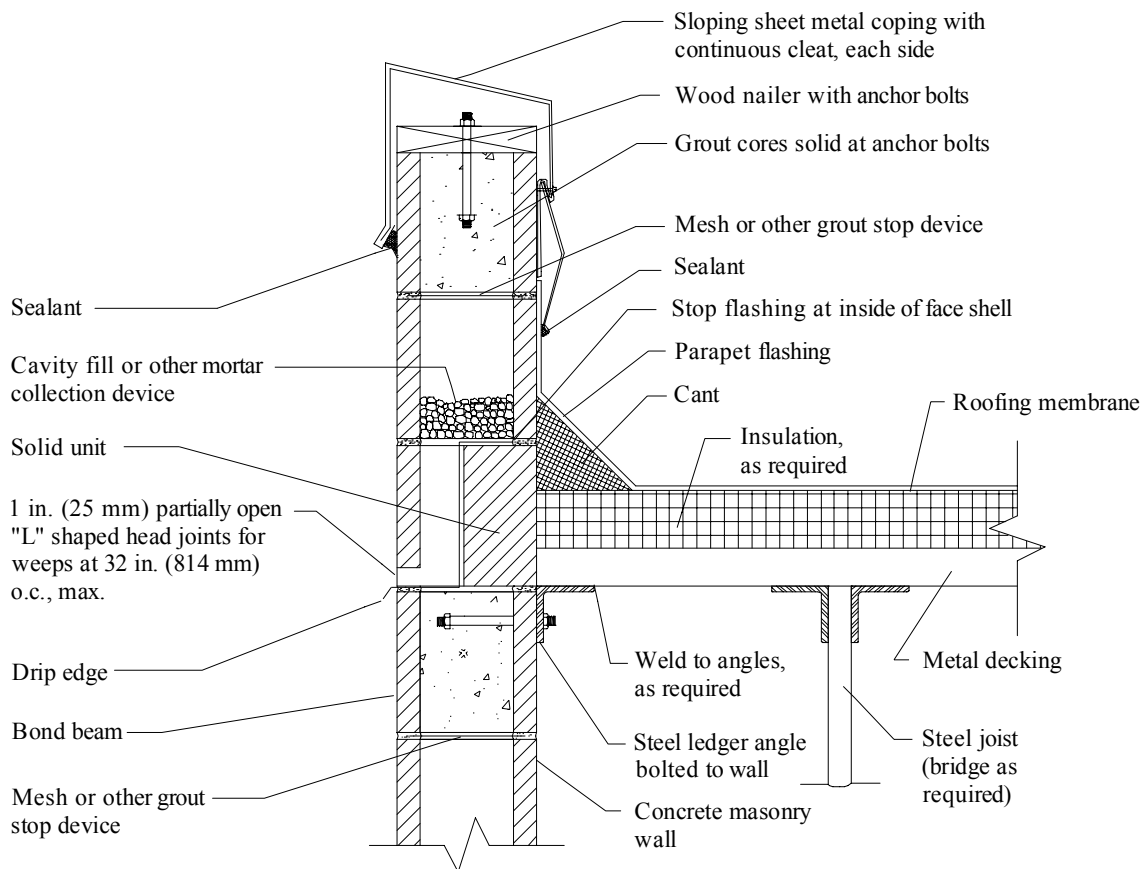
Steel Joist Direct Bearing on Cavity Wall

A 1 inch (25 mm) clear air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or by drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) clear air space is preferred. As an alternative, proprietary insulating drainage products can be used without the need for a clear air space.



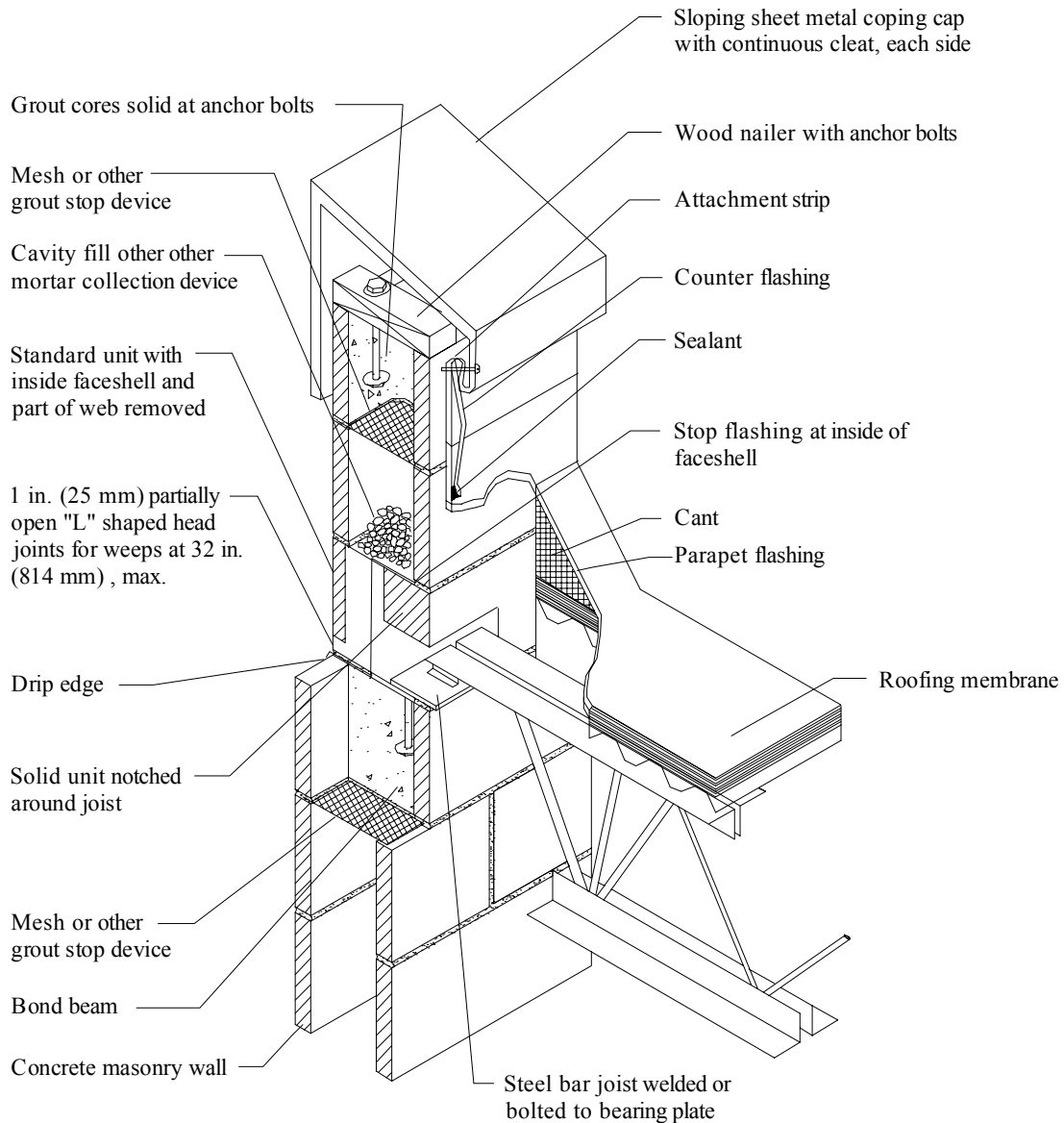
Steel Joist Roof System at Sidewall

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



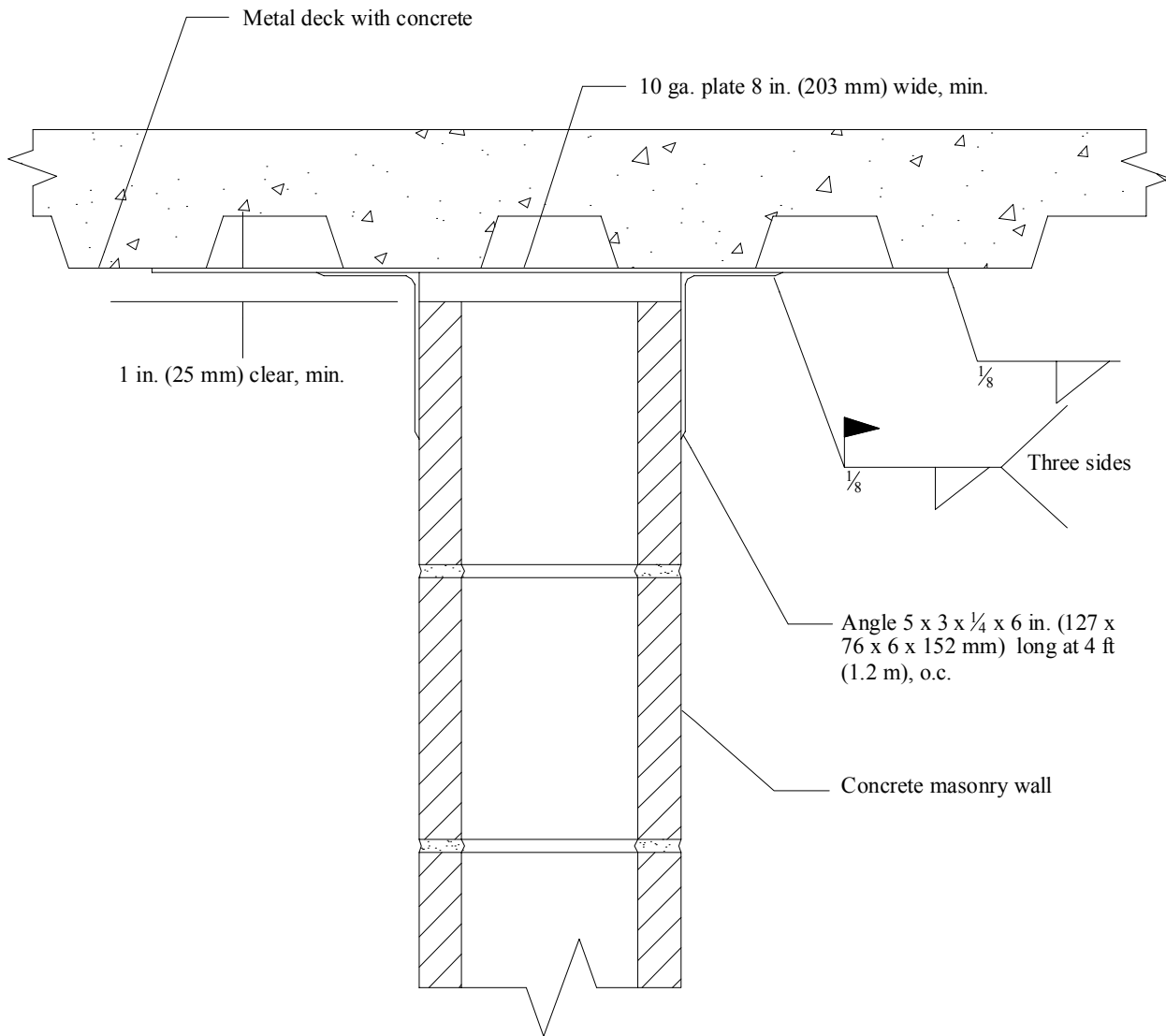
Steel Joist with Pocket

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.

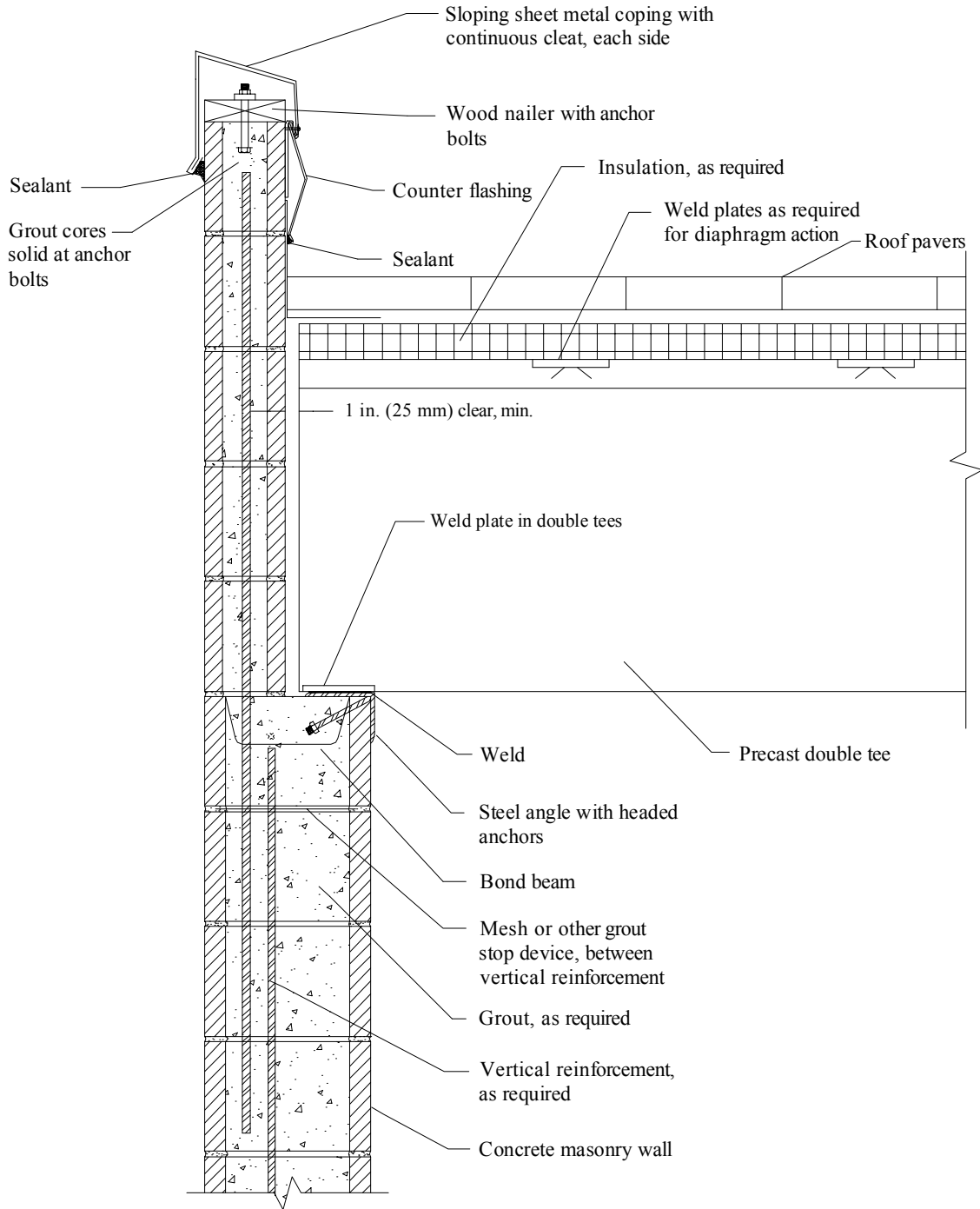


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Metal Deck Roof to Nonbearing Wall

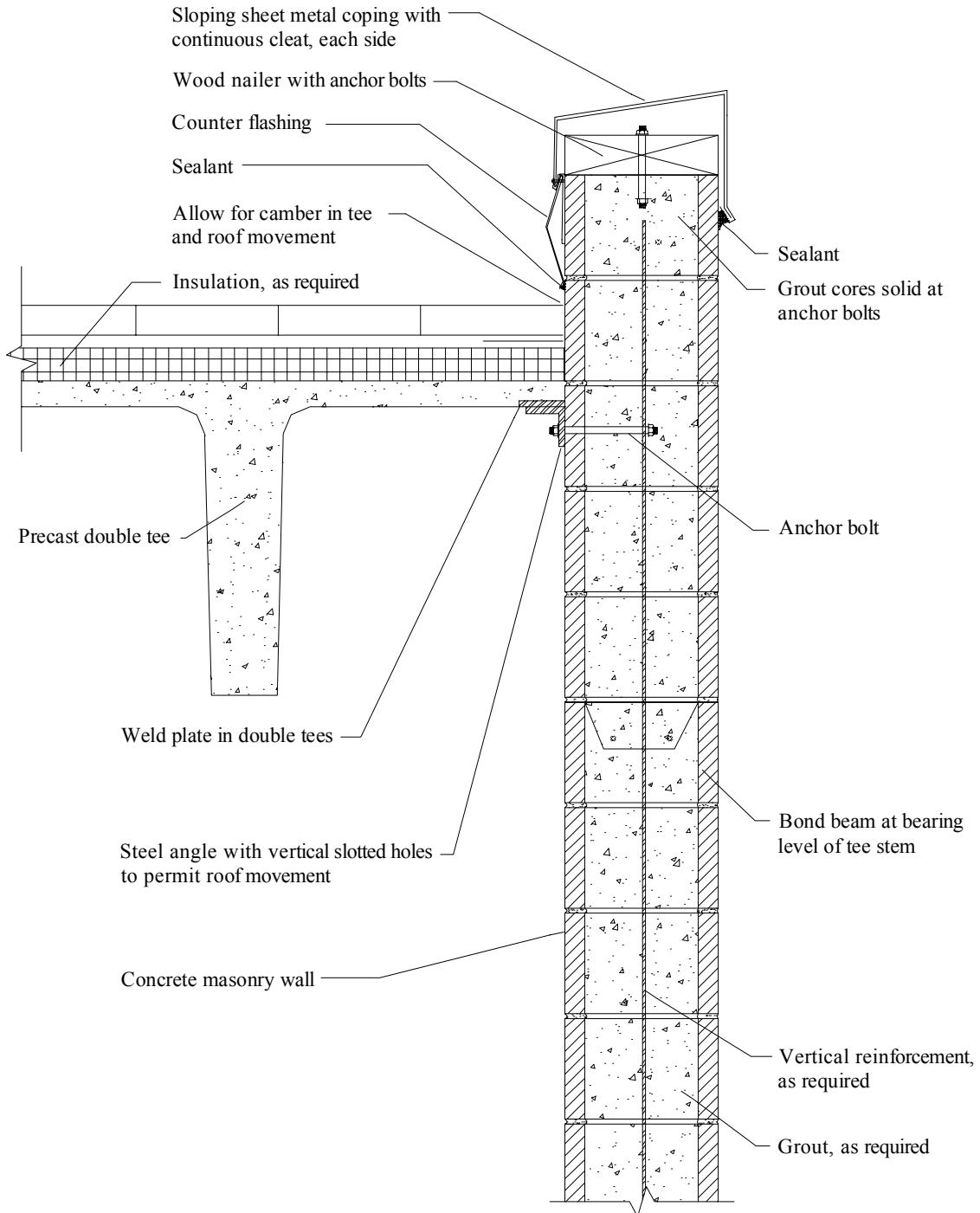


Precast Double Tee Roof at Bearing



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Precast Double Tee Roof at Sidewall



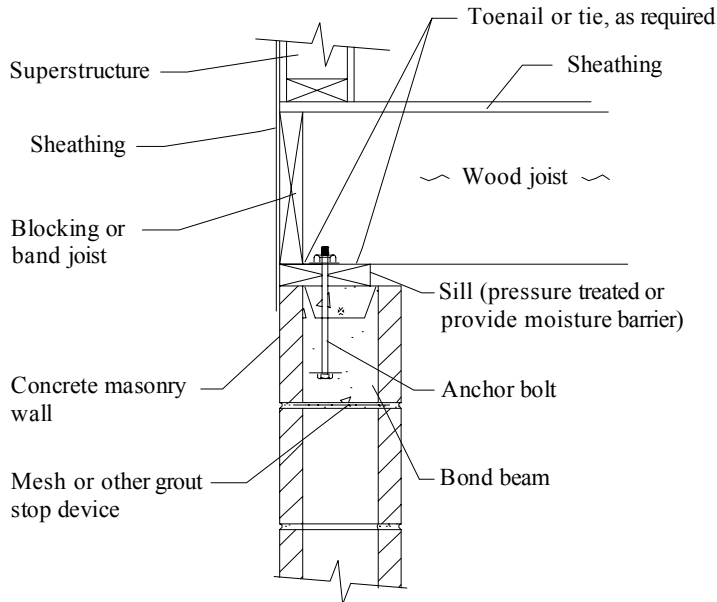
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6B — Wall to Floor

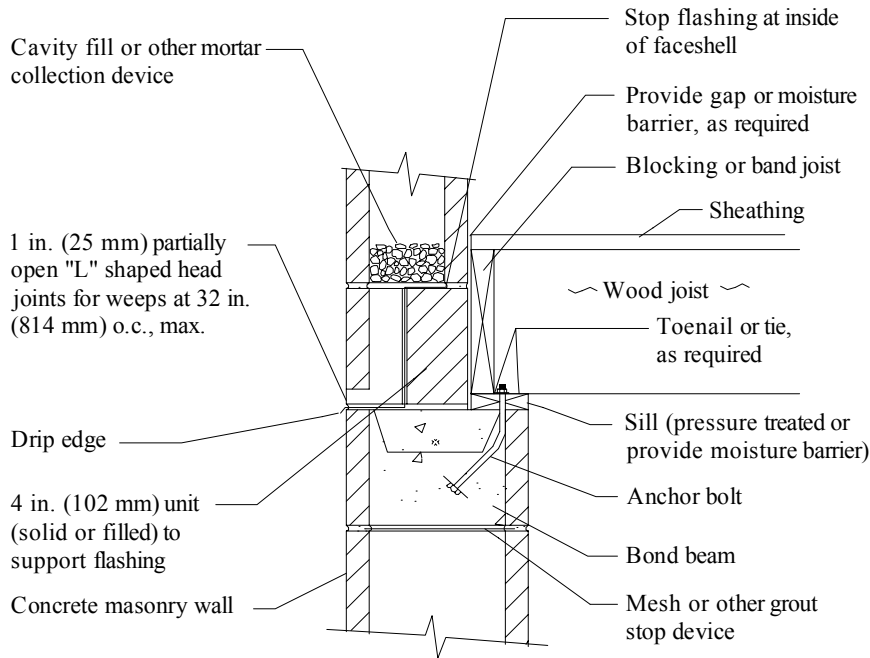
Structurally floor connections play much the same role as flat roof connections— they distribute lateral load from the walls receiving it to the floor diaphragm and then again from the diaphragm to the building's shear walls. Reinforcing bars or other anchors are used to transfer these loads. When wood floors are used, the wood should not be in direct contact with the concrete masonry unless the lumber used is pressure-treated or naturally decay resistant. In other cases, place a moisture barrier between the wood and the concrete masonry.

Direct Bearing Wood Floor Joist

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



(a) Wood Frame Wall Continuing Above

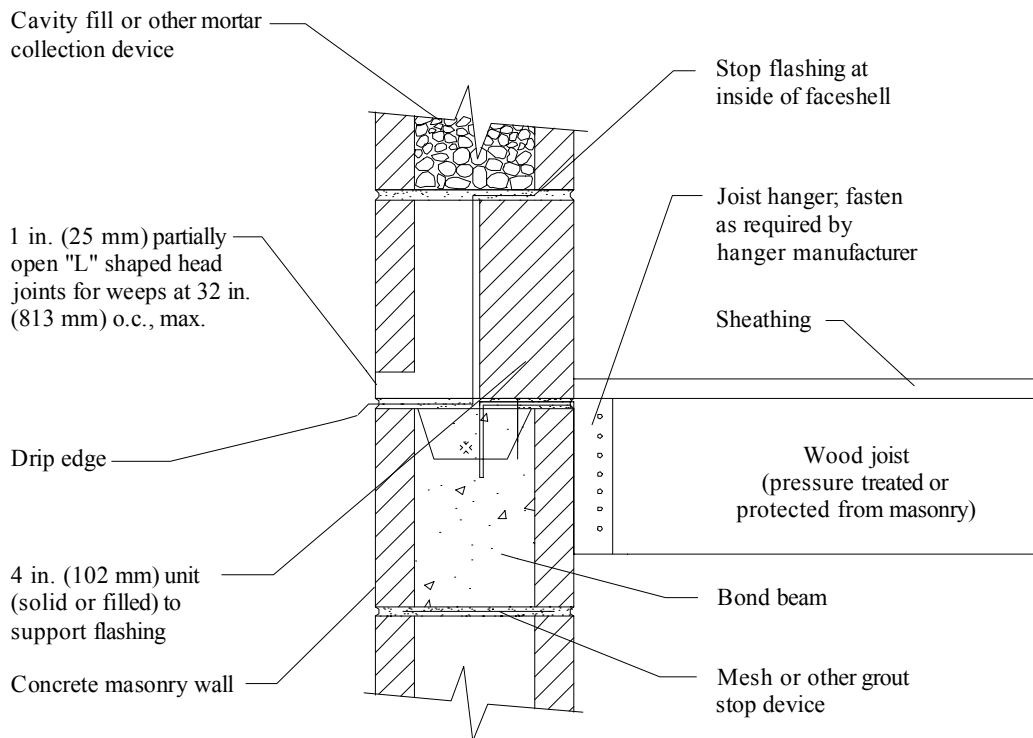


(b) Masonry Wall Continuing Above

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Wood Floor Joist Hanger

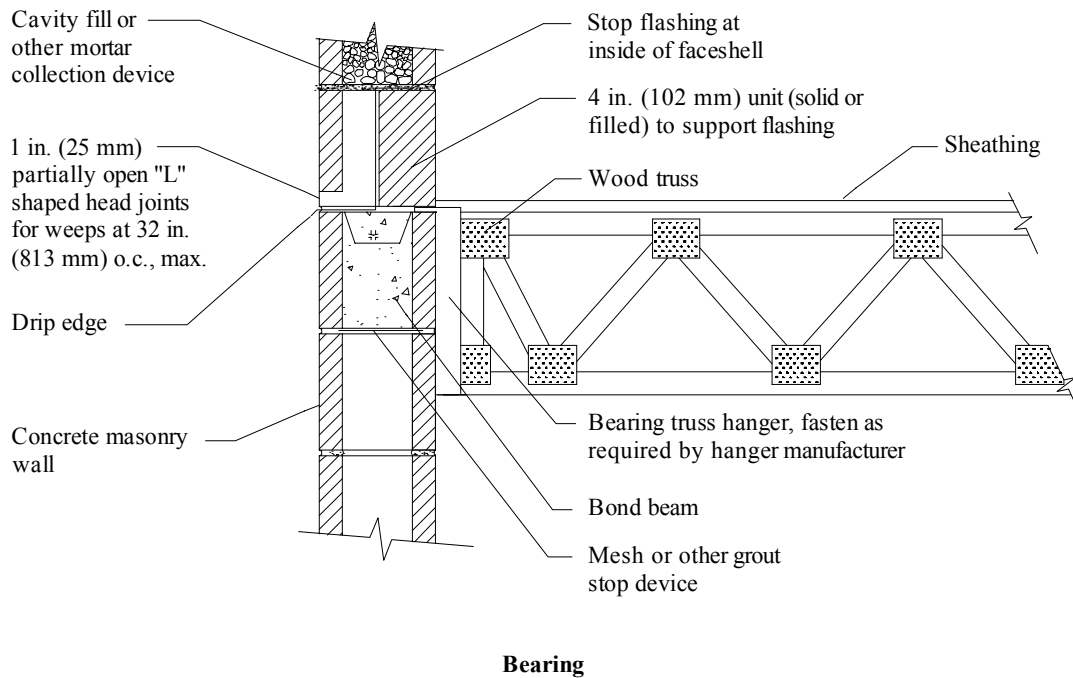
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Wood Floor Truss Hanger

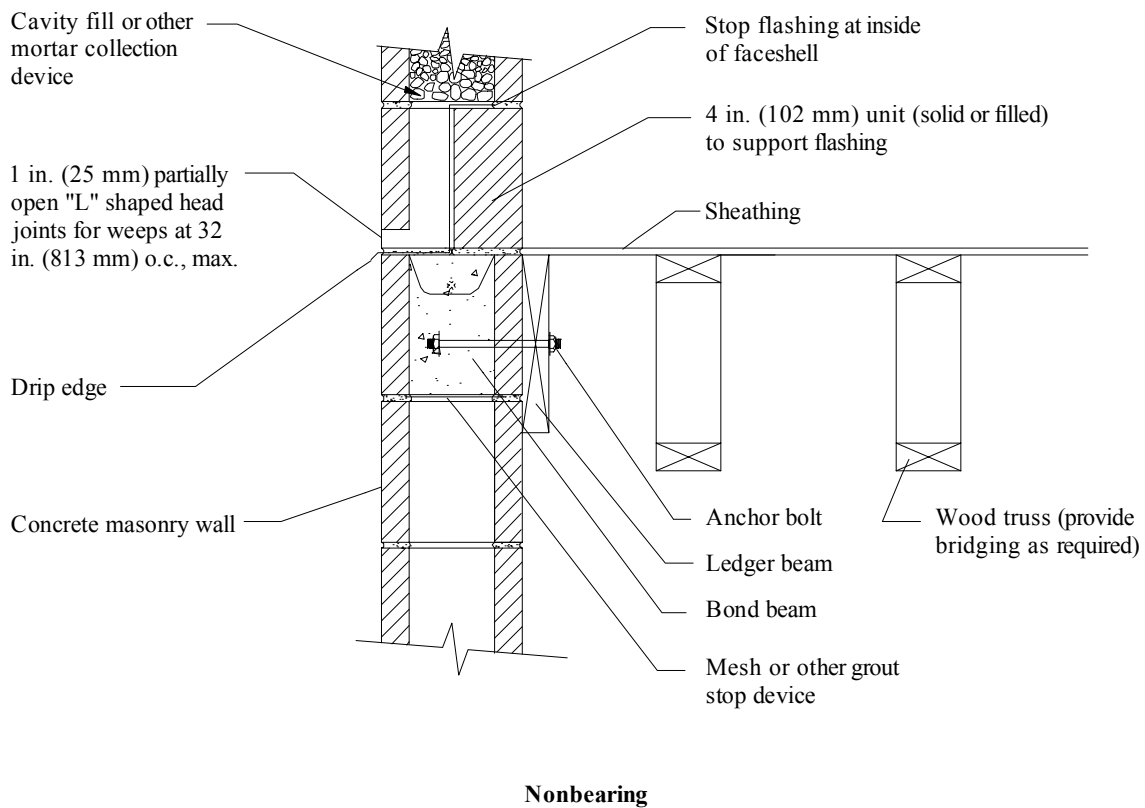
A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.

A more common alternative to the detail illustrated below is with top chord bearing on the wood truss.



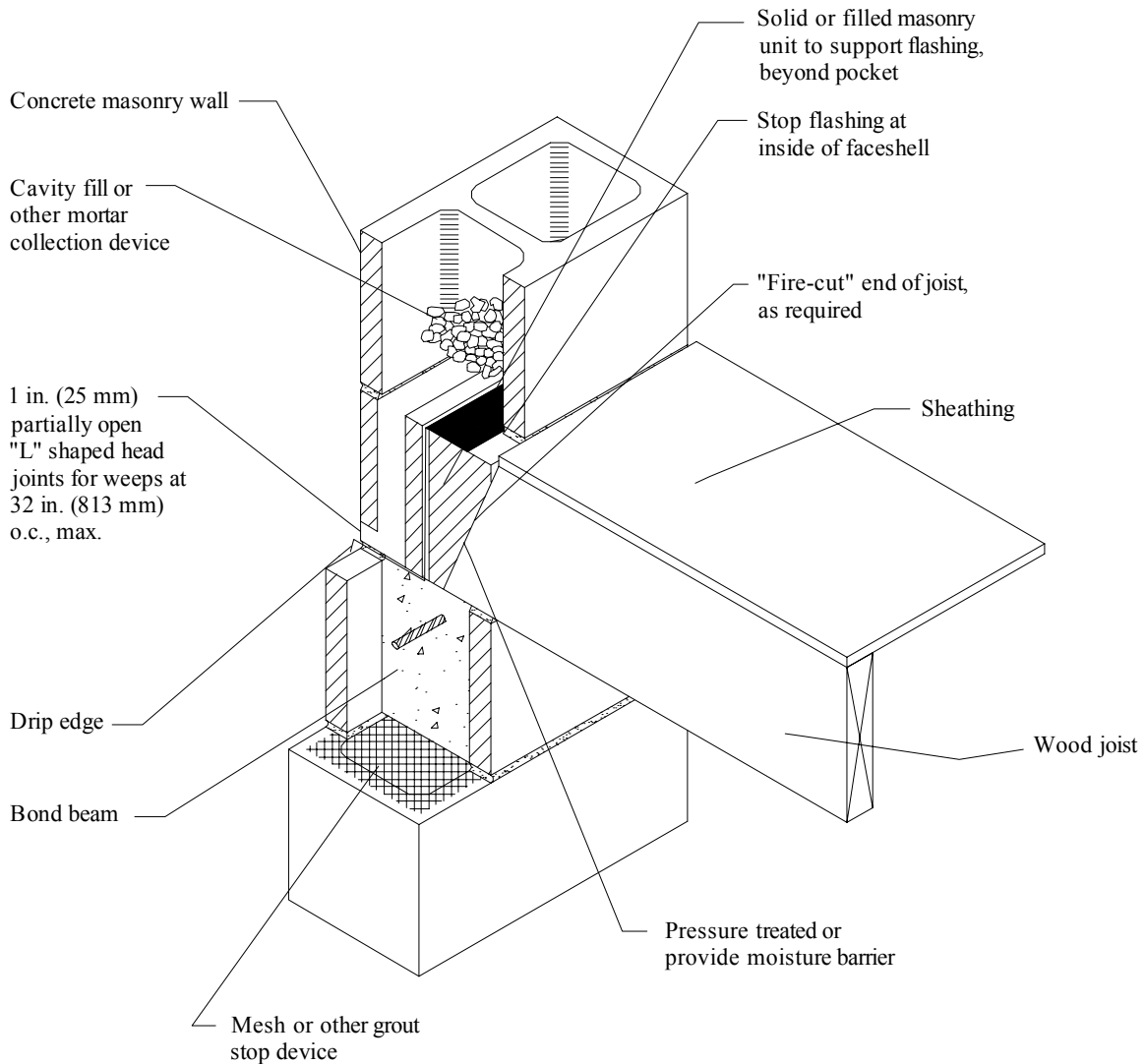
Wood Floor Truss

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



Wood Floor Joist with Pocket

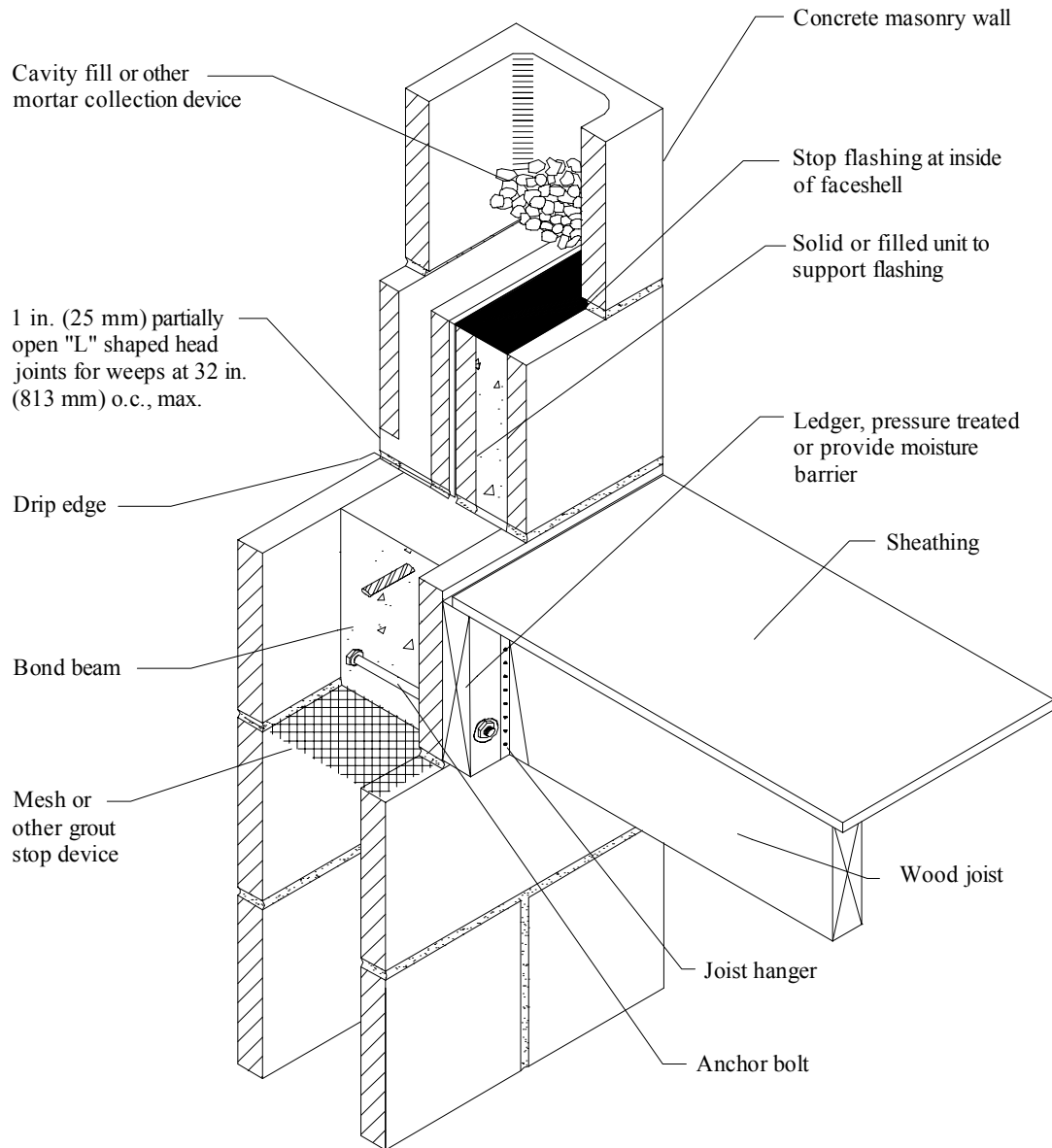
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Wood Ledger and Hanger

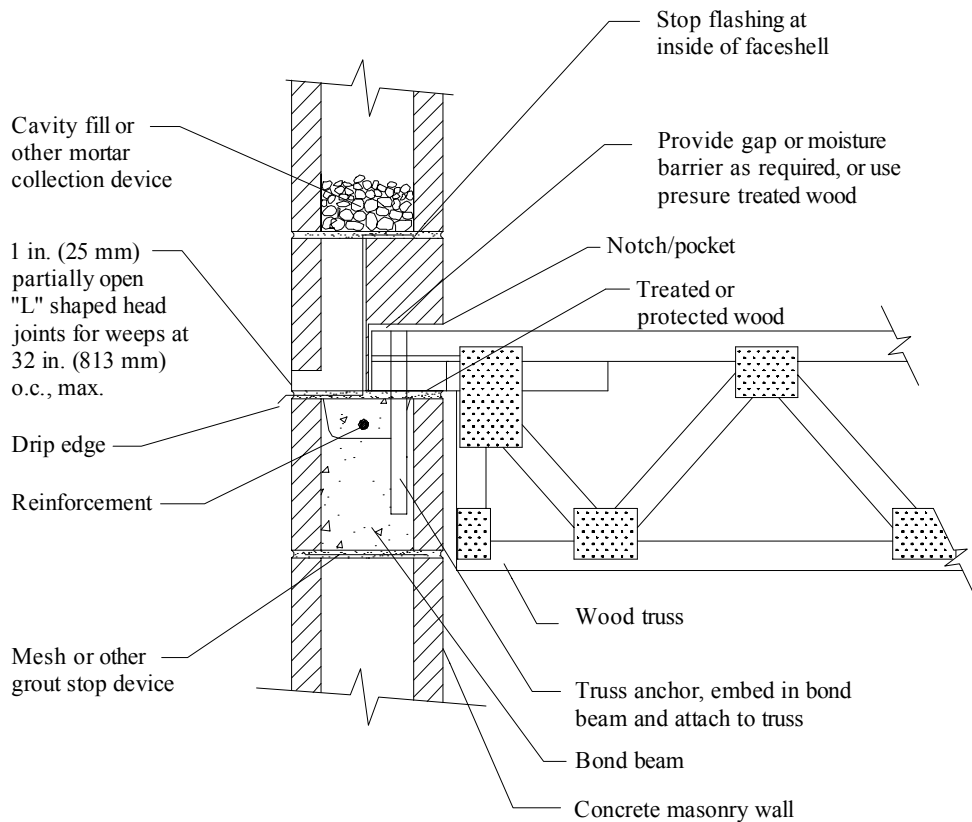
A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



Wood Floor Truss Pocket

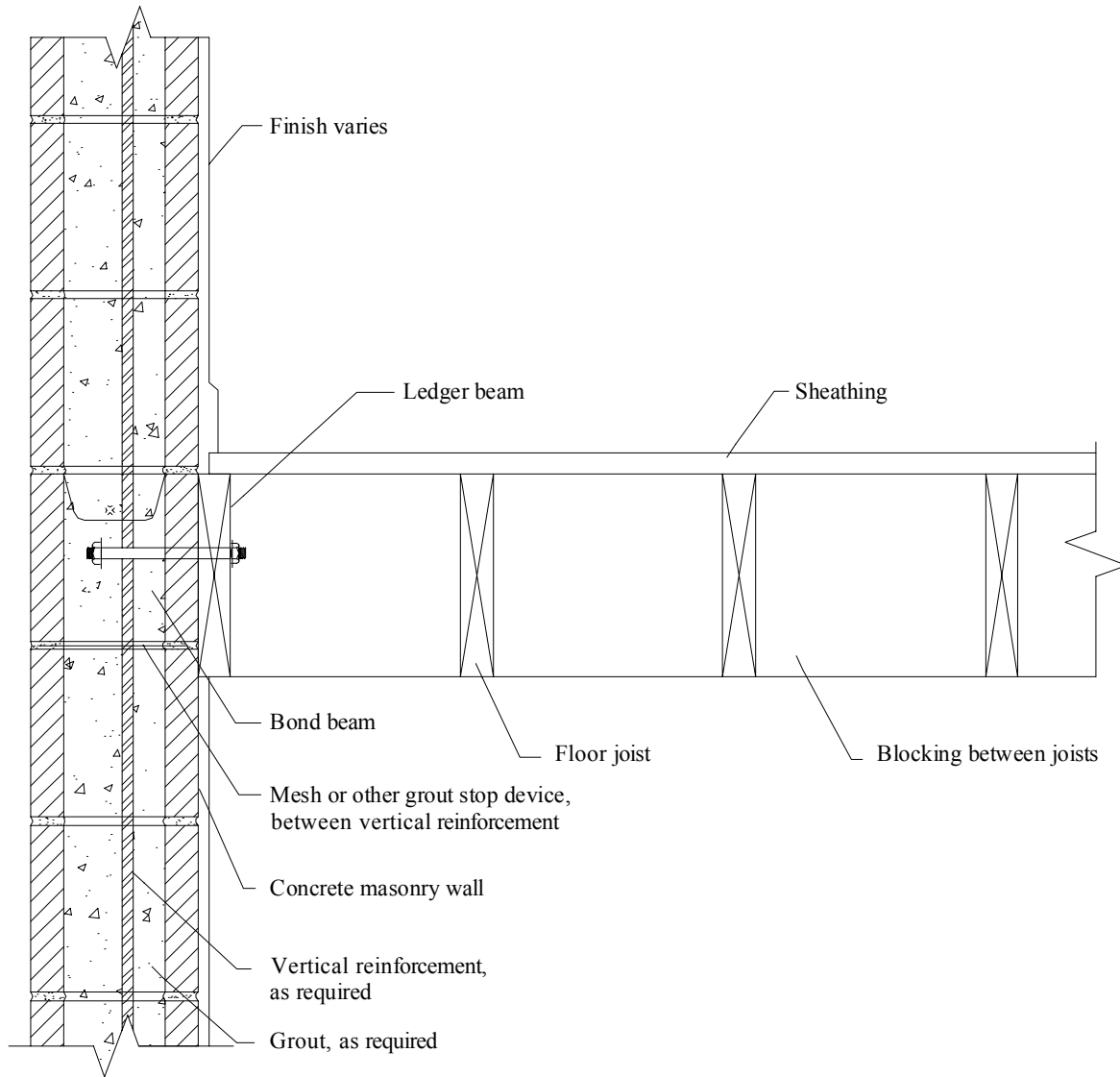
This connection is typically made by building the masonry wall up to the level of the wood truss top cord. After the trusses are placed and anchored, masonry construction continues, with concrete masonry units cut as necessary to accommodate the truss top cord. In some cases, the masonry is constructed first with openings left for the wood trusses. When this method is used, care must be taken to properly locate the openings.

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



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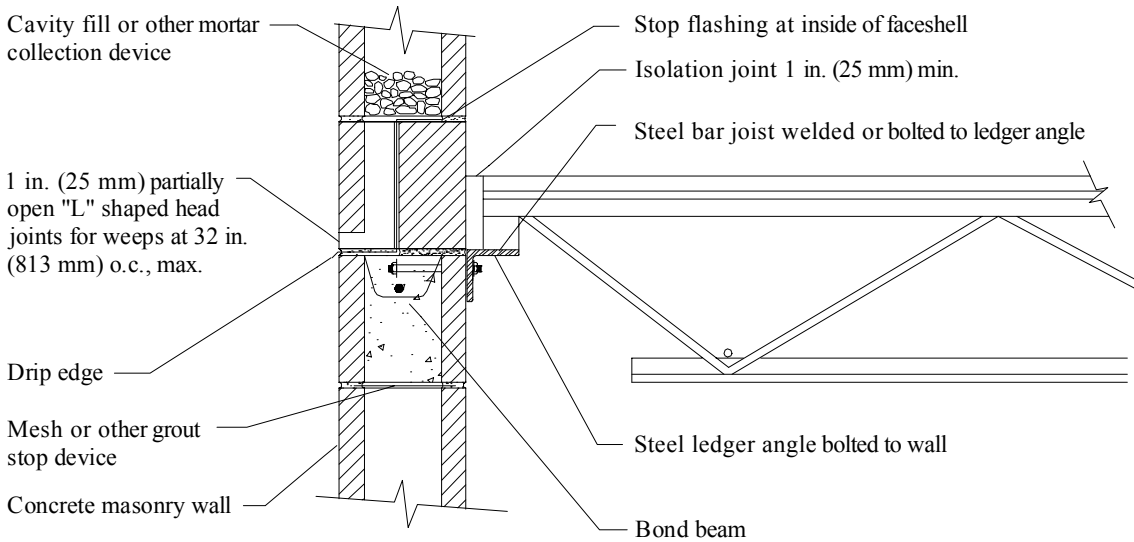
Wood Joist at Sidewall



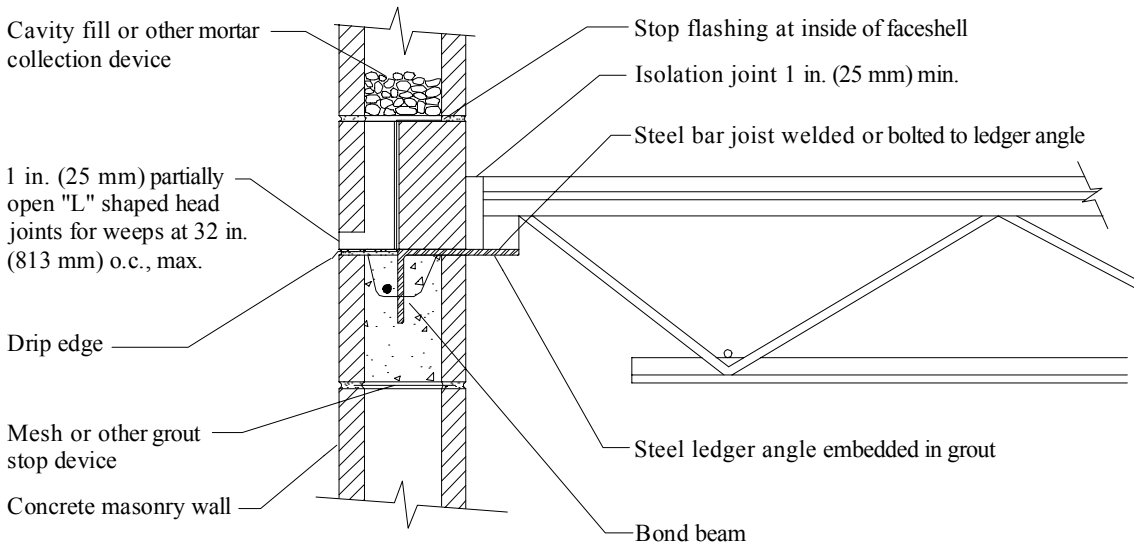
Steel Joist with Ledger Angle

Two alternatives are shown. In (a), the ledger angle is bolted to the exterior of the concrete masonry wall. In (b), the angle is embedded in the concrete masonry bond beam. In both cases, the steel bar joist is either welded or bolted to the angle.

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



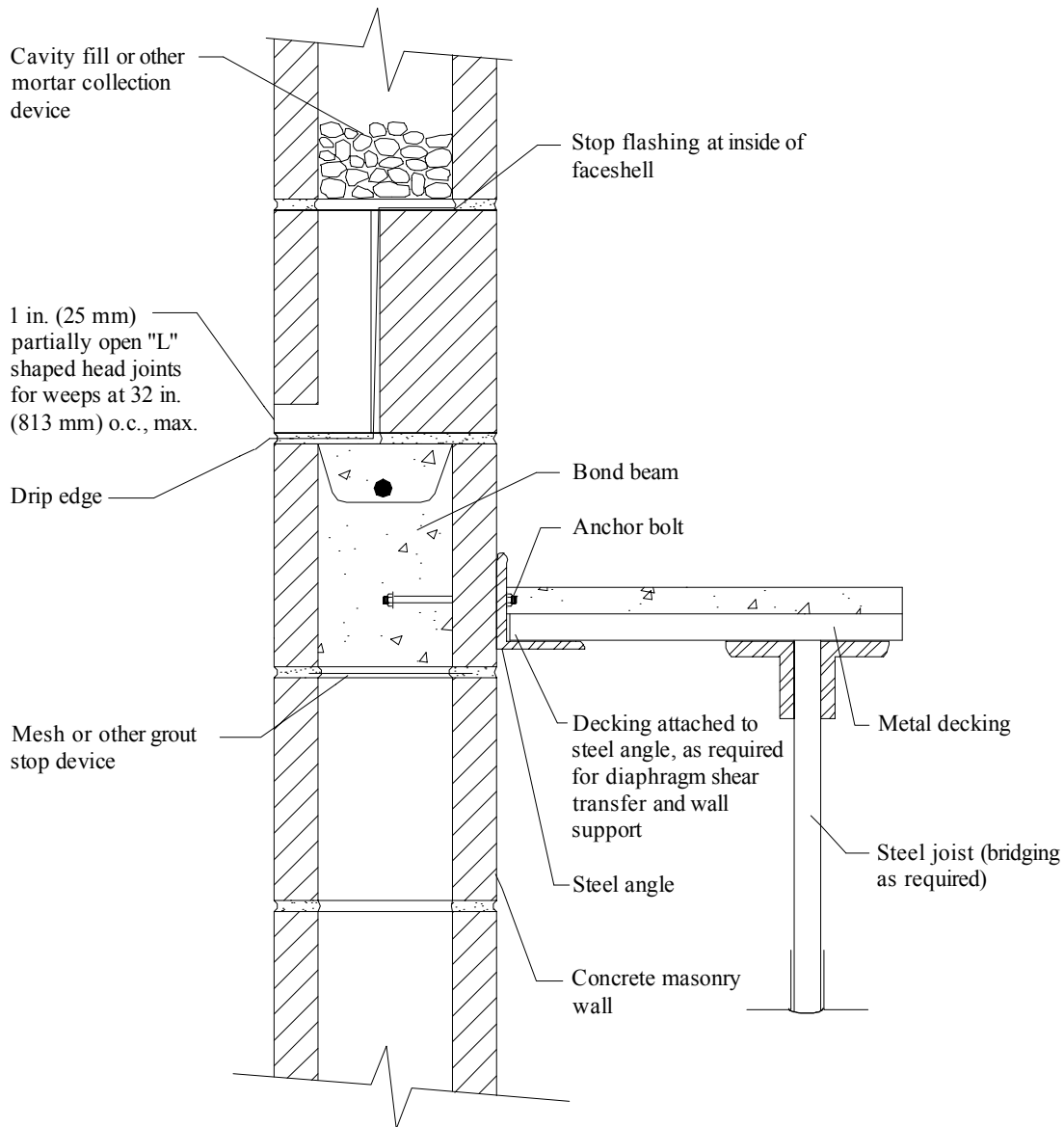
(a) Ledger Angle Bolted to Concrete Masonry



(b) Ledger Angle Embedded in Concrete Masonry

Steel Joist at Sidewall

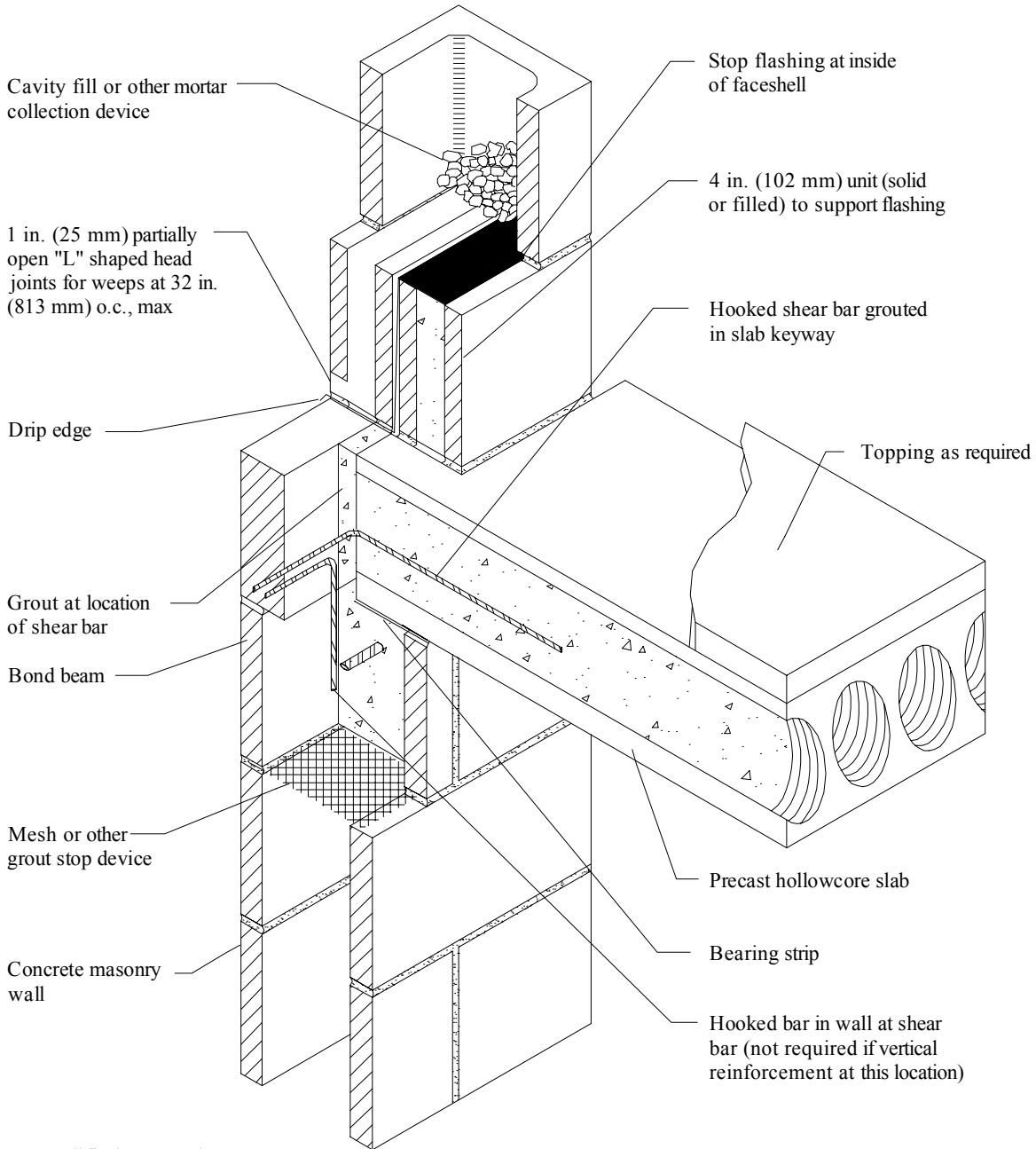
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Last Modified: December, 2002

Concrete Hollowcore at Bearing

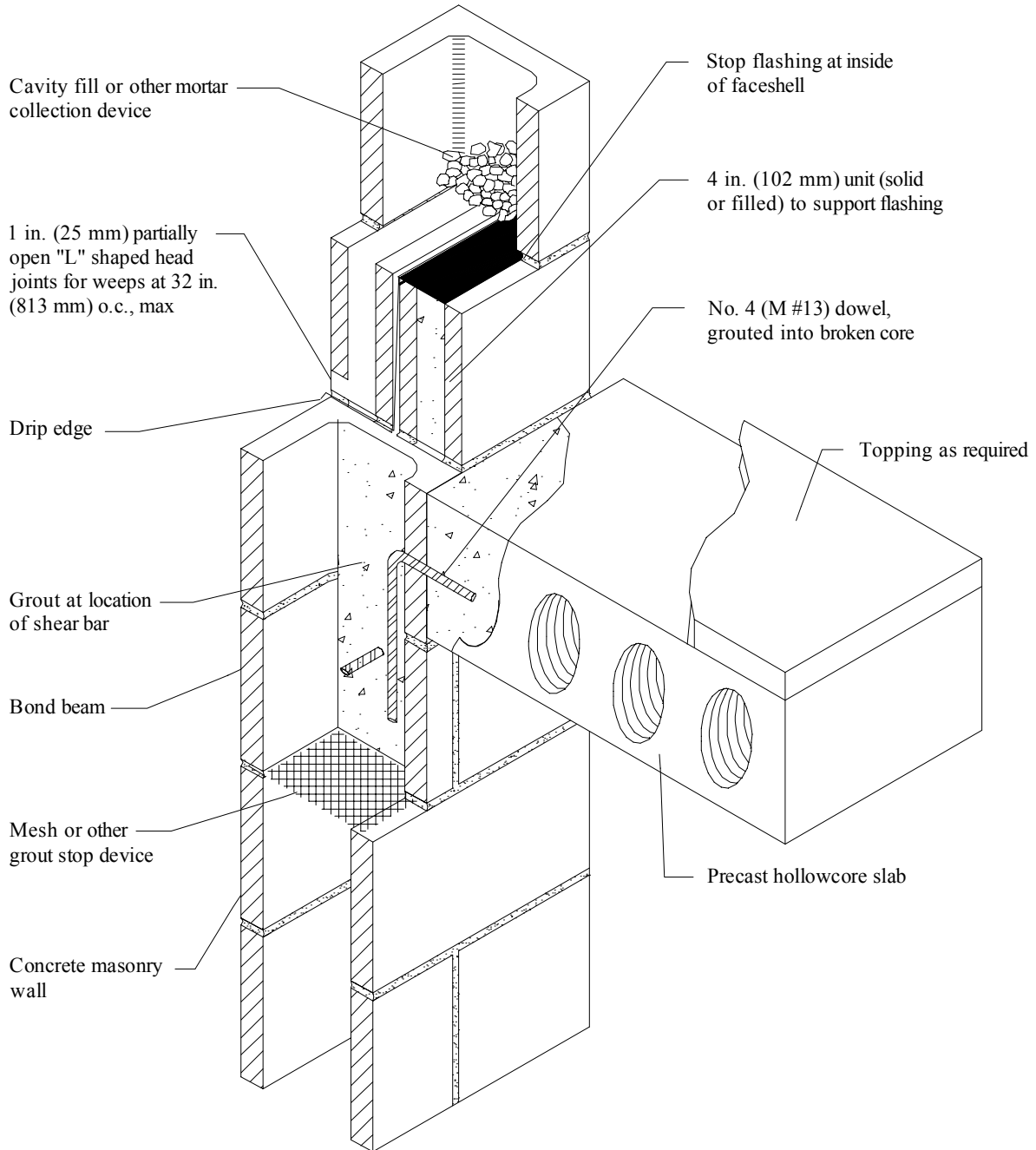
A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells of a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



Last Modified: December, 2002

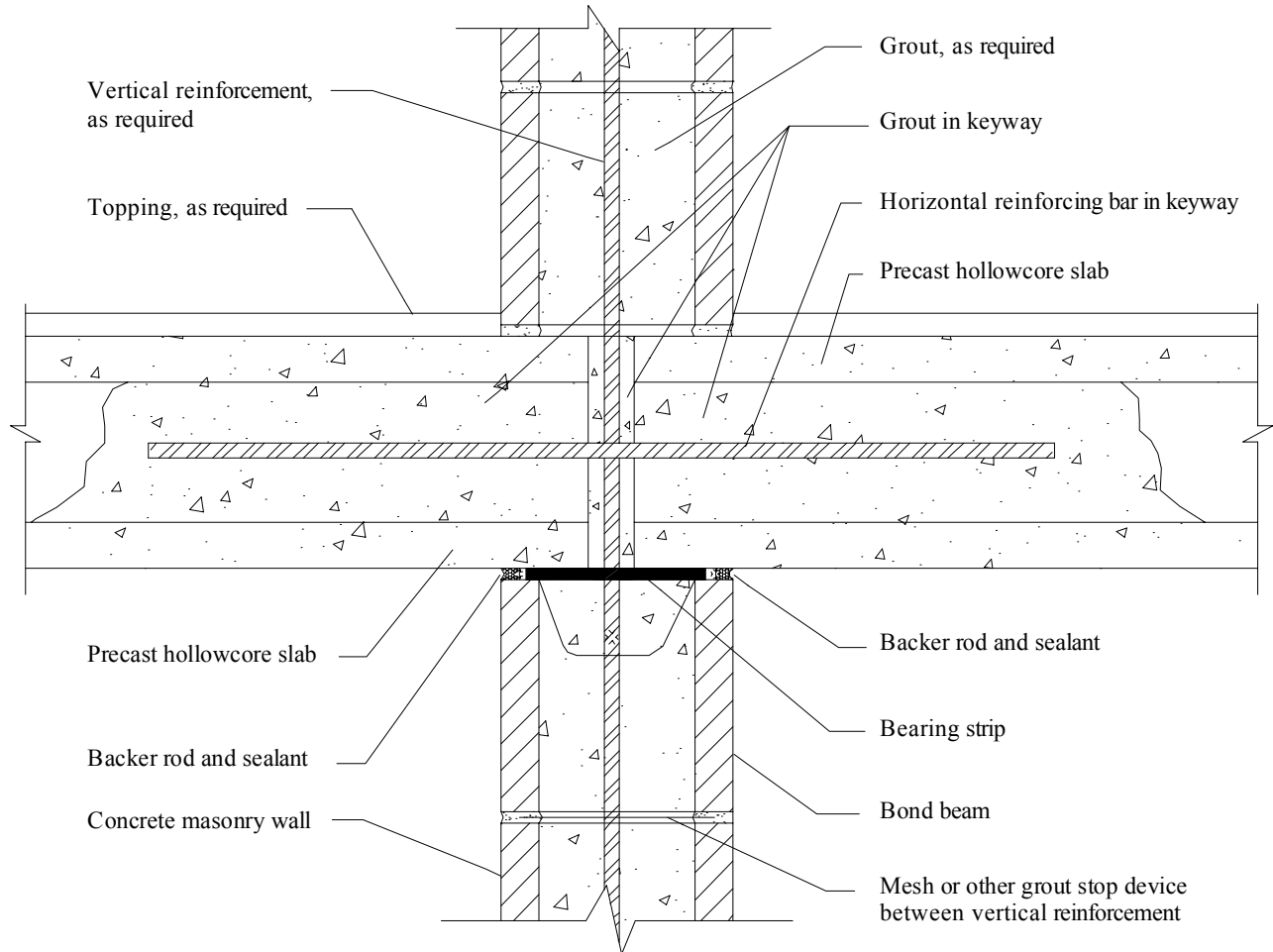
Concrete Hollowcore at Sidewall

A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using mortar nets at regular intervals or filling the cells a few courses at a time as the wall is laid up. As an alternative, every other veneer unit on top of the flashing can be left out to serve as cleanouts until the wall is completed.



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Concrete Hollowcore at Interior Bearing Wall

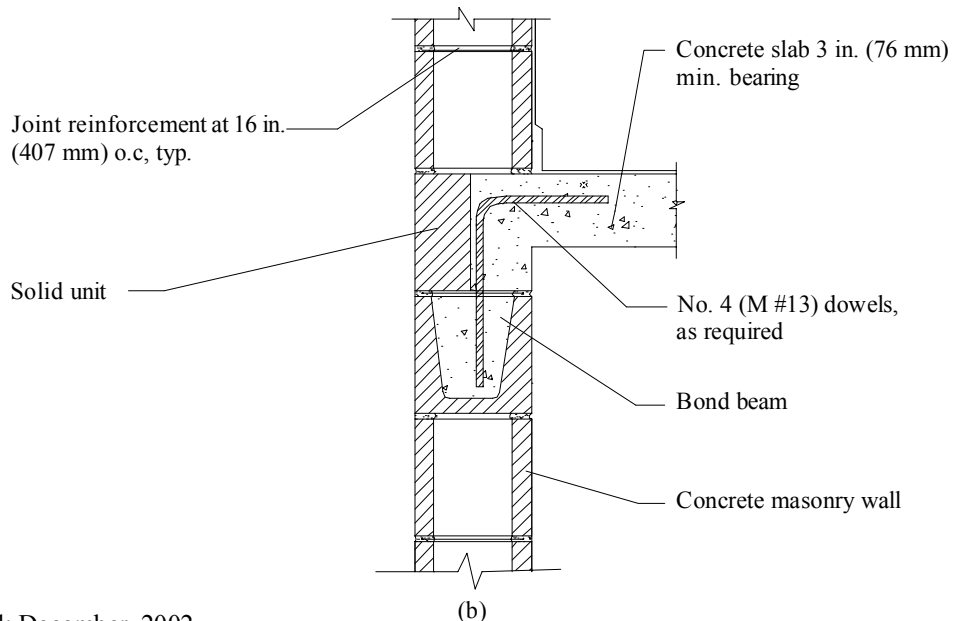
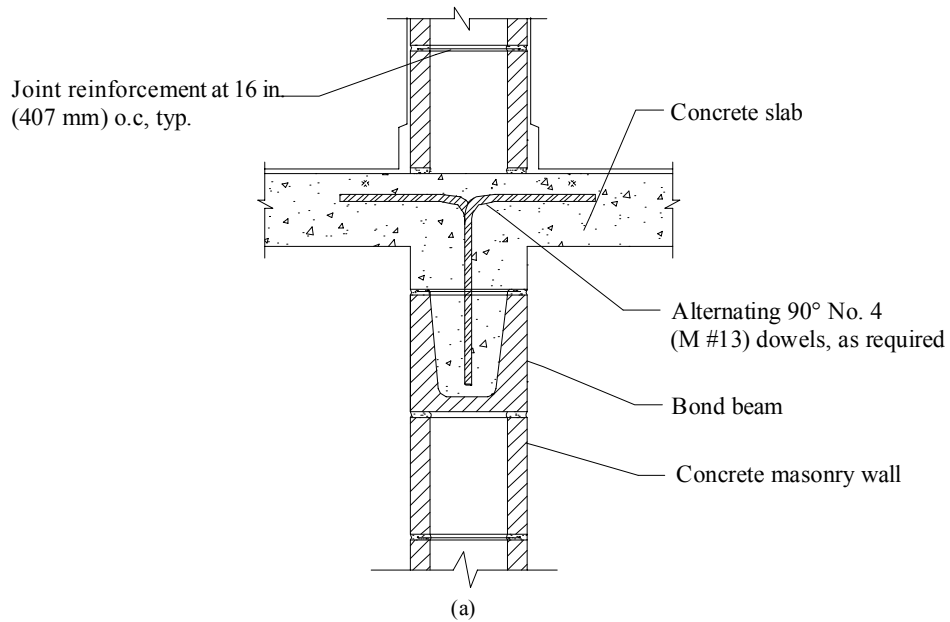


Last Modified: December, 2002

Cast-in-place Concrete Slab to Concrete Masonry Wall

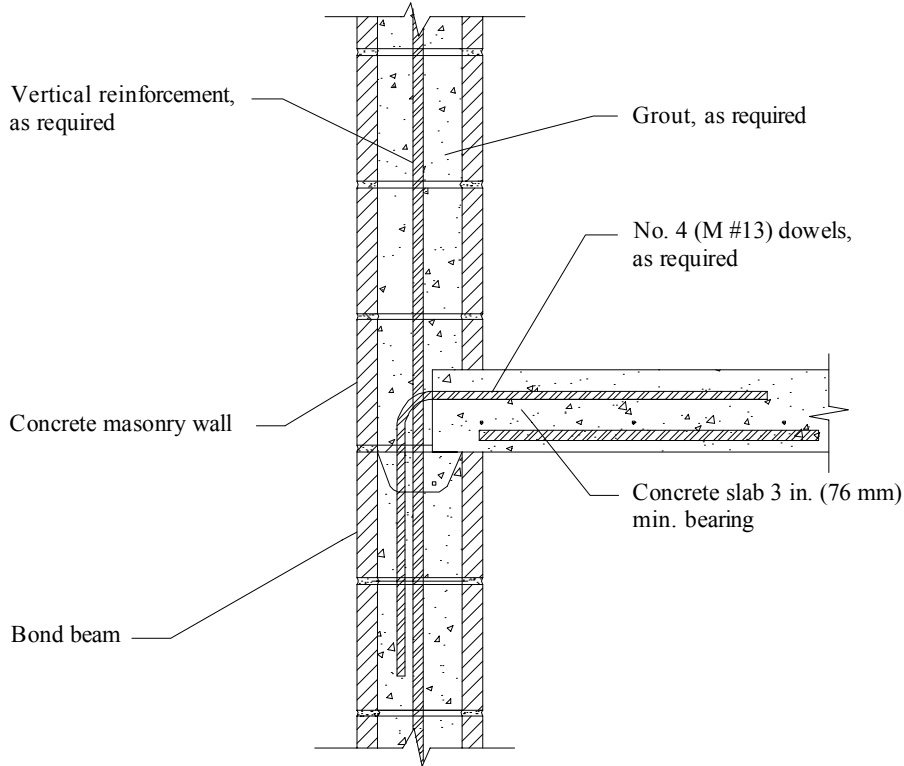
Detail (a) shows an interior concrete masonry wall. Conventional CMU with wire mesh grout stop could be used as an alternative to the bond beam units shown. Details (b), (c) and (d) show alternate methods of bearing concrete floors on exterior concrete masonry walls.

A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or by drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) air space is preferred. As an alternative, proprietary insulating drainage products can be used without the need for a clear air space.

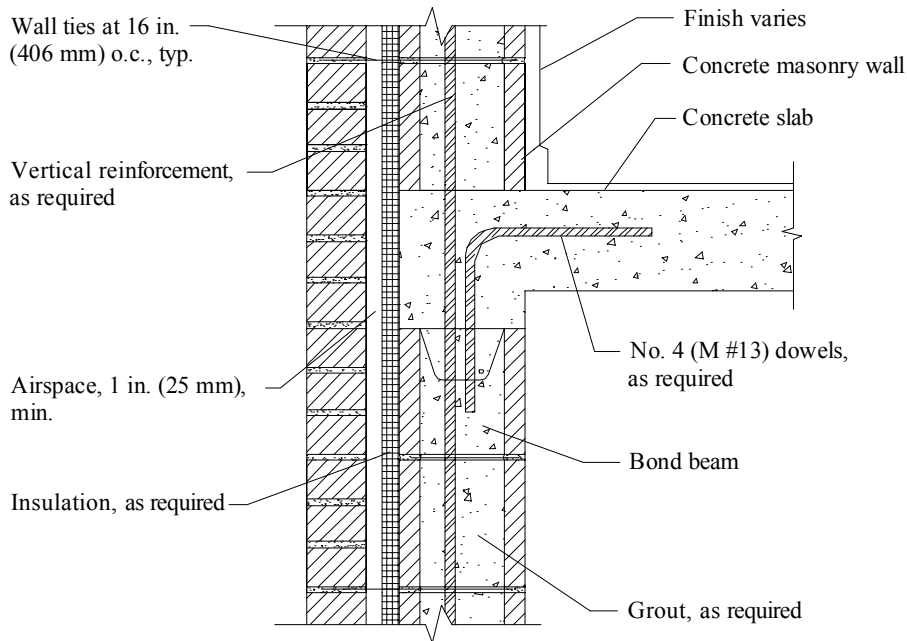


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Cast-in-place Concrete Slab to Concrete Masonry Wall



(c)



(d)

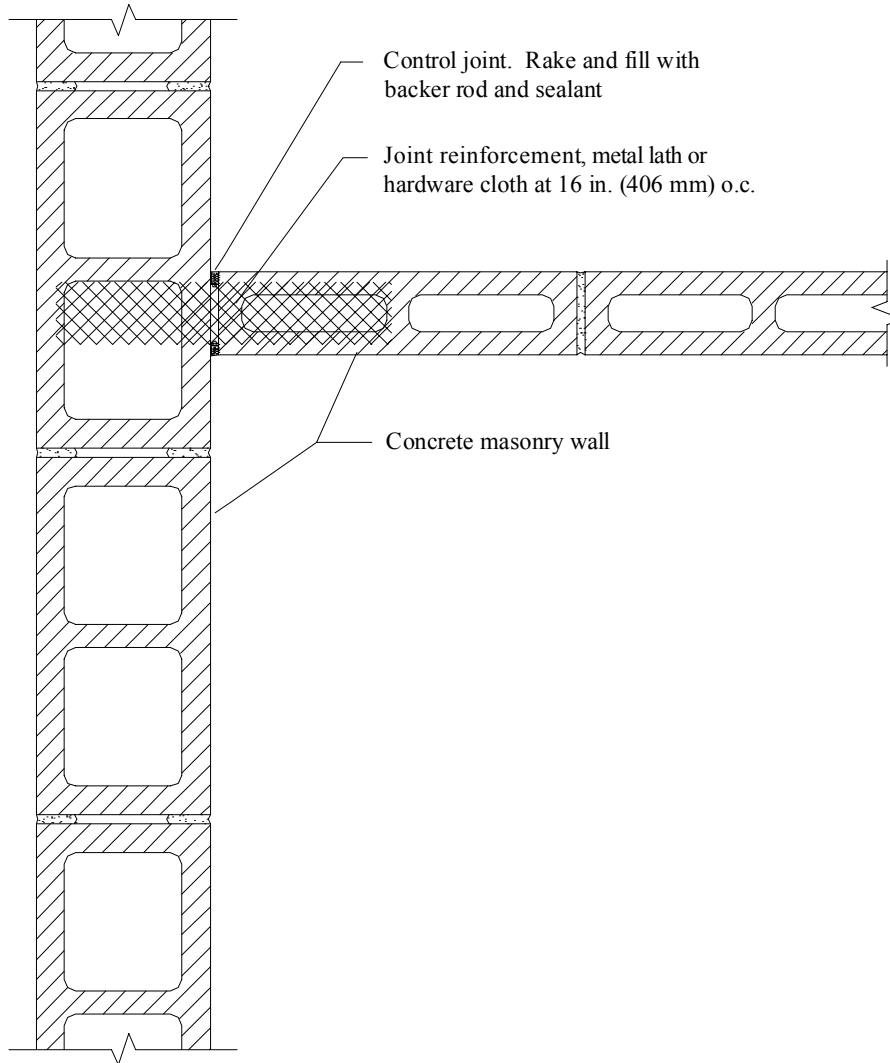
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Section 6C - Wall to Wall

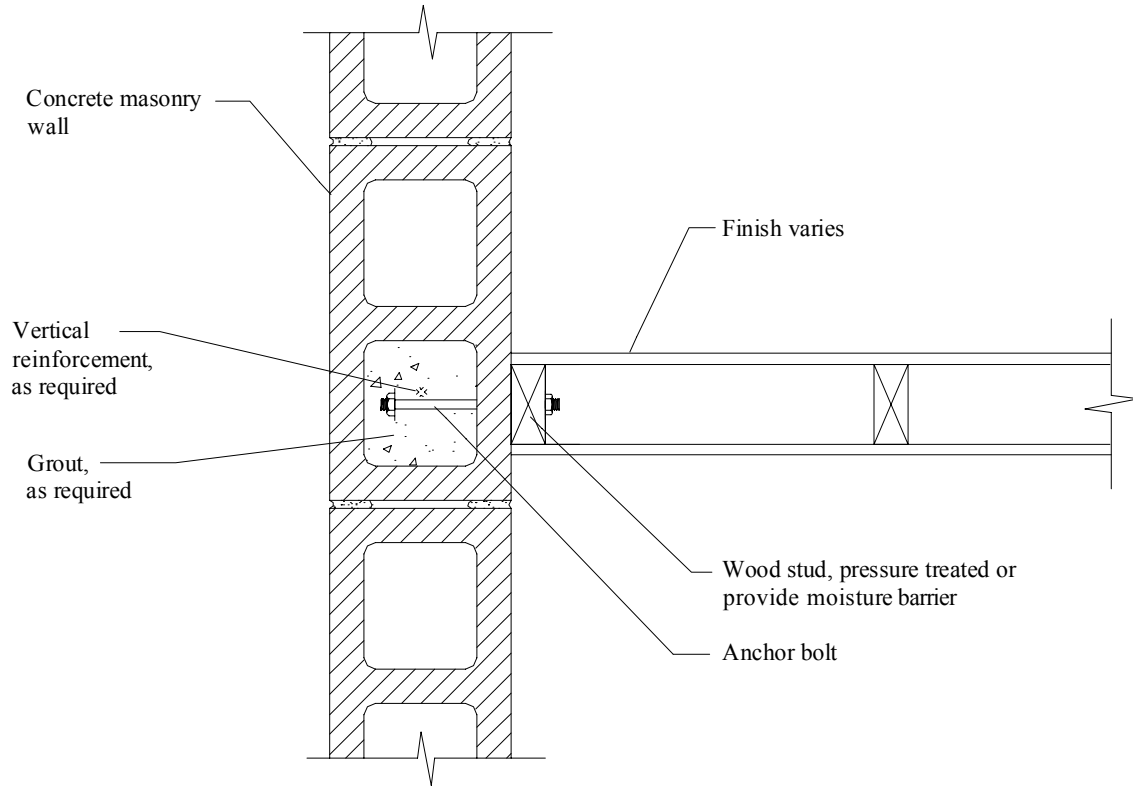
When masonry walls intersect, they must either be connected to ensure adequate shear transfer across the intersection, or they must be constructed such that shear transfer between walls is prevented. When walls are designed to rely on each other for support, the general design requirements of the *Code* include prescriptive criteria for intersecting wall connections to ensure adequate load transfer (see Figure 1E.1). Detail 6C.1 shows an example of where the wall intersection is not designed to transfer load.

Masonry Wall Intersection (No Shear Transfer)

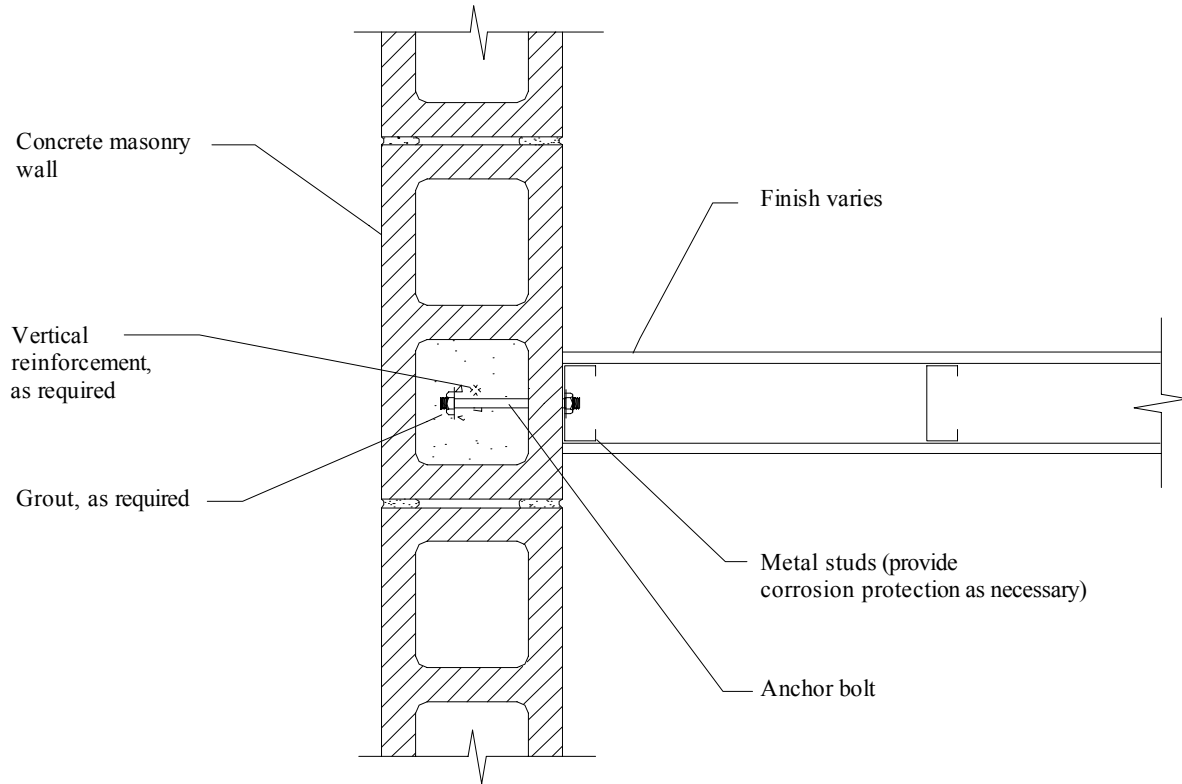
The control joint between walls prevents load transfer. Metal ties, joint reinforcement or hardware cloth is used to provide support at the joint while also allowing for in-plane movement of the cross wall. Figure 1E.1 shows code requirements for masonry wall intersections that allow shear transfer.



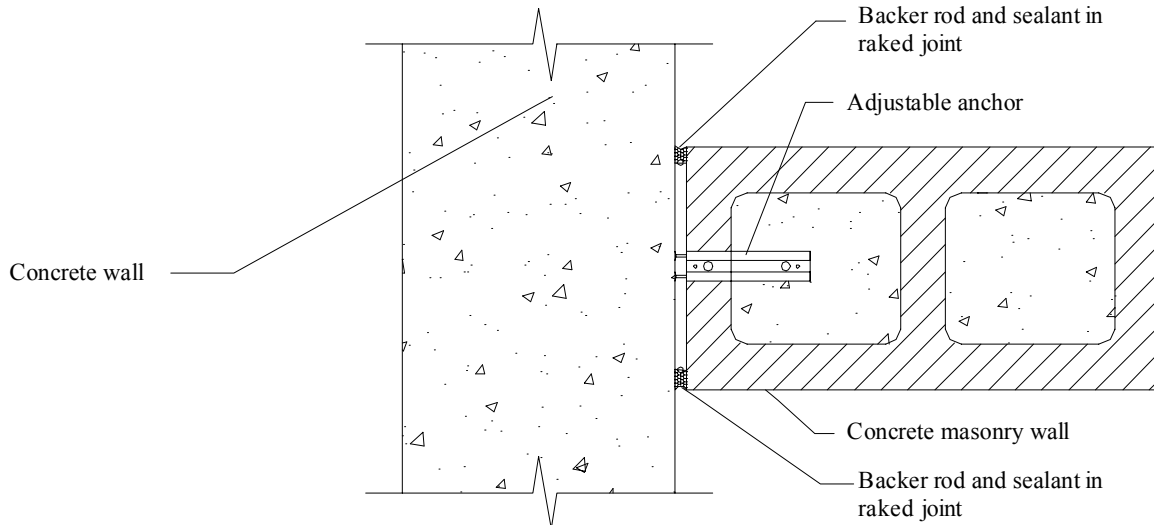
Concrete Masonry/Wood Stud Wall Intersection



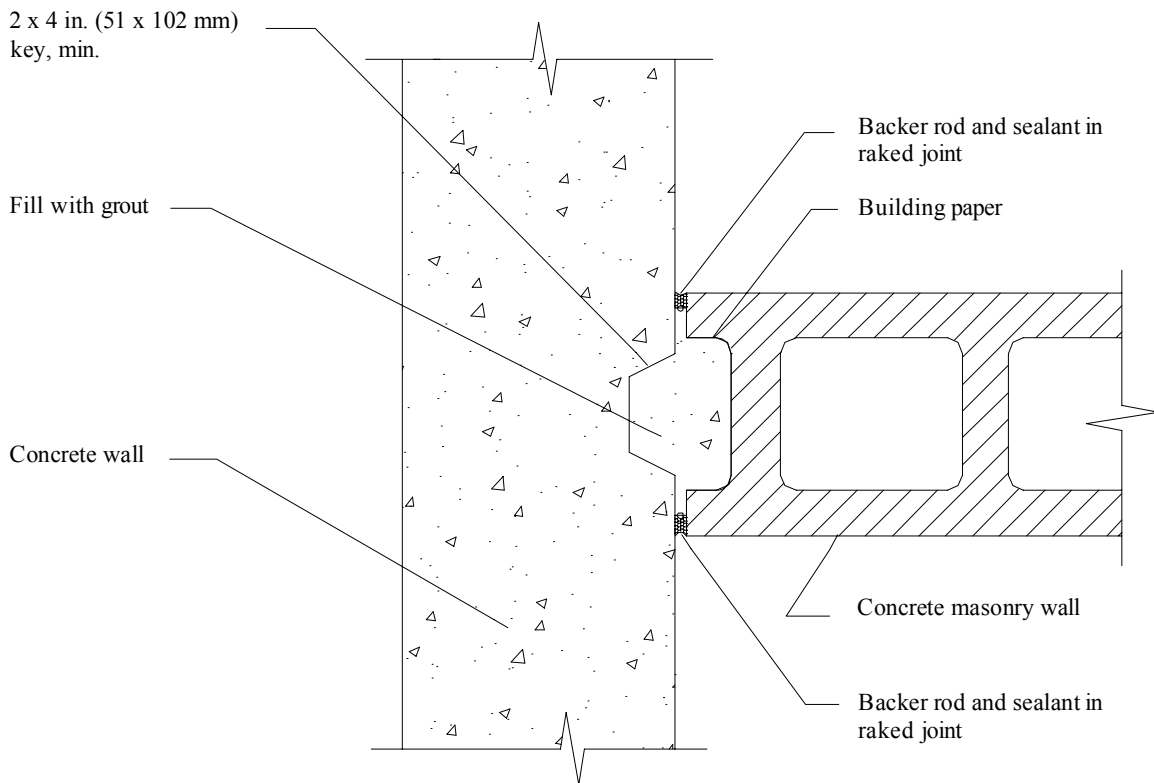
Concrete Masonry/Steel Stud Wall Intersection



Concrete Masonry/Concrete Wall Intersection



(a) Adjustable Anchor



(b) Grouted Keyway

Last Modified: December, 2002

References:

- 6.1 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
- 6.2 *Concrete Masonry Homes: Recommended Practices*. U. S. Department of Housing and Urban Development, Office of Policy Development and research, 1999.
- 6.3 *Generic Wall Design for Single-Wythe Loadbearing Walls*. Masonry Institute of Michigan, 2000.
- 6.4 *Floor and Roof Connections to Concrete Masonry Walls*, TEK 5-7A. National Concrete Masonry Association, 2001.

Chapter 7 — Reinforcement Details

Reinforcement increases the strength and ductility of concrete masonry walls. Reinforcement types include mild steel reinforcing bars and joint reinforcement manufactured from cold-drawn wire (see Section 2F). Prestressing tendons are discussed in Section 3D.

Reinforcing bars are available in the United States in eleven standard bar sizes designated No. 3 through 11, No. 14, and No. 18 (M #10 through M #36, M #45 and M #58), although bars larger than No. 11 (M #36) are not permitted in masonry work. Reinforcing bars must be of the specified diameter, kind and grade to assure compliance with the shop drawings and contract documents. Table 7.1, lists allowable tensile force in Grade 60 reinforcing bars. Steel grade refers to the steel's nominal yield tensile strength in ksi. Grade 60 steel, with a tensile strength of 60 ksi (414 MPa) is the most commonly used, although Grades 40 and 50 may also be available.

Reinforcing steel must also be placed in the proper location to be effective. Building codes and standards require reinforcing steel to be located within certain tolerances. *Specification for Masonry Structures* (Ref. 7.1) governs reinforcement installation to ensure elements are placed as assumed in the design, so that structural performance is not reduced. The requirements also minimize corrosion by providing for a minimum masonry and grout cover around reinforcing bars, and ensure there is sufficient clearance for grout and mortar to surround reinforcement and accessories, so that stresses can be properly transferred (see Section 1E).

Development length or anchorage is necessary to transfer the forces acting on the reinforcement. Reinforcing bars can be anchored by embedment length, hook or mechanical device. Reinforcing bars anchored by embedment length rely on bond and interlock at the deformations along the bar and by ensuring that the masonry cover is sufficient to prevent splitting from the reinforcing bar to the free surface.

Splices ensure continuity in the reinforcement. Reinforcing bars may be spliced using lap, welded, or mechanical splices. *Building Code Requirements for Masonry Structures* (Ref. 7.2) contains requirements for each splice type to ensure adequate load transfer from bar to bar (see Tables 7.2 and 7.3 below). Mechanical splices must be capable of developing at least 125% of the specified yield strength of the bar in tension or compression, as required. This tensile strength requirement ensures sufficient splice strength to avoid brittle failure. Mechanical splices are typically threaded reinforcing bars, joined using couplers designed for this application. Welded splices are accomplished by butting and welding the bars. End bearing splices may be used only for bars required for compression and only in members containing closed ties, closed stirrups or spirals.

Vertical steel may be secured in place before the units are laid, or placed into position after laying is completed. With standard two-core concrete masonry units the mason must lift the units over any protruding reinforcing bars, so placing units is most effective when protruding lap splices are relatively short. Figure 7A.1 shows examples of concrete masonry shapes developed specifically to accommodate reinforcement.

Where reinforced elements intersect, the potential exists for congestion. Reinforcement should be placed such that grout can flow easily between and around all reinforcement to ensure adequate bond with the masonry.

Mud, oil, and other materials which adversely affect bond must be removed from reinforcement. Similarly, heavy rust and mill scale also need to be removed. Light rust, mill scale or a combination of both need not be removed, provided the dimensions and weights (including heights of deformations) of a cleaned sample are not less than those required by the ASTM specification for the reinforcement.

Reinforcement details for seismic and high wind applications are shown in Chapter 8. Reinforcement requirements for columns are shown in Figure 1E.11.

Table 7.1 - Allowable Tensile Force for Grade 60 Reinforcing Bars

Bar size, No.	Allowable tensile force, lb (kN)
3 (M #10)	2,640 (11.7)
4 (M #13)	4,800 (21.3)
5 (M #16)	7,440 (33.0)
6 (M #19)	10,560 (46.9)
7 (M #22)	14,400 (64.0)
8 (M #25)	18,960 (84.3)
9 (M #29)	24,000(106.0)

Table 7.2 - Allowable Stress Design Lap Splice Length Requirements ^a

Bar size, No.	Maximum transverse distance between lapped bars, in. (mm)	Minimum lap splice length ^b , in. (mm)
3 (M #10)	3.6 (91)	18 (457)
4 (M #13)	4.8(122)	24 (610)
5 (M #16)	6.0(152)	30 (762)
6 (M #19)	7.2(183)	36 (914)
7 (M #22)	8.0(203)	42 (1,067)
8 (M #25)	8.0(203)	48 (1,219)
9 (M #29)	8.0(203)	54 (1,372)

a Based on requirements for Grade 60 reinforcing steel. Increase these minimum lap splice lengths by 50 % when using epoxy-coated reinforcing bars.
b $l_d = 0.002d_b F_s$ (metric: $l_d = 0.29d_b F_s$)

Table 7.3 - Strength Design Lap Splice Length Requirements ^a

Bar size	Minimum lap splice length ^b , in. (mm) based on $K^c =$		
	$5d_b$	1.5 in. (38 mm)	2 in. (51 mm)
No. 3 (M #10)	19 (480)	24 (600)	18 (450)
No. 4 (M #13)	25 (639)	42 (1,066)	32 (799)
No. 5 (M #16)	32 (799)	66 (1,665)	49 (1,249)
No. 6 (M #19)	53 (1,342)	132 (3,357)	99 (2,518)
No. 7 (M #22)	62 (1,567)	180 (4,569)	135 (3,427)
No. 8 (M #25)	76 (1,918)	252 (6,394)	189 (4,796)
No. 9 (M #29)	85 (2,164)	320 (8,136)	240 (6,102)

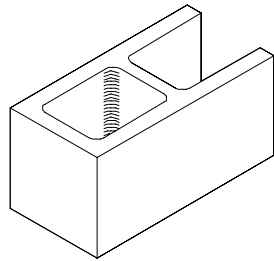
a Based on Grade 60 reinforcing bars, $f_m' = 1,500$ psi (MPa).
b $l_d = 0.13 d_b^2 f_s / K (f_m')^{1/2} / \phi$ (metric: $l_d = 1.5 d_b^2 f_s / K (f_m')^{1/2} / \phi$)
c K = the least of the least of the masonry cover, the clear spacing between adjacent reinforcement and $5 d_b$

Last Modified: December, 2002

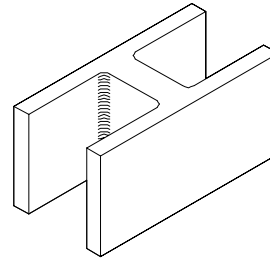
Special Unit Shapes

The concrete masonry unit shapes shown below have been developed specifically to accommodate reinforced construction. Units with one or two open ends can be placed around vertical reinforcing bars, eliminating the need to lift units over the tops of bars or threading the reinforcement through the masonry cores after the wall is constructed.

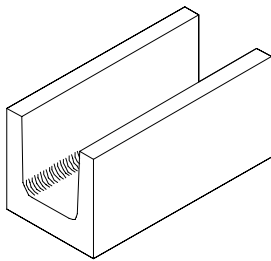
Bond beams can be accommodated either by saw-cutting standard units or by using bond beam units. Bond beam units are manufactured with reduced-height webs or with "knock-out" webs which are removed prior to placement in the wall. Lintel units are available in various depths to carry appropriate lintel loads over door and window openings. The solid bottom confines grout to the lintel.



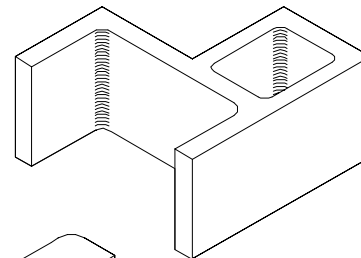
Open End, or "A" Shaped Unit



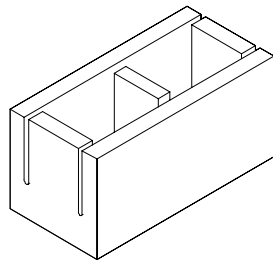
Double Open End or "H" Shaped Unit



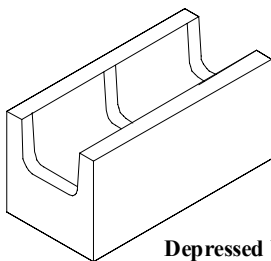
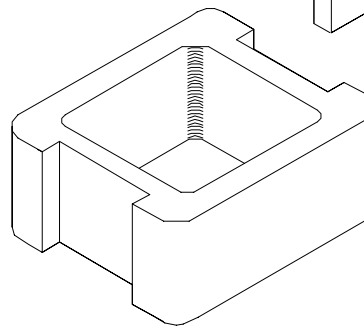
Lintel Unit



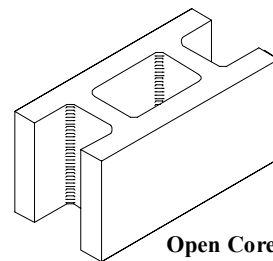
Pilaster Units



Knock-Out Bond Beam Unit



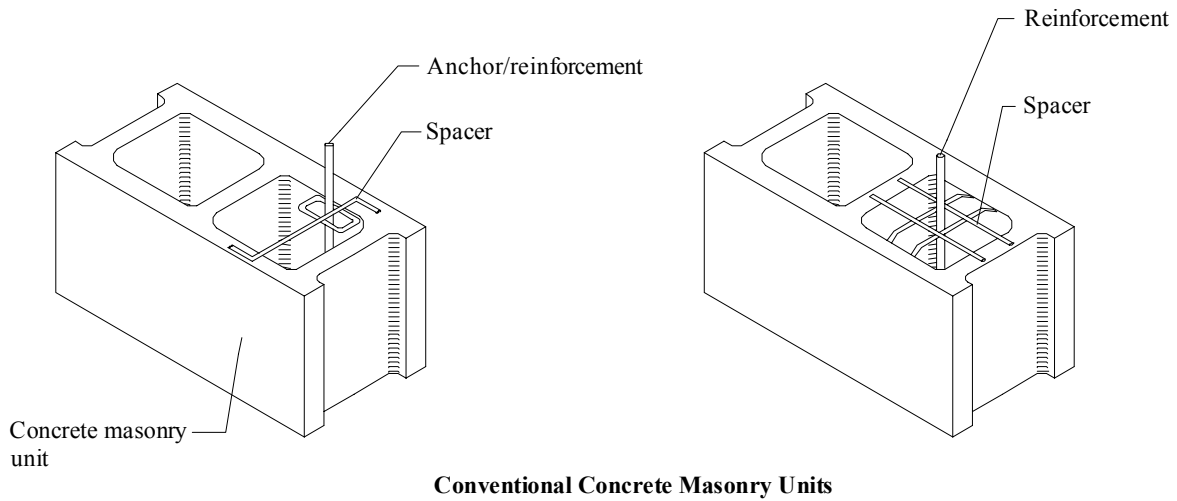
Depressed Web Bond Beam Unit



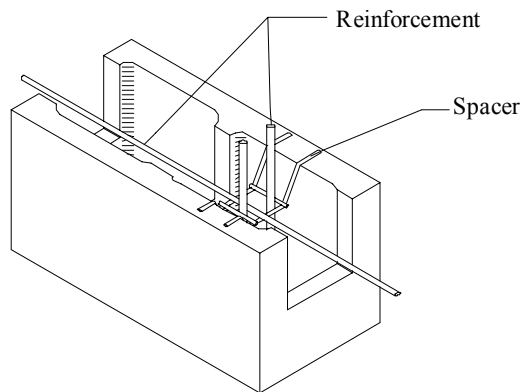
Open Core Unit

Bar Positioners

When steel is placed after wall erection, steel spacers or bar positioners may be used to accurately keep horizontal and vertical reinforcement in place to prevent displacement during grouting, which could impact structural performance.



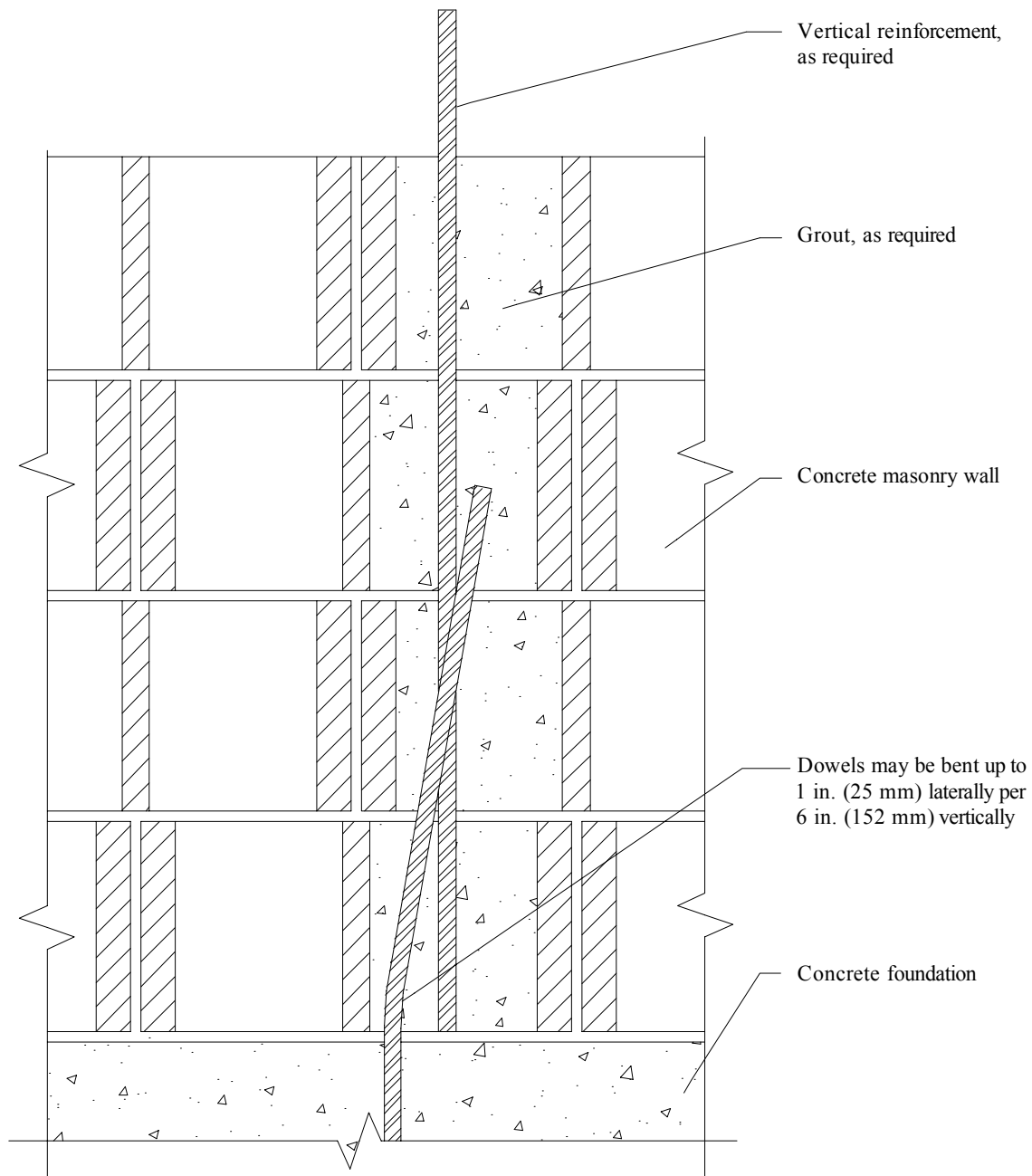
Conventional Concrete Masonry Units



Bond Beam Unit

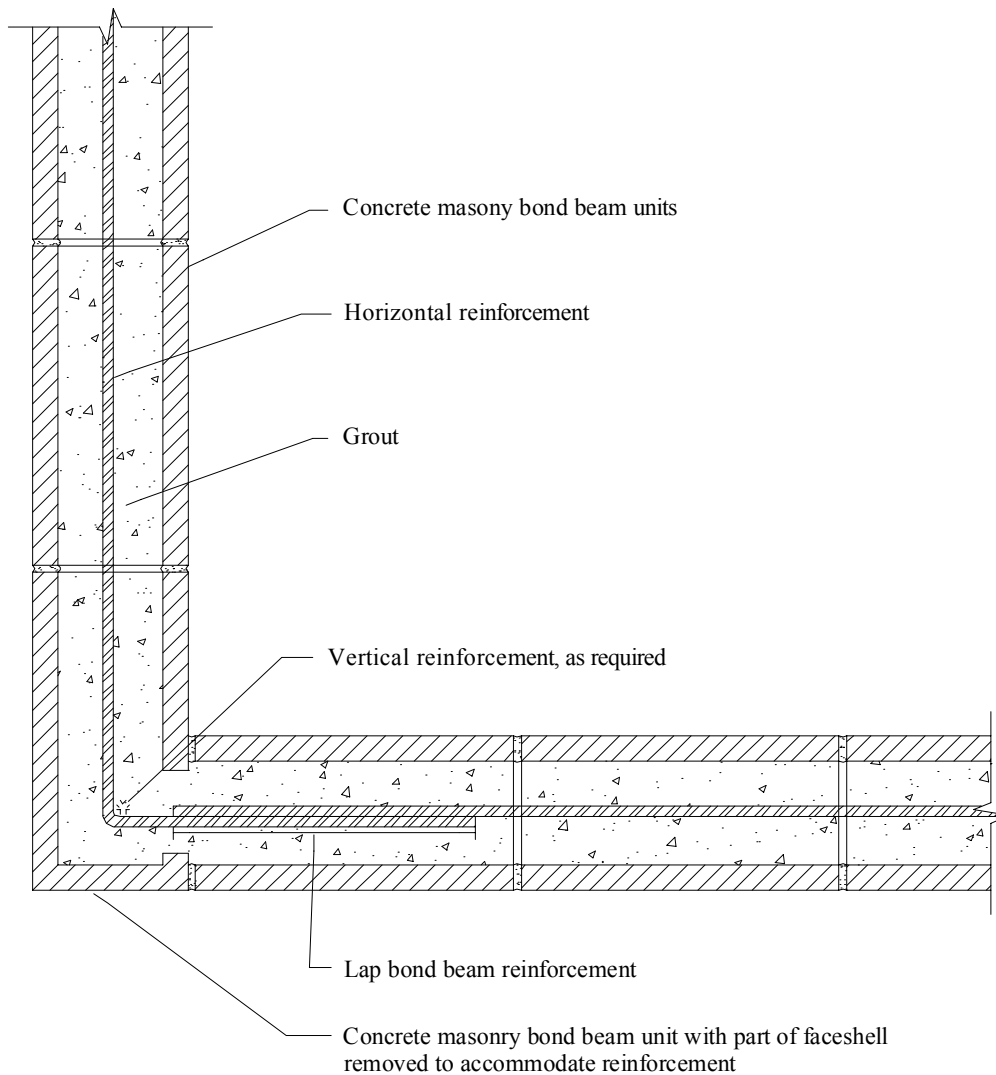
Foundation Dowel Alignment

Improperly located foundation dowels may be bent to align with vertical masonry cores. Concrete column dowel bars that are out of position are permitted to be bent 1 inch (25 mm) laterally for each 6 inches (152 mm) of bar protruding from the foundation (Ref. 7.3).



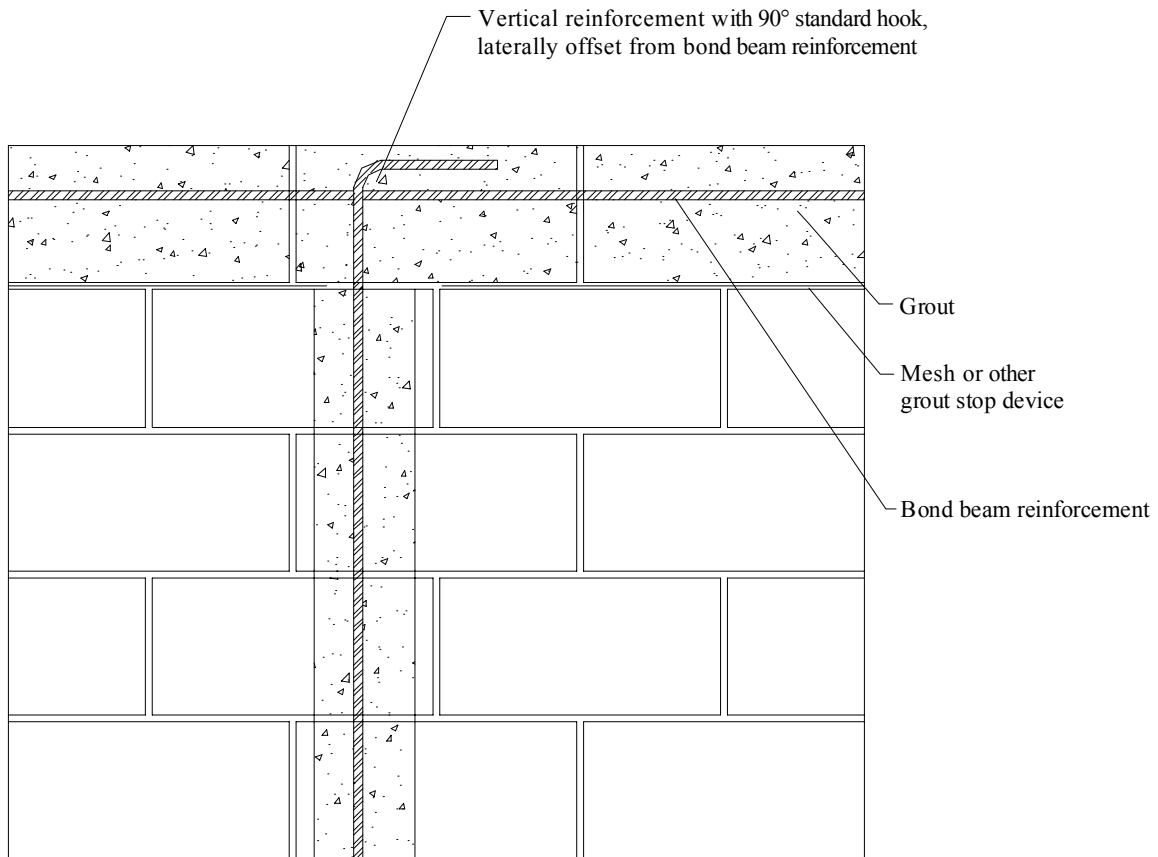
Corner with Continuous Vertical and Bond Beam Reinforcement

Splicing reinforcing bars at the corner provides continuity. When the bond beams contain two layers of reinforcement, the bottom layer should be lapped in one wall, and the top layer lapped in the other wall. When the bond beam contains two reinforcing bars at the same elevation, only one of the two is typically lapped around the corner. As an alternative to using bond beam units as shown, standard units can be saw-cut to remove part of the cross-webs to accommodate the horizontal reinforcement.



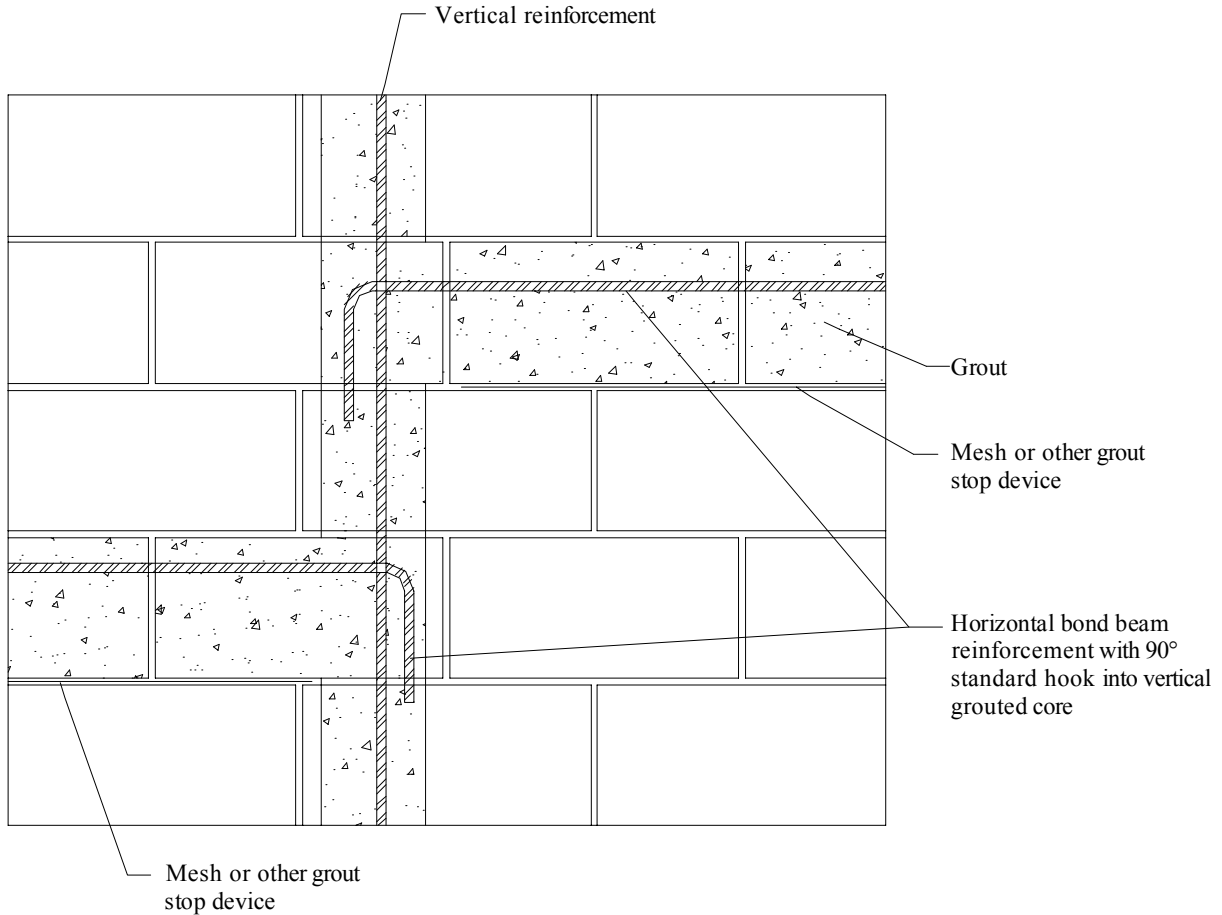
Intersection of Vertical and Bond Beam Reinforcement at Top of Wall for Uplift Resistance

The ninety-degree standard hook in the vertical reinforcement provides uplift resistance. For applications with little or no net uplift, the hook is not required. See Figure 1E.5 for standard hook requirements.



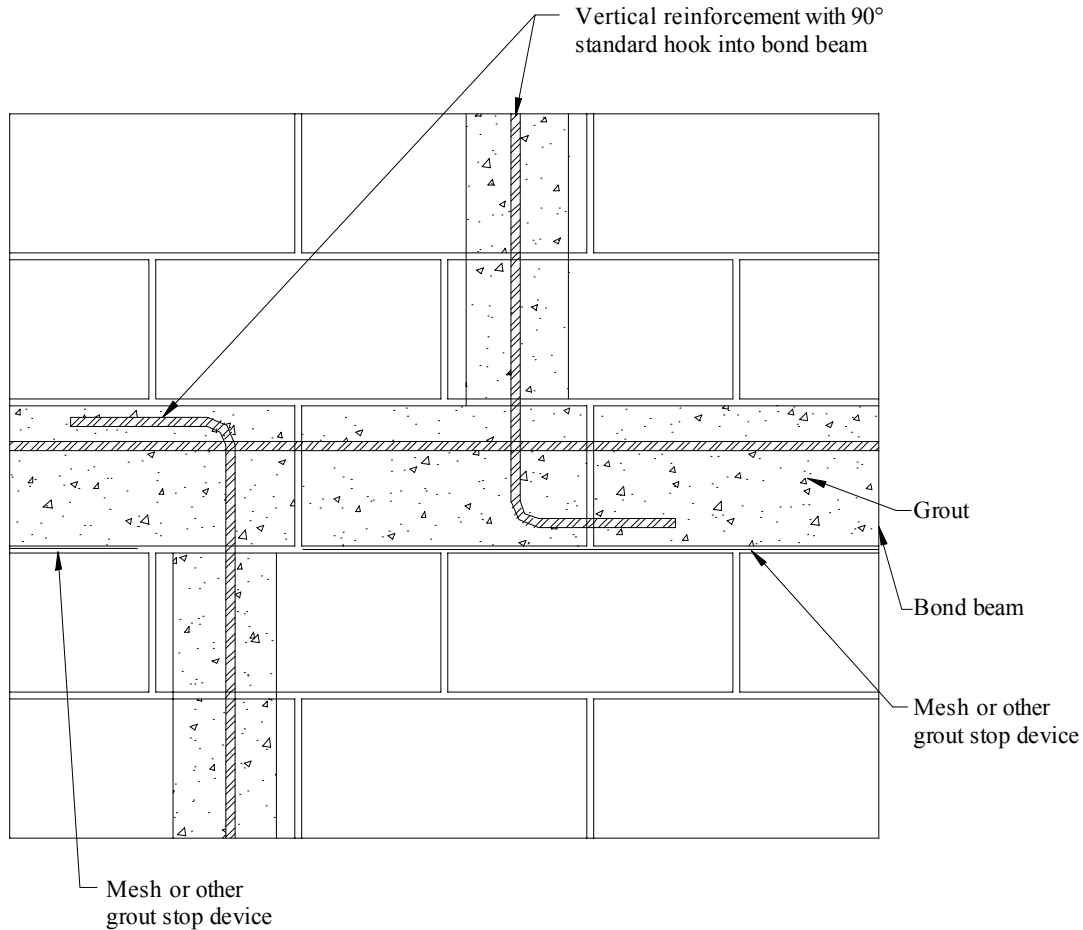
Changing Bond Beam Height

When bond beam height must be changed within a wall, such as to accommodate openings or a change in building height, the following detail helps ensure structural continuity. See Figure 1E.5 for standard hook requirements.



Changing Vertical Reinforcement Location

Between stories, it is preferable to carry vertical reinforcement through in the same vertical core of masonry. When the bars must be offset, such as to accommodate openings, the detail below can be used to help ensure structural continuity. In this detail, the vertical bars are anchored into the bond beam. See Figure 1E.5 for standard hook requirements.



References:

- 7.1 *Specification for Masonry Structures*, ACI 530.1-02/ASCE 6-02/TMS 602-02. Reported by the Masonry Standards Joint Committee, 2002.
- 7.2 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
- 7.3 *Building Code Requirements for Structural Concrete*, ACI 318-02. American Concrete Institute, 2002.

Chapter 8—Details for Earthquake and Wind Resistance

Buildings designed to withstand earthquakes or high winds rely on proper detailing to ensure that the associated loads can be adequately distributed throughout the structure, and ultimately into the ground. Connections between elements are critical to ensuring the structure remains intact during an earthquake, hurricane or other event. In many cases, connection details for earthquake or wind design will differ from conventional connection details (see Chapter 6) only in the number, size or spacing of anchor bolts or other connectors.

One primary goal for buildings subjected to earthquake forces or high winds is to maintain a continuous load path from the roof to the foundation. This allows the structural forces to be safely distributed through the walls to the foundation, where they are dissipated into the ground. If one part of the load path fails, or is discontinuous, building failure may occur. Proper detailing and installation of the mechanical connectors is necessary to maintain this continuous load path.

The concept of the continuous load path requires not only that individual elements are tied together, but also that loads are easily transferred from one element to another - a continuous link is needed from the roof line to the foundation through the sill or bearing plate to the masonry and finally to the footing. This is most directly accomplished by placing the various connections in a direct line from the roof to the foundation. For example, when considering a typical wall elevation, the roof to wall connection should be directly above the wall to foundation connection. When structural elements must be offset, reinforcement should be detailed such that it is structurally continuous, as shown in Chapter 7.

8A — Earthquake Details

During an earthquake, the earth moves randomly, subjecting buildings to both vertical and horizontal movements. Because buildings are designed to handle primarily vertical loading, the vertical movement due to an earthquake is typically accommodated by conventional design. In seismic design, additional horizontal loading imparted during an earthquake must also be accounted for.

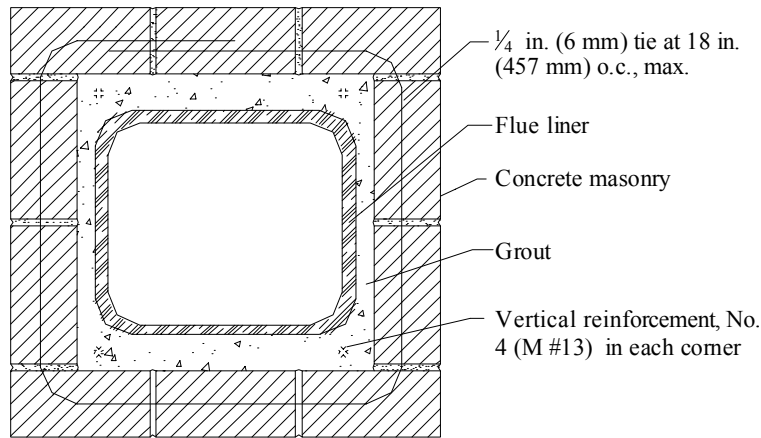
In areas of low seismic risk, the non-seismic design provisions of *Building Code Requirements for Masonry Structures* provide for adequate masonry performance. The one additional seismic requirement is that masonry walls must be adequately anchored to the roof and all floors providing lateral support for the wall. Structures assigned to Seismic Design Categories C, D, E or F must meet additional minimum levels of reinforcement and detailing. Prescriptive minimum reinforcement requirements, as well as seismic requirements for masonry veneers are covered in Section 1E.

Chimney Vertical Reinforcement and Ties

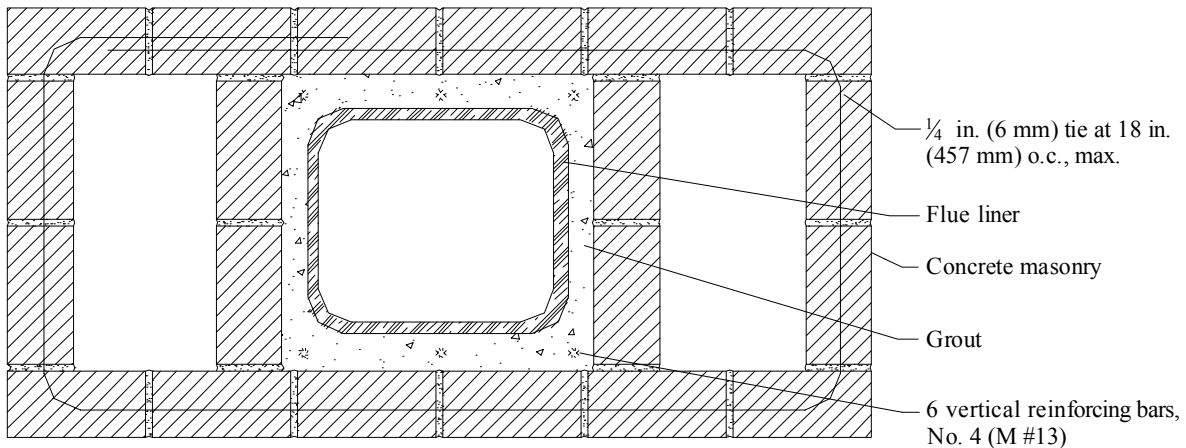
Masonry chimneys perform best when built monolithically with masonry buildings. When attached to wood frame structures, reinforcement and anchorage to the structure improve the chimney's earthquake resistance. This detail shows minimum vertical and joint reinforcement applicable in Seismic Design Category (SDC) D (Ref. 8.7). Chimneys in SDCs A, B and C do not require reinforcement and seismic anchorage.

In addition to placing ties along the height of the chimney, locate two ties at each bend in the vertical reinforcement.

Maintain a minimum clear distance between reinforcing bars and the adjacent face of the masonry unit of ¼ inch (6.4 mm) for fine grout and ½ inch (13 mm) for coarse grout to ensure that grout can flow around the bars (Ref. 8.2).



(a) For Chimneys up to 40 Inches (1,016 mm) Wide



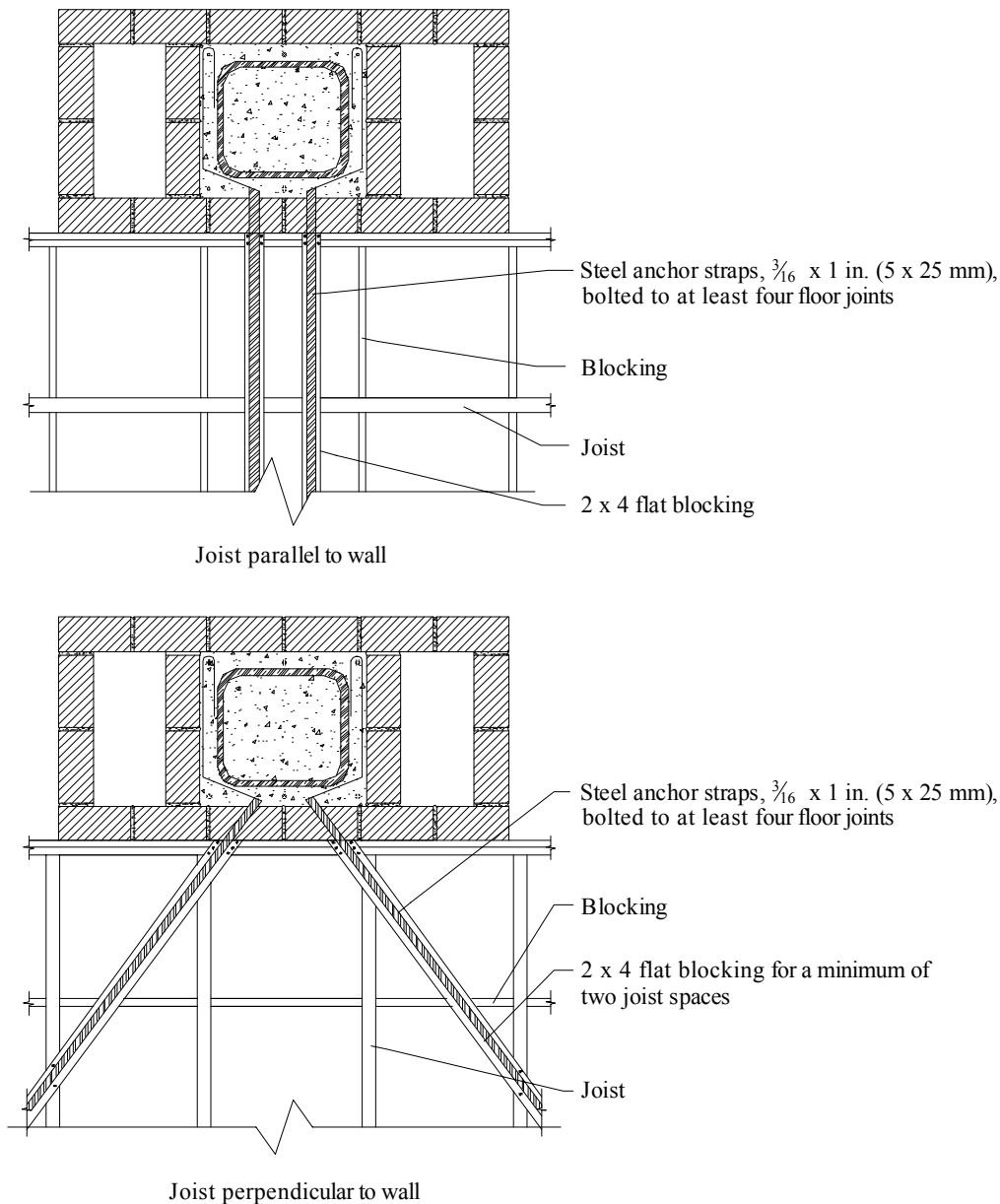
(b) For Chimneys up to 80 Inches (2,032 mm) Wide

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Chimney Anchorage to Building

Masonry chimneys perform best when built monolithically with masonry buildings. When attached to wood frame structures, reinforcement and anchorage to the structure improve the chimney's earthquake resistance. This detail shows anchorage to a wood frame structure for construction in Seismic Design Category (SDC) D (Ref. 8.7). The chimney must be anchored as shown at each floor, ceiling or roof line more than 6 feet (1,829 mm) above grade (except where constructed completely within the exterior walls). Chimneys in SDCs A, B and C do not require reinforcement and seismic anchorage.

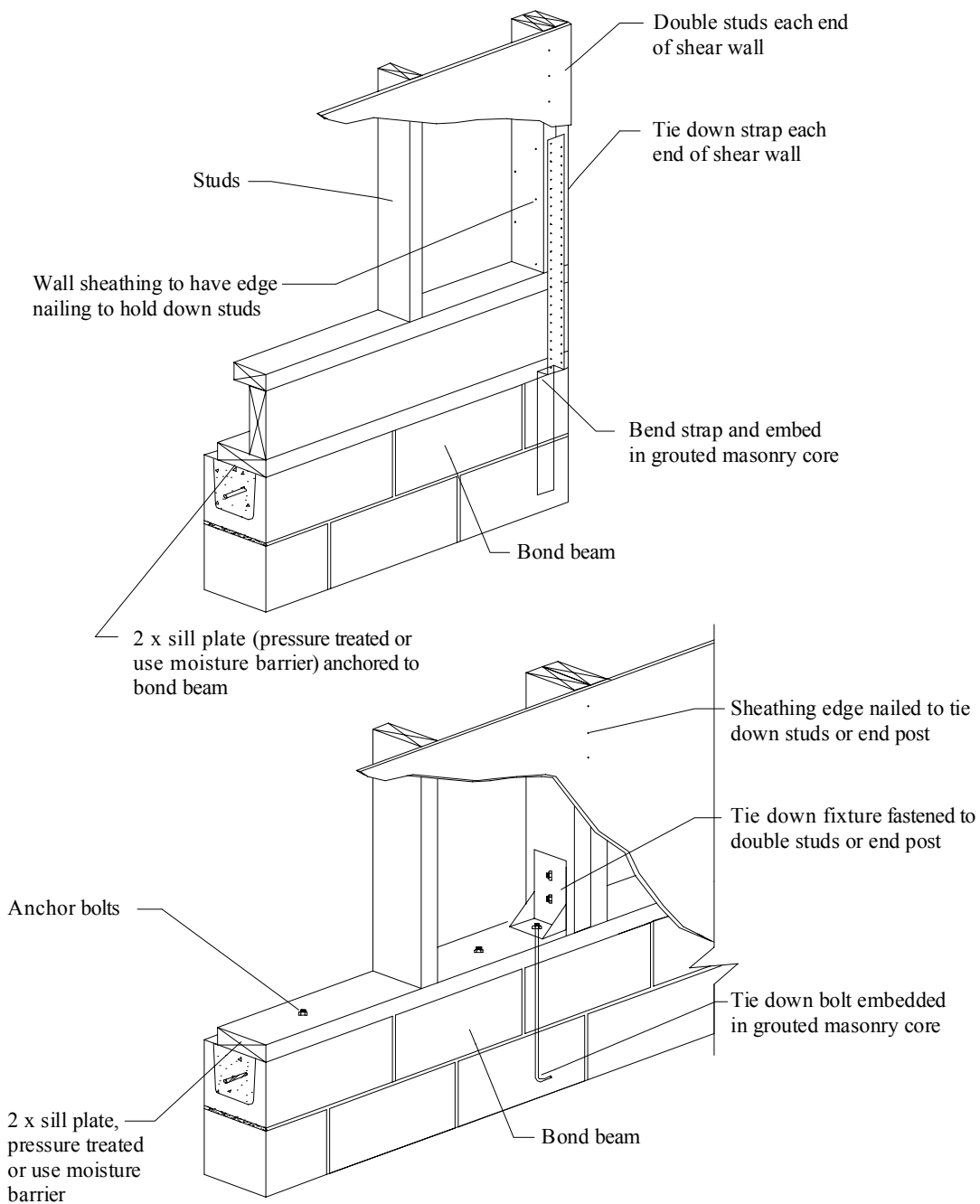
Maintain a minimum clear distance between reinforcing bars and the adjacent face of the masonry unit of ¼ inch (6.4 mm) for fine grout and ½ inch (13 mm) for coarse grout to ensure that grout can flow around the bars (Ref. 8.2).



Last Modified: December, 2002

Tie Downs

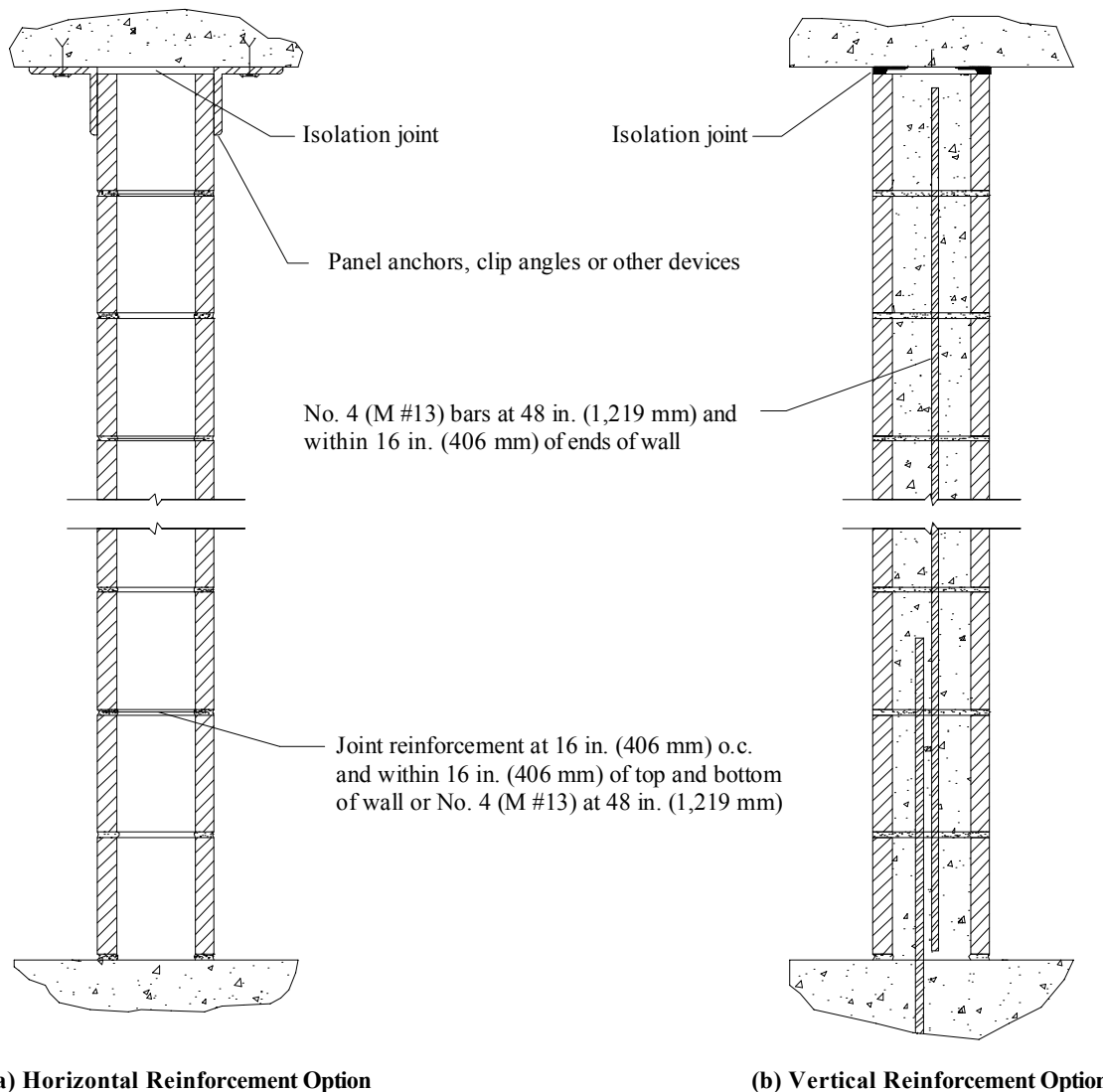
To prevent wood frame shear walls from pulling away from the foundation, corner and end studs should be anchored to the foundation with a tie down device as shown below. Locate tie downs at ends of walls, corners and adjacent to large openings.



Last Modified: December, 2002

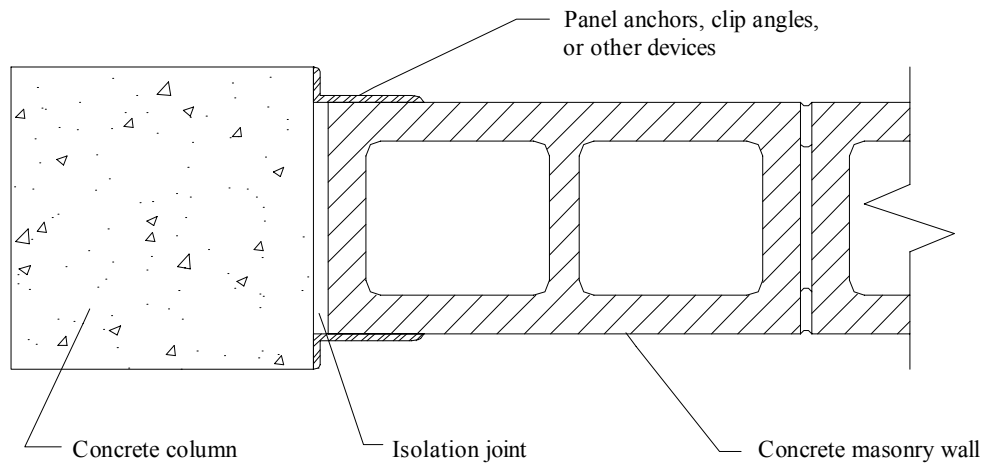
Isolation of Vertically Spanning Nonloadbearing Walls From the Lateral Force-Resisting System

The isolation joint at the tops and ends of partition walls prevents vertical and lateral forces from being transferred to the partition walls, while allowing in-plane movement of the lateral force resisting system. The isolation joints and connectors between the walls and the structure must be designed to accommodate the design story drift. The horizontal and vertical reinforcement sizes and spacings noted are prescriptive minimums(Ref. 8.2). These requirements are fully illustrated in Figure 1E.10.



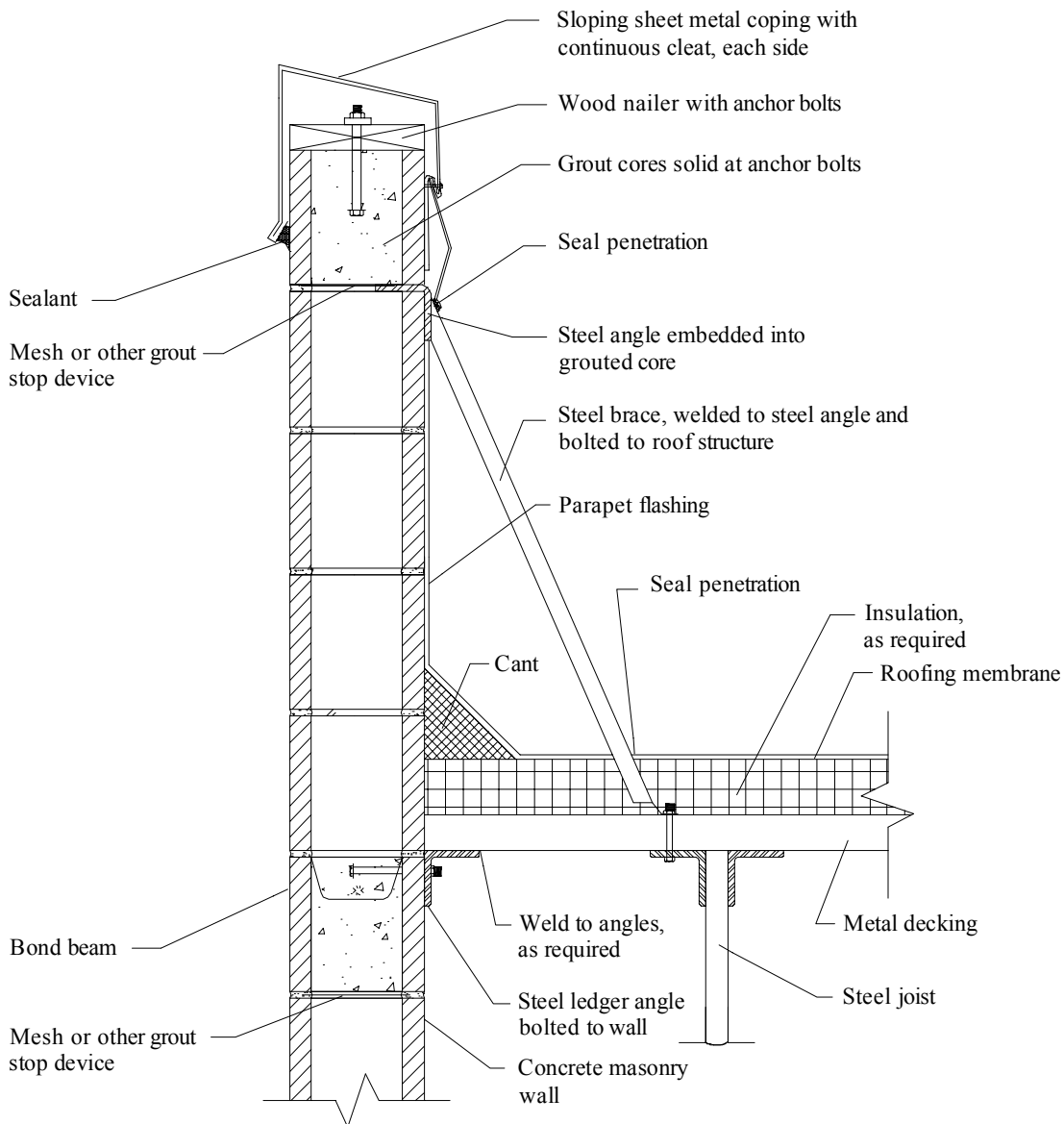
Isolation of Horizontally Spanning Nonloadbearing Walls from the Lateral Force-Resisting System

Isolation joints at the ends of horizontally spanning nonloadbearing walls prevent forces from being transferred to the partition walls while allowing in-plane movement of the lateral force-resisting system. The isolation joints and connectors between the walls and the structure must be designed to accommodate the design story drift. See Figure 1E.10 for masonry partition wall prescriptive reinforcement requirements for Seismic Design categories C, D, E and F.



Parapet Bracing

Parapets, like chimneys, are prone to damage during earthquakes if not properly reinforced and/or braced. SSTD 13 (Ref. 8.5), contains the following recommendations for parapets in seismic areas. In Seismic Design Category (SDC) A, unreinforced parapets must be at least 8 inches (203 mm) thick, and be no higher than three times their thickness. In SDC B, parapet height is restricted to 4 feet (1,200 mm). In addition, parapets higher than three times their thickness must be vertically reinforced with a minimum of No. 4 (M #13) bars at 72 inches (1,830 mm) on center. In addition to this, in SDC C and D, the parapet must have horizontal reinforcement (minimum of one No. 4 (M #13) bar) within 16 inches (406 mm) of the top. Parapet bracing can be used in addition to these minimum requirements, and is often used to retrofit unreinforced masonry parapets as well. In new construction, reinforcing the parapet is preferable to using bracing, because the bracing connections penetrate roofing and flashing, providing a potential for water penetration.



Last Modified: December, 2002

8B — High Winds

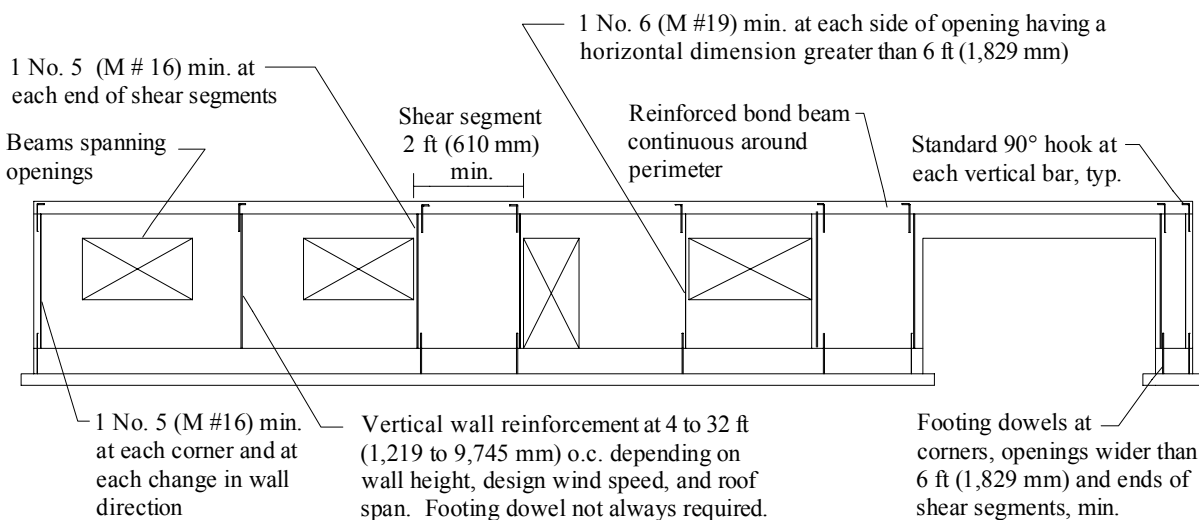
High winds subject buildings to large horizontal forces as well as to significant uplift. The critical damage to buildings in such events typically occurs due to uplift on the roof. Reinforced concrete masonry is well suited to resist these loads due to its relatively large mass available to resist the large uplift and overturning forces. Additionally, the grout and reinforcing steel tie the walls into a strong, cohesive unit minimizing the number of connectors needed and reducing the margin for error, as a structure is only as strong as its weakest link.

As with seismic design, connections between individual building elements - roof, walls, floors and foundation - are critical to maintaining structural continuity during a high wind event. A primary goal for buildings subjected to high winds is to maintain a continuous load path from the roof to the foundation. This allows wind uplift forces on the roof to be safely distributed through the walls to the foundation, where they are dissipated into the ground. If one part of the load path fails, or is discontinuous, building failure may occur. Details for maintaining continuity at changes in bond beam height and vertical reinforcement locations are shown in Chapter 7.

Proper detailing and installation of mechanical connectors is necessary for maintaining continuous load paths. Note that in order for connectors to provide their rated load capacity, they must be installed according to the manufacturer's specifications. In coastal areas, corrosion protection of the connectors is especially important due to the corrosive environment.

In addition to a continuously reinforced bond beam around the entire perimeter of the building, vertical reinforcement must be placed throughout a wall to resist design loads, including: corners; wall intersections; on each side of openings wider than 6 feet (1,829 mm); at the ends of shear segments; and at all locations where girders or girder trusses bear on the concrete masonry wall. Each of the exterior walls on all four sides of the building and all interior walls designed as shear walls must have at least one 2 foot (610 mm) minimum section of wall identified as a shear segment to resist the high lateral loads generated. Longer shear segments are more effective and are recommended where possible or required by design. See the following figure, "Typical Reinforcement for High Wind Areas," for an illustrated summary of reinforcement requirements (Ref. 8.6).

Reinforcement must be properly spliced to provide continuity for the load path. A splice length of 40 bar diameters is required per *Building Code Requirements for Masonry Structures* (ref. 8.2) for Grade 40 reinforcement and 48 bar diameters for Grade 60 reinforcement. If the wall was designed assuming Grade 40 and Grade 60 was used, however, the 40 bar diameter lap splice may be used. See Figure 1E.5 for standard hook requirements.



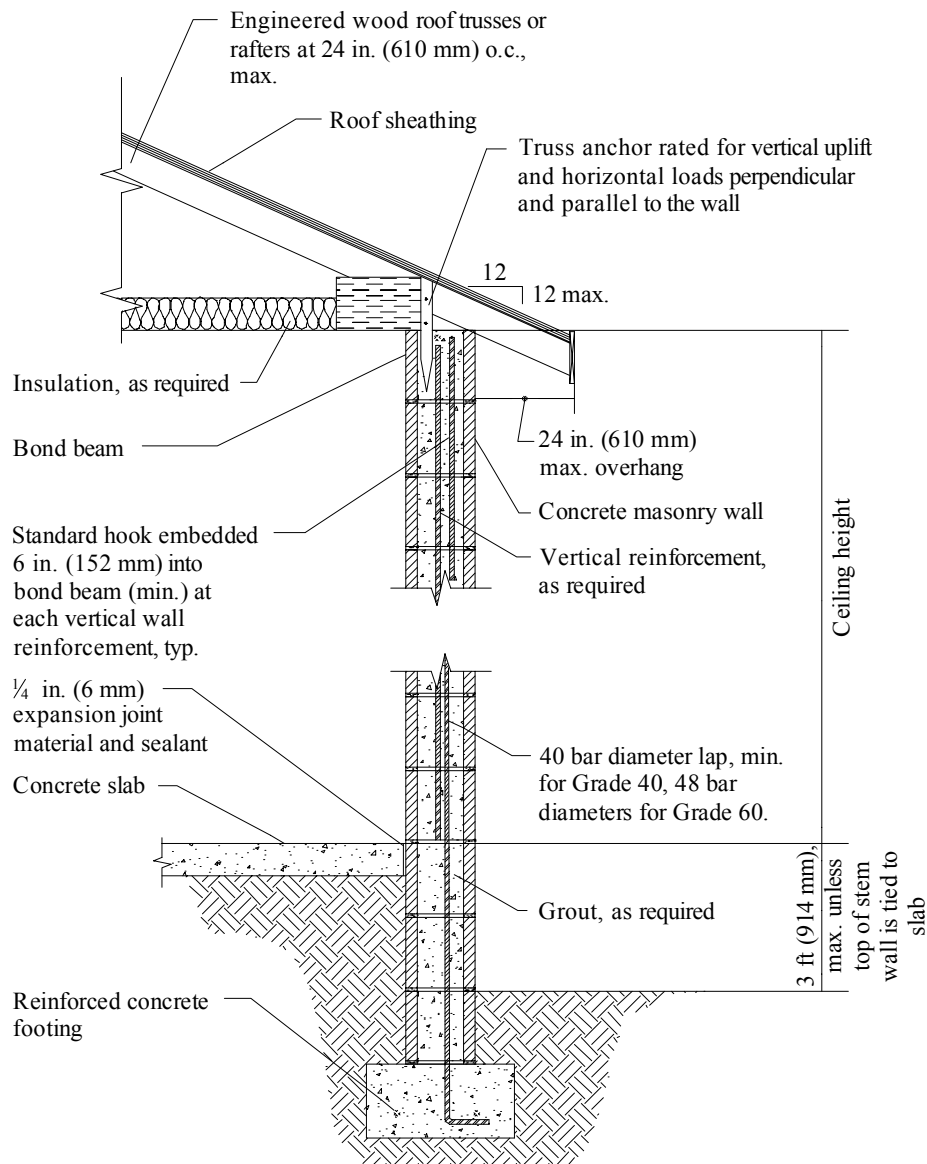
Typical Reinforcement for High Wind Areas

Last Modified: December, 2002

Exterior Loadbearing Wall

This detail shows a typical loadbearing wall with floating floor slab. Vertical reinforcement should be placed in the center of the concrete masonry cores to adequately resist both wind pressure and suction on the wall. Bond beam depth and minimum horizontal reinforcement varies with design wind velocity, ceiling height, roof truss span and spacing of vertical wall reinforcement.

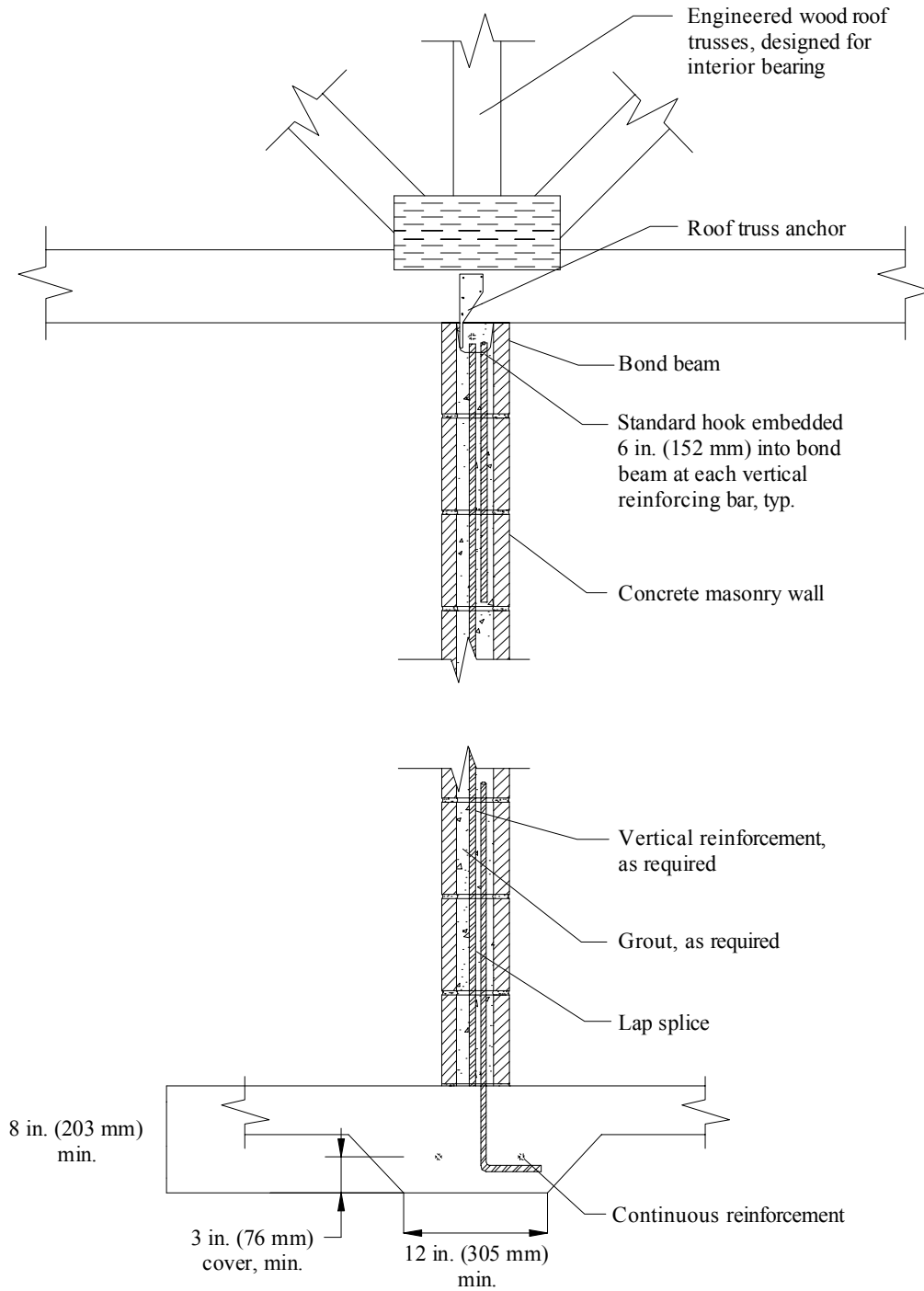
Since wind suction forces on the leeward side of a building can be essentially as high as the pressure forces on the windward side, limitations are placed on the height above grade for this detail. However, if the slab is laterally supported and tied to the concrete floor slab with 6 x 6 W1.4 x W1.4 (152 x 152 MW) welded wire fabric extending into the slab at least 10 feet (3,050 mm) and into the bond beam 6 inches (152 mm) or with No. 3 reinforcement (M #10 at 1,219 mm) o.c. maximum extending into the slab at least 10 feet (3,050 mm) and hooked into the bond beam, the foundation wall may be extended to 8 feet (2,440 mm) above grade (ref. 8.6).



Last Modified: December, 2002

Interior Loadbearing Wall

This detail is applicable for walls at least 6 inches (152 mm) thick. Net uplift capacity of the roof truss anchors depends on the roof truss span, design wind velocity and whether the truss anchor is located within the wind end zone (wind uplift forces are higher around the perimeter of the roof).

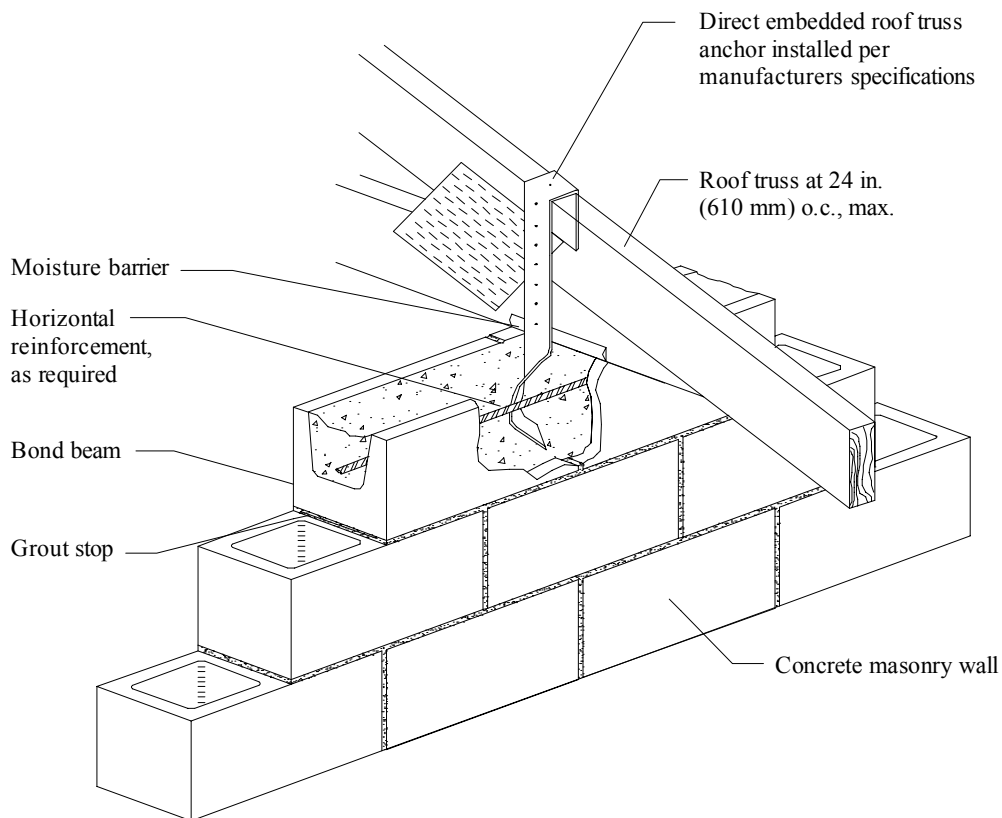


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Roof Truss Anchor

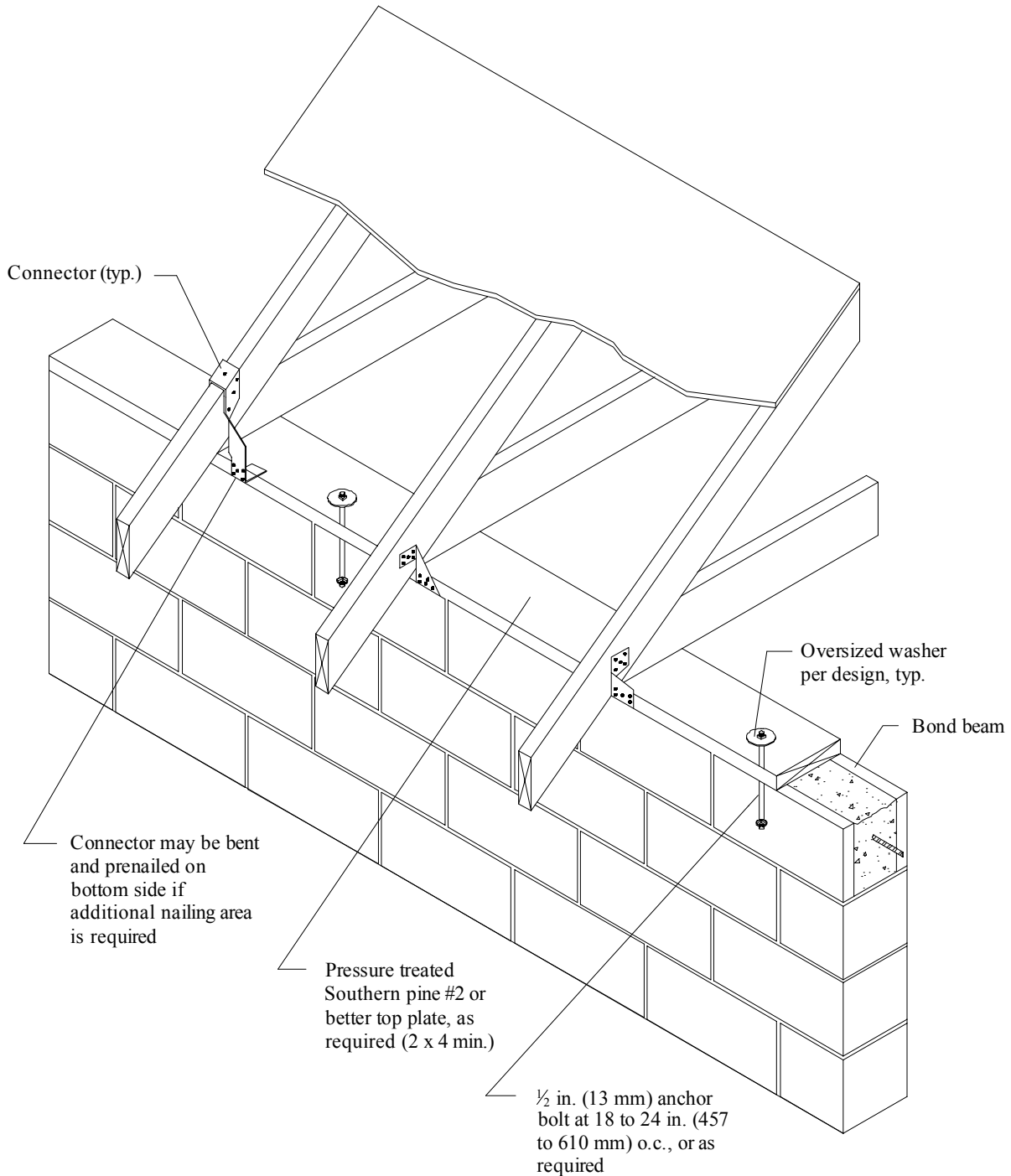
The direct embedded roof truss anchor method of connecting the roof to walls is preferred over the bolted top plate and hurricane clip method, as it generally has greater capacity and fewer connections. Additionally, the nail area available for the hurricane clip is limited by the thickness of the top plate.

The detail shows a typical roof truss anchor cast into the bond beam of a concrete masonry bearing wall. The required anchor load capacity depends on the design wind speed as well as the roof truss span. In addition to being rated for uplift, the anchor must be rated for horizontal forces parallel to the wall (in-plane) and perpendicular to the wall (out-of-plane).



Bolted Top Plate Alternate

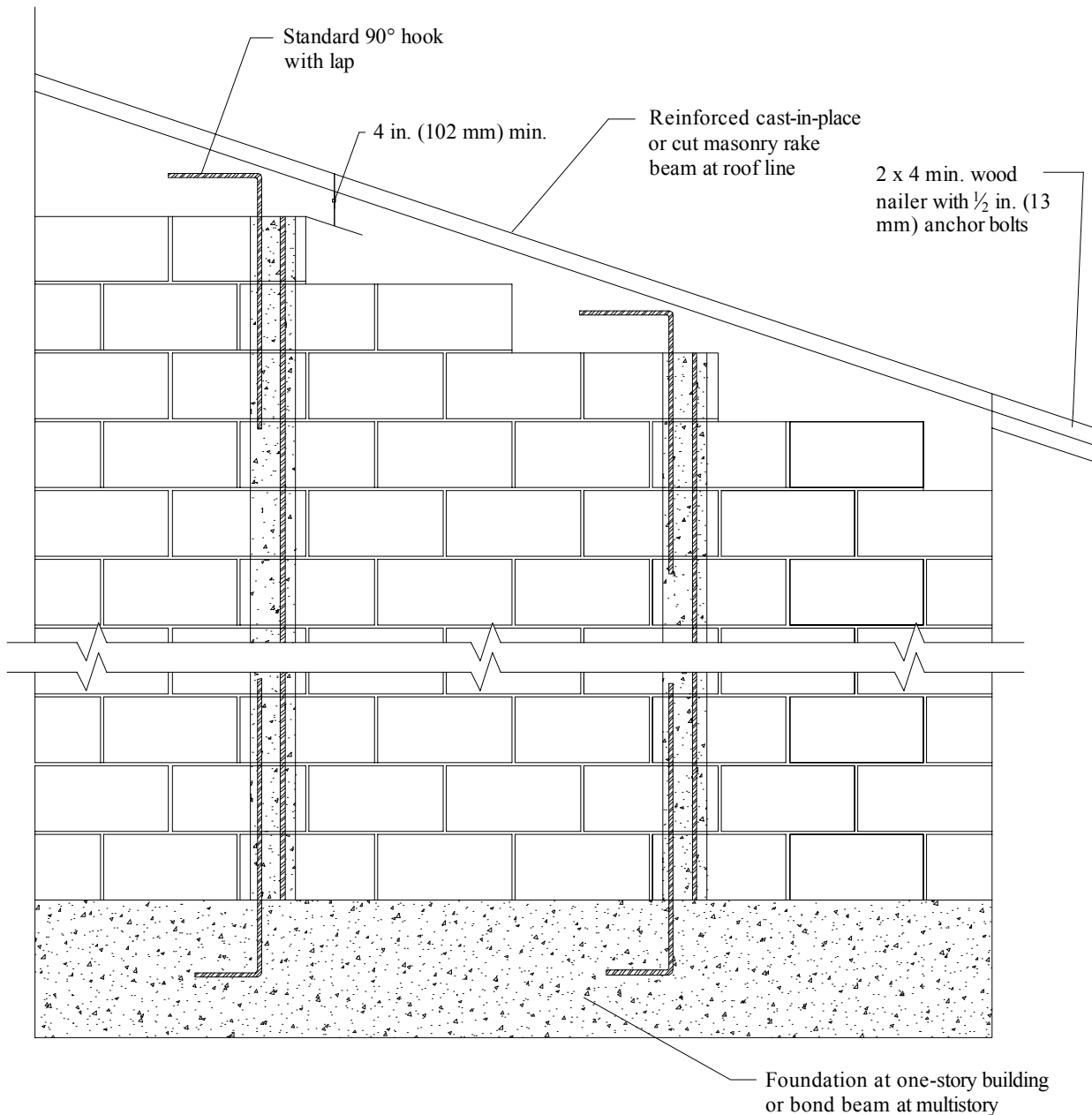
The bolted top plate alternate may also be used for the roof to wall connection; however, a much reduced anchor bolt spacing (24 inches (610 mm) maximum) must be used since the top plate is loaded in its weak direction. The detail illustrates several different types of connectors that are commonly used to connect the truss to the top plate.



Last Modified: December, 2002

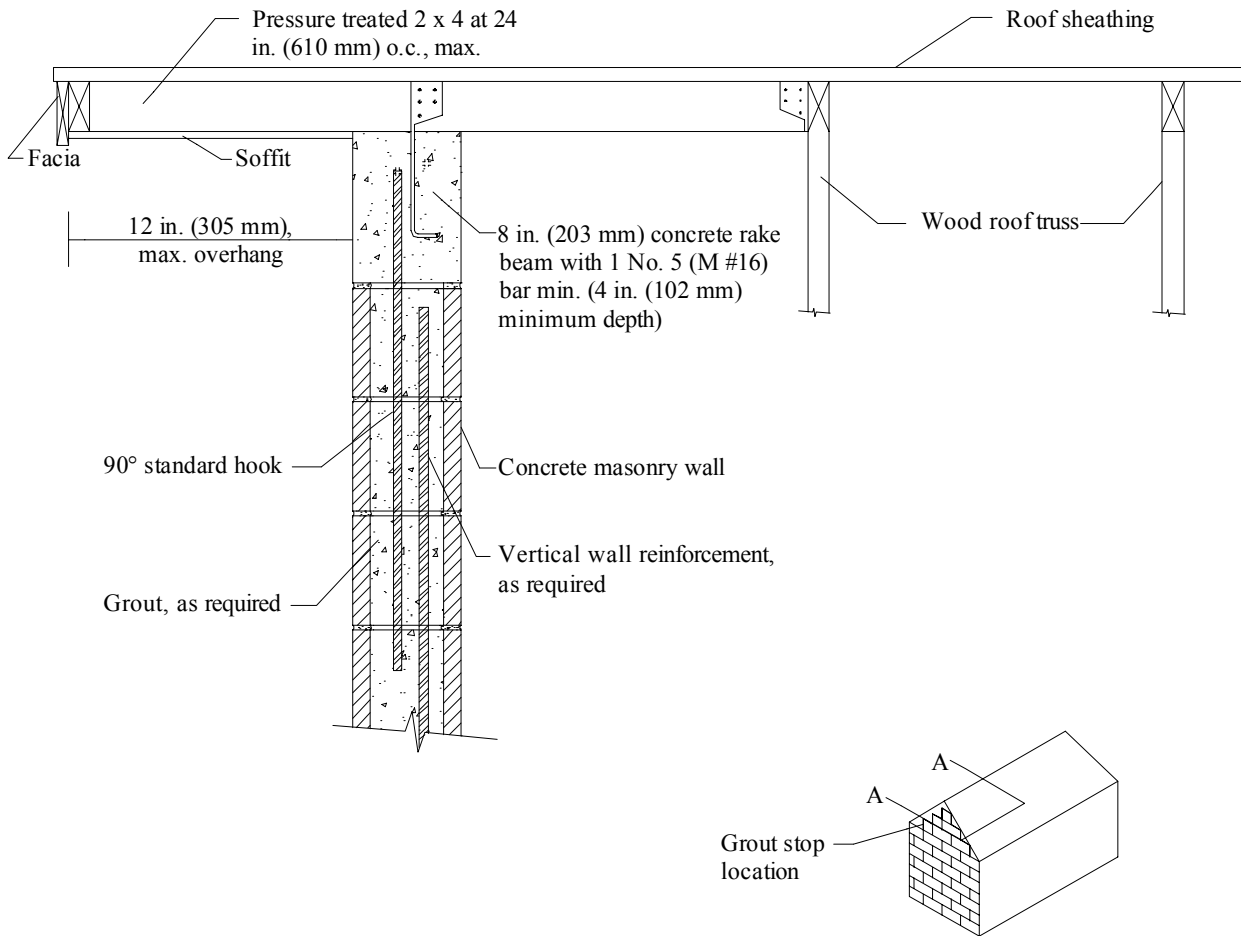
Continuous Gable Endwall Reinforcement

Because of their exposure, gable end walls are more prone to damage than are hipped roofs unless the joint at the top of the end wall and the bottom of the gable is laterally supported for both inward and outward forces. The details show alternate constructions using a raked concrete bond beam and a cut masonry bond beam along the top of full height reinforced concrete masonry gable end walls.



Gable End Wall - Concrete Rake Beam with Outlooker Type Overhang

The figure below shows a detail of a continuously reinforced cast-in-place concrete rake beam along the top of the gable end wall. The beam is formed over uncut block in courses successively shortened to match the slope of the roof. A minimum of 4 inches (102 mm) is needed from the highest projected corner of block to the top of the beam. Reinforcement that is continuous with the bond beam reinforcement in the side walls is placed in the top of the beam. In this detail, an outlooker type overhang is shown where the rake beam is constructed 3 1/2 inches (89 mm) lower than the trusses so that a pressure treated 2 x 4 can pass over it. A ladder type overhang detail also can be used with the concrete rake beam where the beam is constructed to the same height as the trusses similar to that shown for the cut masonry rake beam.



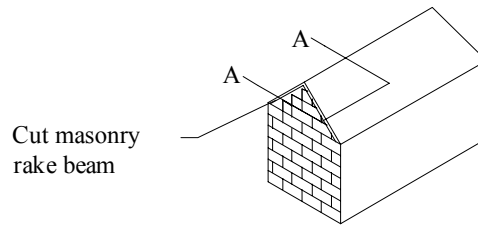
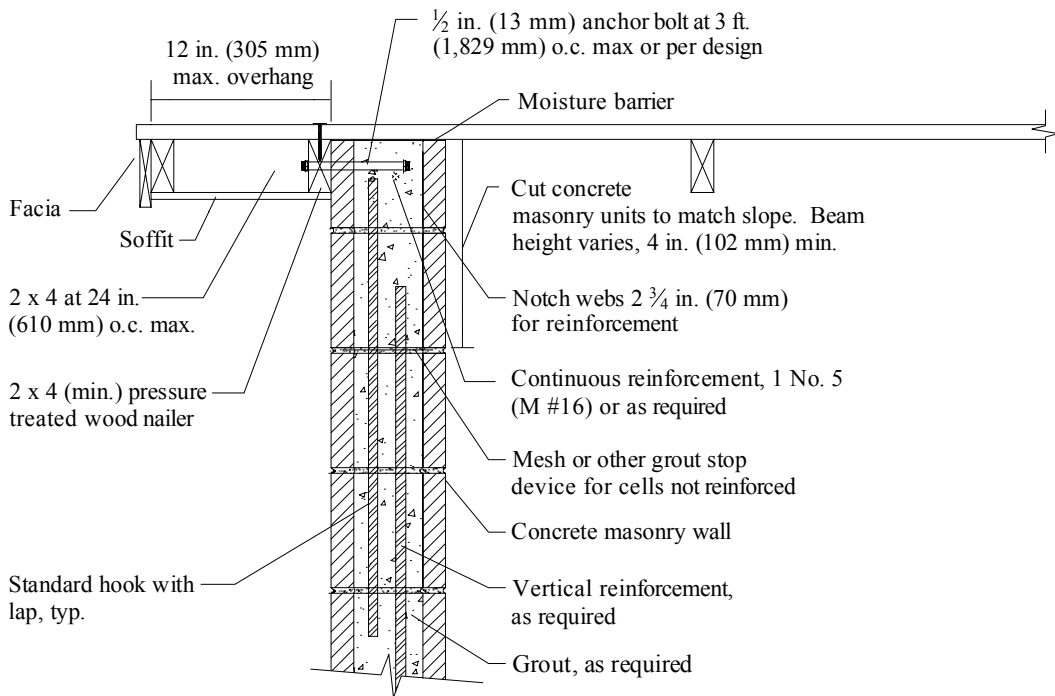
Section A-A Concrete Rake Beam with Outlooker Type Overhang

(Note: A concrete rake beam also may be used with a ladder type overhang detail.)

Last Modified: December, 2002

Gable End Wall - Cut Concrete Masonry Rake Beam with Ladder Type Overhang

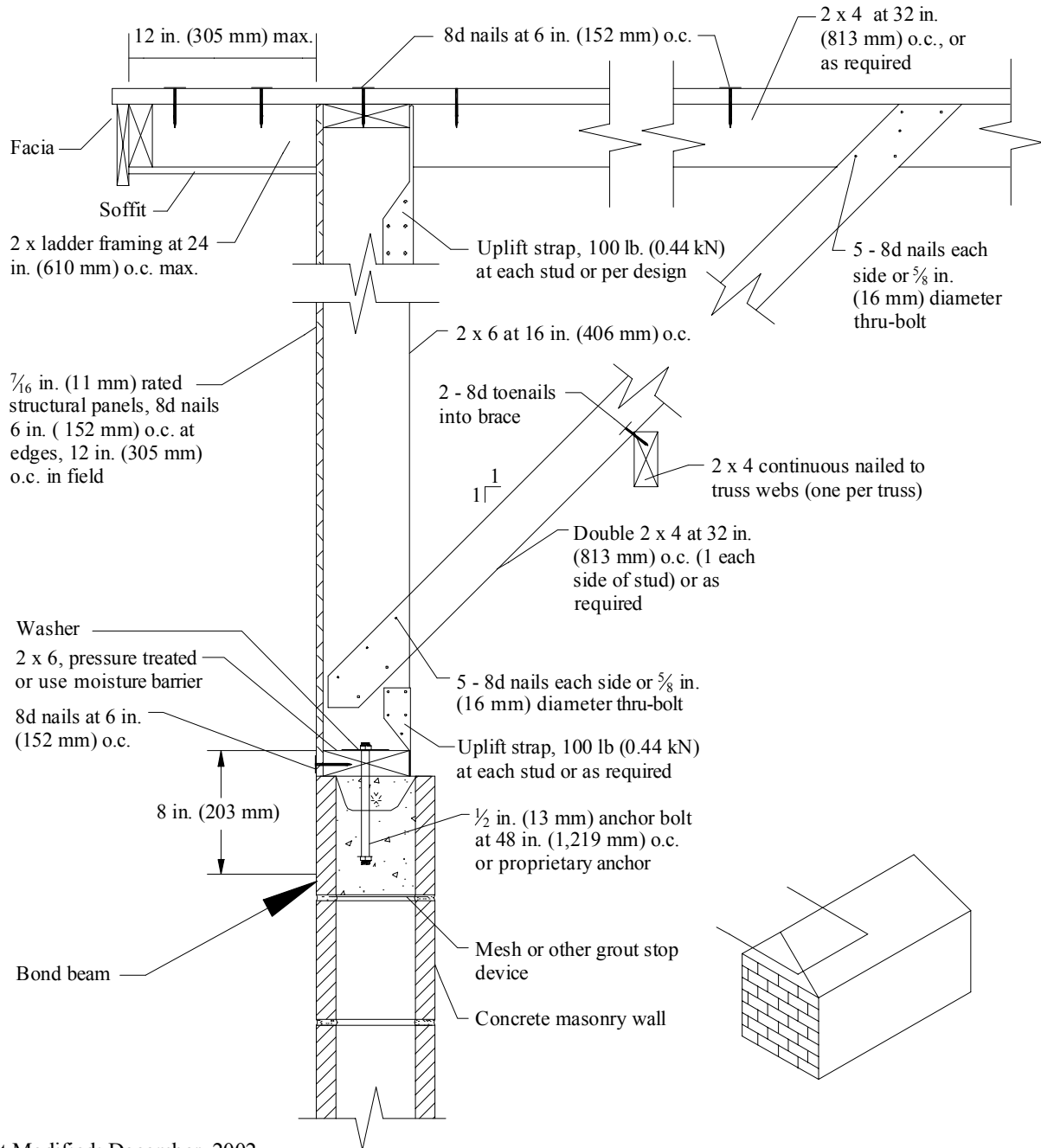
The detail below shows a continuously reinforced cut masonry rake beam along the top of the gable end wall. Masonry units are cut to conform to the roof slope at the same height as the roof trusses. A 2 3/4 inch (70 mm) deep notch is cut into the tops of the webs to allow placement of reinforcement that is continuous with the bond beam reinforcement in the side walls. A minimum of height of 4 inches (102 mm) is needed for the cut masonry bond beam. In this figure, a ladder type overhang is shown. However, an outlooker type overhang detail can be used similar to that shown for the cast-in-place concrete rake beam.



(b) Section A-A Cut Masonry Rake Beam and Ladder Type Overhang Detail
(Note: A cut masonry rake beam also may be used with an outlooker type overhang detail)

Braced Gable End Wall Option

In normal concrete masonry gable end wall construction, the masonry at the gable end is usually stopped at the eave height and then the construction is continued to the roof diaphragm with conventional wood framing. This results in a weak point at the juncture of the two materials with little capability to resist the high lateral loads produced by high winds. The detail below provides the necessary lateral support. The number and spacing of braces is dependent on design wind speed, roof slope and roof span.



Last Modified: December, 2002

References:

- 8.1 *Home Builders Guide to Seismic Resistant Construction*. Federal Emergency Management Agency.
- 8.2 *Building Code Requirements for Masonry Structures*, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
- 8.3 *Seismic Design Provisions for Masonry Structures*, TEK 14-18. National Concrete Masonry Association, 1996.
- 8.4 *The Guide to Concrete Masonry Residential Construction in High Wind Areas*. Florida Concrete & Products Association, Inc., 1997.
- 8.5 *Standard for Seismic Resistant Residential Construction*, SSTD 13-99. Southern Building Code Congress International, Inc., 1999.
- 8.6 *Standard for Hurricane Resistant Residential Construction*, SSTD 10-99, Southern Building Code Congress International, Inc., 1999.
- 8.7 *International Building Code*, International Code Council, 2000.

Section 9A - Parapets

Parapets are wall sections that extend above the roofline. They are most commonly used to enclose rooftop mechanical systems, but may also be required to prevent fire spread or provide fall protection. Parapets are unique in that they are exposed to the weather on three sides, requiring rigorous attention to detail to prevent water penetration, to provide adequate structural stability and to avoid thermal bridges which can increase energy consumption.

The top of the parapet is most susceptible to water penetration, and is protected using a coping (precast concrete or stone) or a metal cap.

Recommendations for water penetration resistance of concrete masonry walls also apply to parapets. In addition, the design should consider the potential for ponding water and drifting snow on the back side of the parapet facing the roof. Roof flashing should extend up the back side of the parapet and terminate under counterflashing. Flashing installed at the base of the parapet collects any water that may penetrate and directs it out of the masonry through weep holes before it can travel into the wall below (also see Figure 2D.5 and Section 6A). Any sealants or coatings for water penetration used on the wall exterior should be continued up the parapet face.

Although typically not large structures, parapets are exposed to large air pressure differentials requiring adequate structural strength, particularly when cantilevered from the roof deck. Cantilevered parapets are often reinforced for this reason. If the wall below the parapet is reinforced, the wall reinforcement can be continued up into the parapet. Or, the parapet can be anchored to the roof deck with vertical reinforcing dowels.

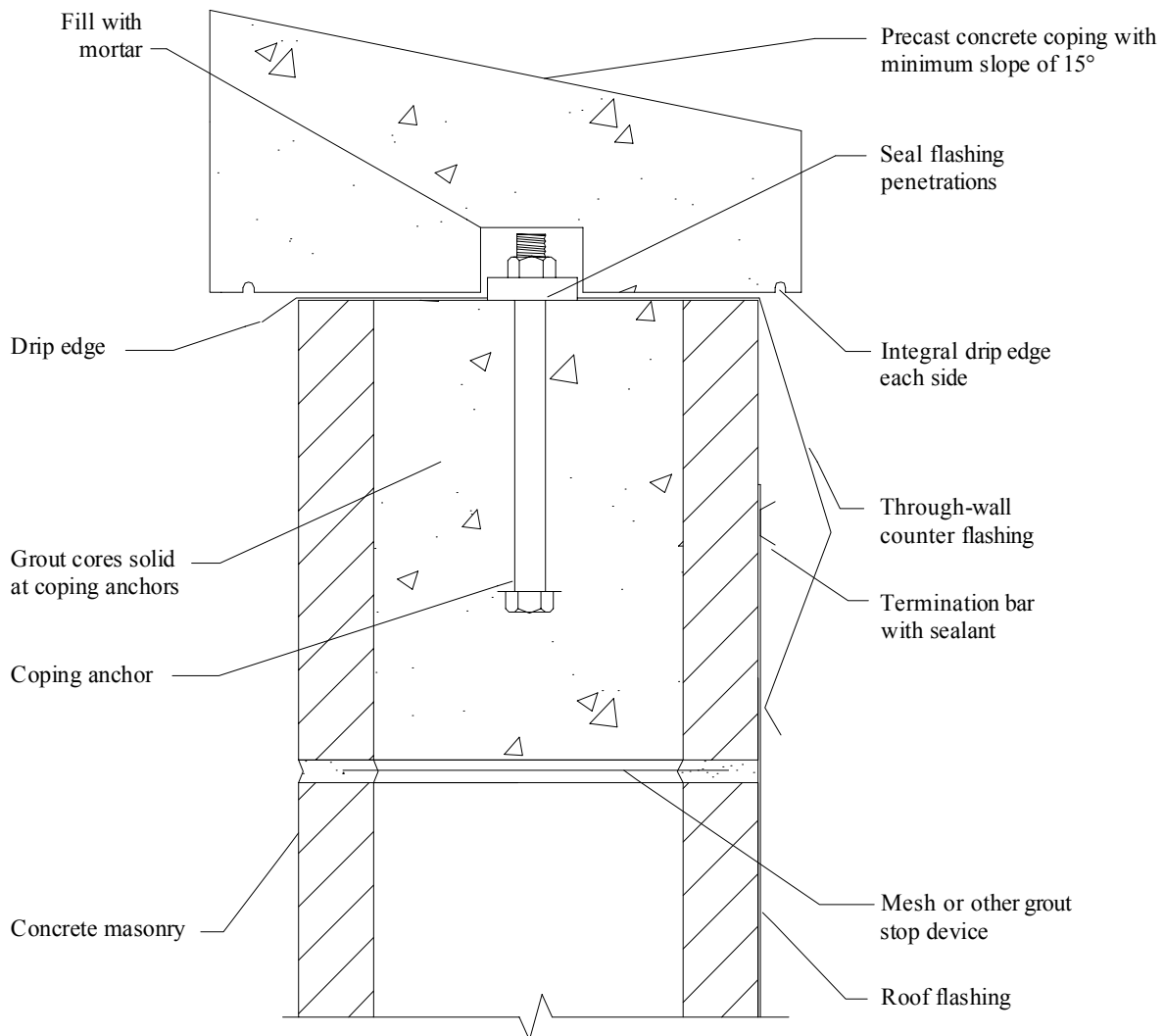
Parapets can be sized according to prescriptive empirical requirements, such as those in *Building Code Requirements for Masonry Structures* (Ref. 9.1). Under certain design conditions (basic wind speed less than or equal to 110 mph (145 km/hr), Seismic Design Category A, B, or C) the *Code* provides the following design provisions for parapets:

- minimum thickness of 8 inches (203 mm), and
- parapet height less than or equal to three times the parapet thickness.

Parapets, because of their exposure, can also act as thermal fins, wicking heat up through the wall and subsequently decreasing the building's energy efficiency. On cavity walls, the cavity insulation can be extended up through the height of the parapet to help reduce this heat loss. Ideally, the parapet can be insulated on the back side as well, maintaining a thermal boundary between the interior of the building and the outdoor environment.

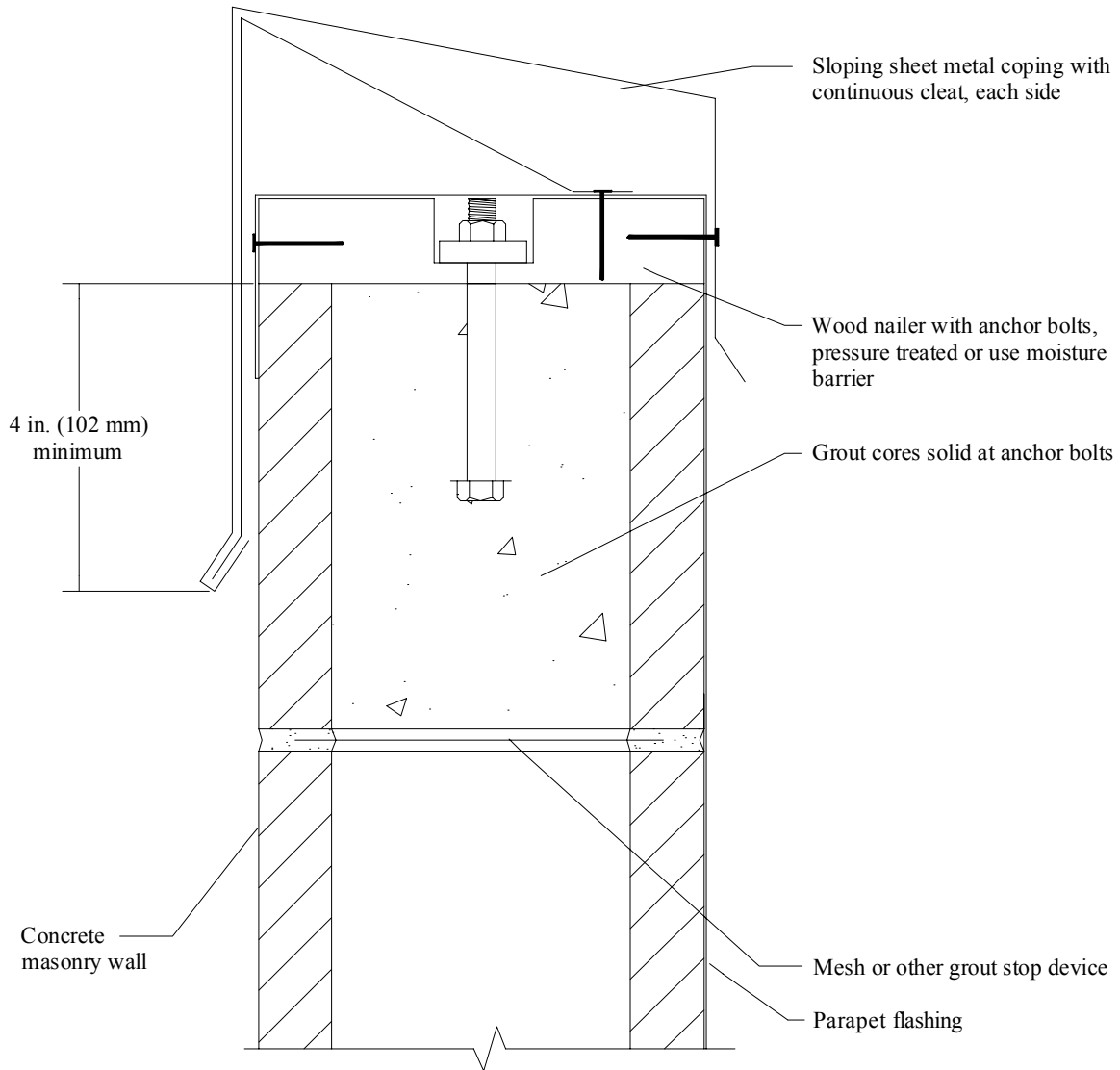
Parapet With Precast Concrete Coping, Low Parapet Option

Joints between coping sections should be filled with a backer rod and elastomeric sealant to help keep them watertight (the joint should not contain mortar). The coping rests on through-wall flashing and is typically held in place with a stainless steel anchoring system. Where anchors penetrate the through-wall flashing, mastic should be used generously to seal off this potential water entry route.



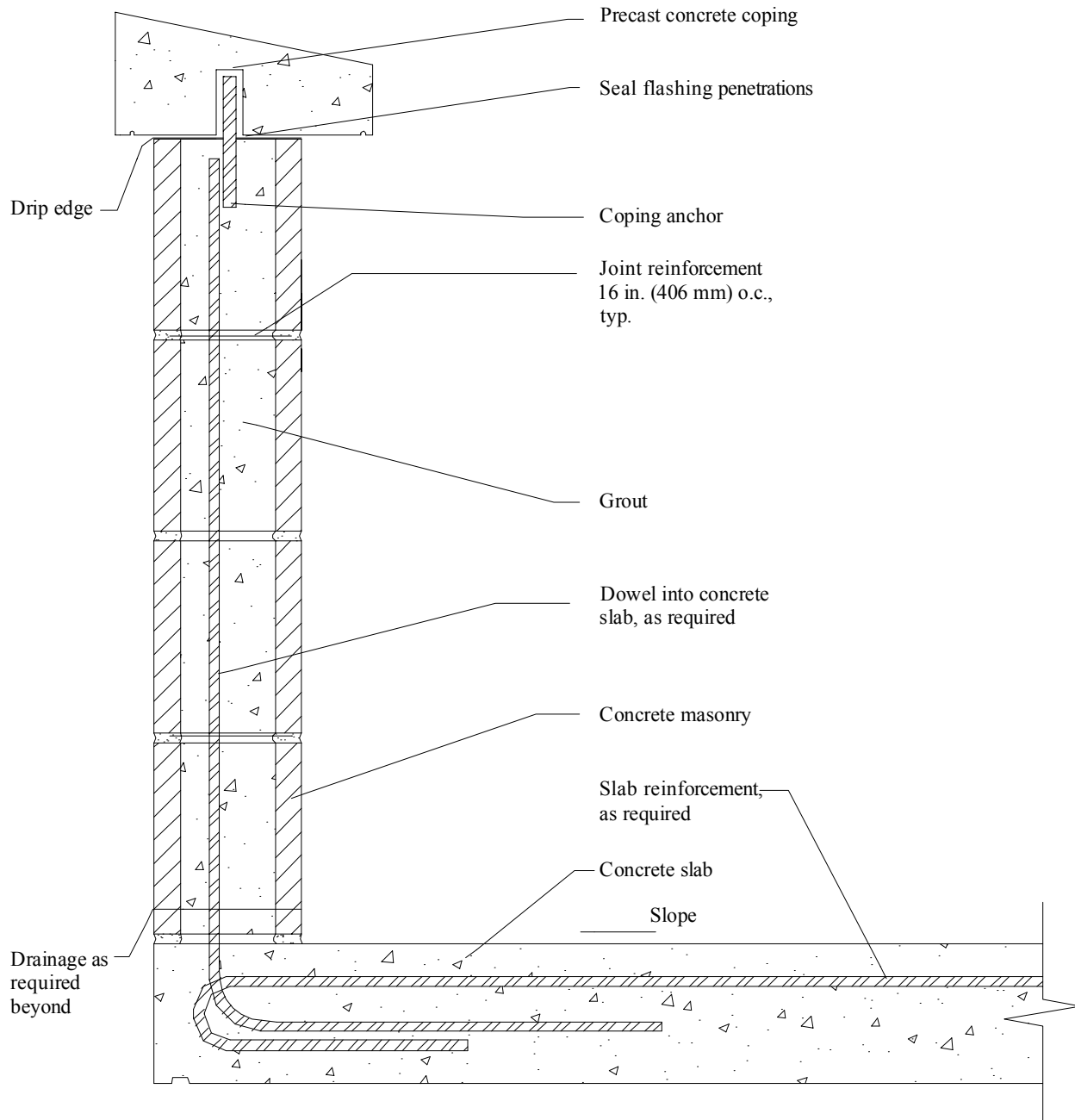
Parapet With Metal Cap, Low Parapet Option

Metal caps come in fairly long sections with lap joints between the sections. The lap joints should be located above control joints in the masonry if possible to help accommodate the differential thermal expansion between the metal and the masonry. Integral cap flashing and drips typically extend over both sides of the parapet. Because metal caps are nonporous, through-wall flashing under the cap is considered optional. However, since the coping can leak at the splice points, through-wall flashing is advantageous. When the parapet is not too tall, the roof flashing is extended over the wood nailer. This detail should be used with caution as some roofing membranes can shrink causing the parapet to pull away from the wall.



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Cantilevered Parapet at Concrete Balcony



Last Modified: December, 2002

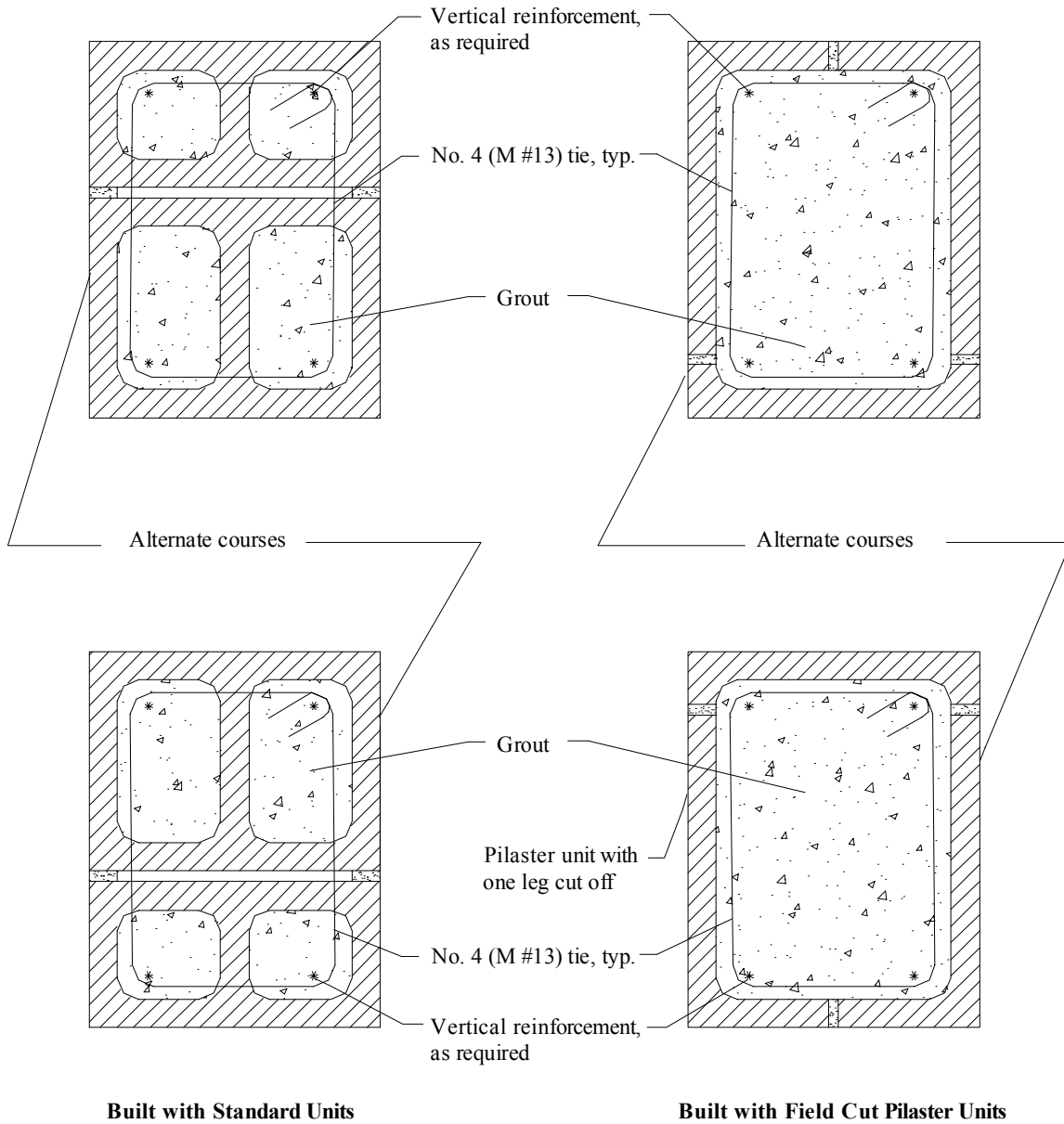
9B — Concrete Masonry Columns

Columns function primarily as compression members when supporting beams, girders, trusses or similar elements.

Because column failure has the potential to damage other structural members, a series of special requirements are imposed on columns by *Building Code Requirements for Masonry Structures* (Ref. 9.1) in addition to the requirements for reinforced concrete masonry wall design. Prescriptive concrete masonry column detailing requirements are shown in Figure 1E.11.

For masonry anchorage to steel or concrete columns, see Section 3B.

Column Construction



Last Modified: December, 2002

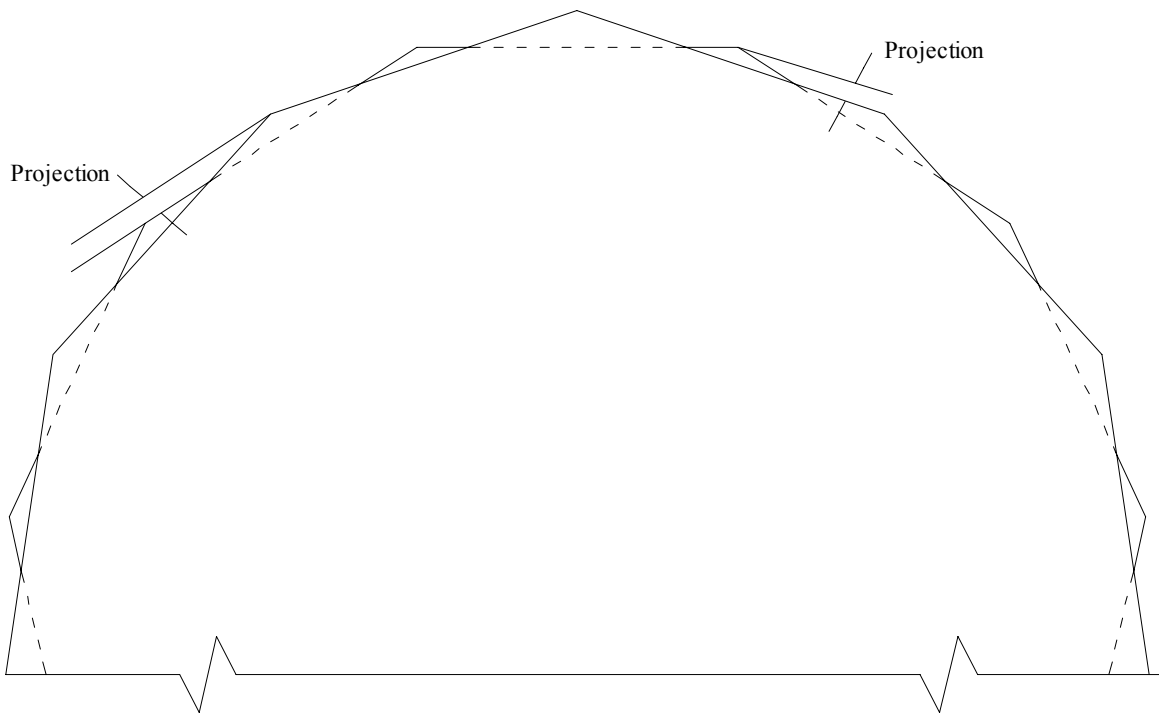
Section 9C - Radial Walls

When curvilinear walls are constructed with rectangular units, unit corners will project to some degree. The size of the projection affects the overall wall texture and shadow patterns. Typically, projections of $\frac{1}{8}$ to $\frac{1}{4}$ inch (3.2 to 6.4 mm) are considered acceptable (see figure below).

Minimum radii for curved walls are listed in Table 1, based on $\frac{3}{8}$ inch (10 mm) thick mortar joints on exterior, $\frac{1}{8}$ inch (3.2 mm) mortar joints on interior, and running bond. Smaller radii are possible by using shorter units, by saw-cutting the flanges off stretcher units.

Table 1 - Minimum Radii for Nominal 16 inch (406 mm) Long Concrete Masonry Units

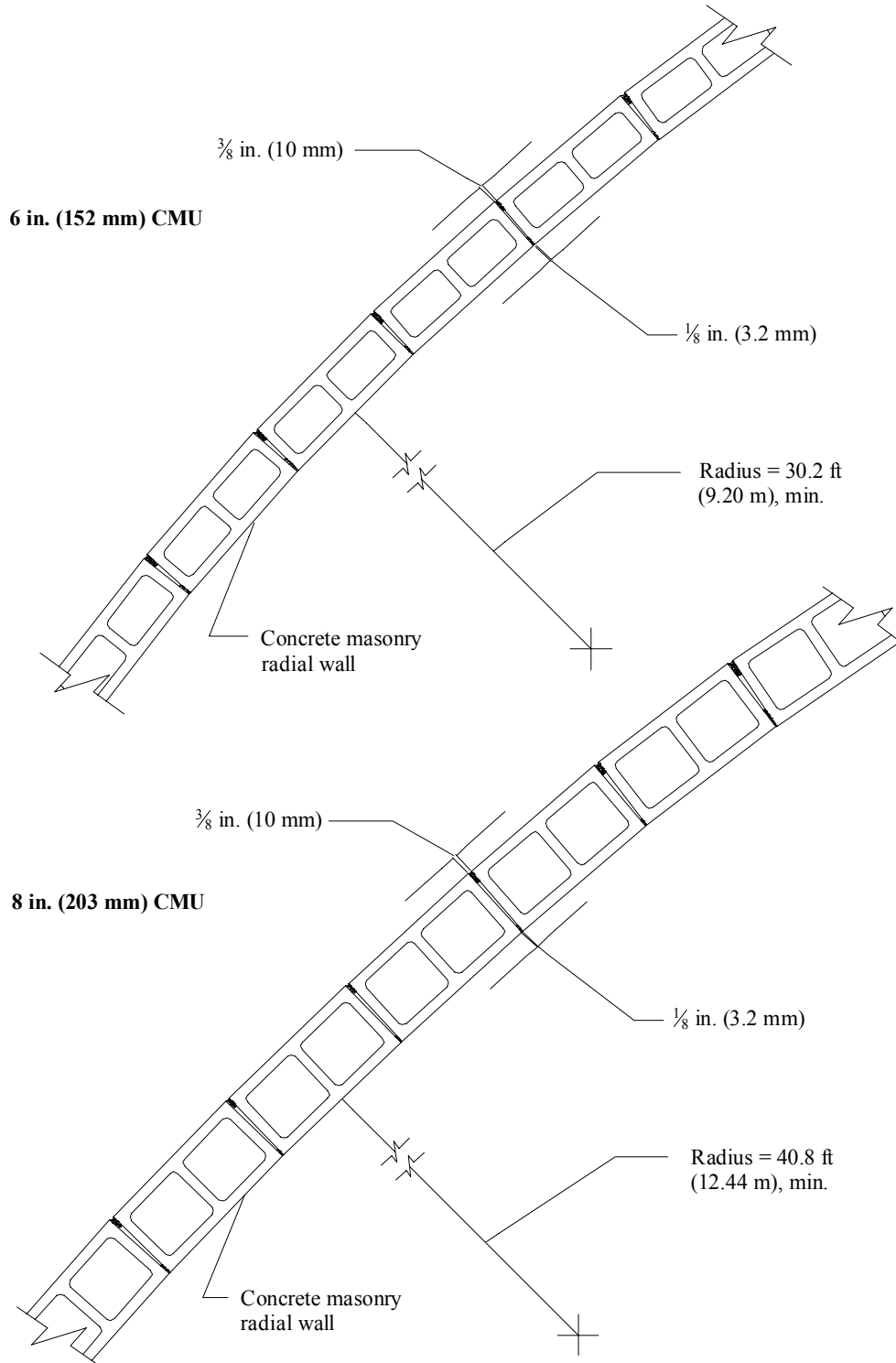
Nominal unit width, in. (mm)	Minimum radii, ft (m)	Typical unit projection, in. (mm)
4 (102)	19.5 (5.94)	$\frac{1}{8}$ (3.2)
6 (152)	30.2 (9.20)	$\frac{3}{32}$ (2.4)
8 (203)	40.8 (12.44)	$\frac{1}{16}$ (1.6)
10 (254)	51.3 (15.64)	$\frac{1}{16}$ (1.6)
12 (406)	62.2 (18.96)	$\frac{1}{16}$ (1.6)



Concrete Masonry Unit Projections in Running Bond

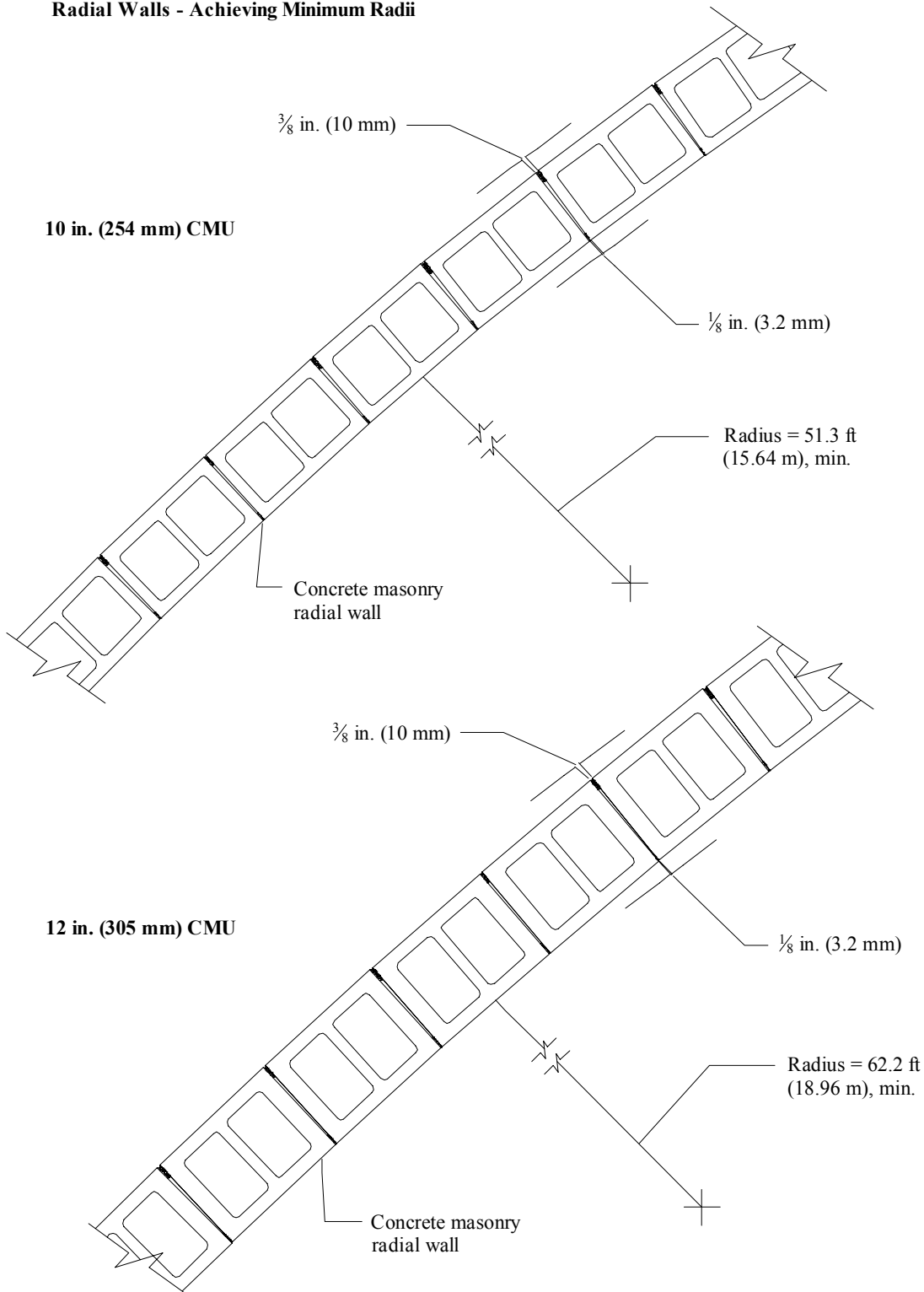
Last Modified: December, 2002

Radial Walls - Achieving Minimum Radii



Last Modified: December, 2002

Radial Walls - Achieving Minimum Radii



Last Modified: December, 2002

Section 9D - Banding

When bands of clay masonry are used as an accent in concrete masonry walls, and vice versa, detailing is required to accommodate the concrete masonry shrinkage and clay masonry expansion occurring side by side. Without due consideration of these opposing movements, cracking can result. In veneers and cavity walls, the cracking is primarily an aesthetic issue, as any water that penetrates the veneer through cracks between the two materials drains down the cavity and is directed out of the wall via flashing and weep holes.

When detailing a wall to accommodate movement, the design goal is to allow the movement to occur (as restraint will cause cracking) while providing appropriate support. In general, several strategies are used to accommodate movement: movement joints (control joints in concrete masonry and expansion joints in clay masonry); horizontal joint reinforcement to take tension due to concrete masonry shrinkage and help keep any cracks that occur closed; and sometimes horizontal joints that allow longitudinal movement. In veneers, it is particularly important that the band, as well as the wall panel above and below the band, be supported by wall ties. Wall ties should be installed within 12 inches (305 mm) of the top and bottom of the band to help ensure the surrounding masonry is adequately supported.

Using a lower compressive strength mortar helps ensure that if cracks do occur, they occur in the mortar joint rather than through the unit. Type N mortar is often specified for veneers, because it tends to be more flexible than other mortar Types.

Multi-Course Concrete Masonry Band in Clay Brick Veneer

Horizontal joint reinforcement is placed in the mortar joints above and below the band to take stress from the differential movement in that plane. For bands higher than two courses, joint reinforcement should also be placed within the band itself at 16 inches (406 mm) on center vertically. Ideally, the joint reinforcement and ties should be placed in alternate joints so that one does not interfere the other. Some designers, however, prefer placing joint reinforcement in every bed joint in the concrete masonry band, particularly if the aspect ratio of the band is high. In this case, a tie which accommodates both tie and wire in the same mortar joint should be used, such as a seismic clip type wall tie.

Although the detail in (a) has demonstrated good performance in many areas of the United States, there are locations where use of bond breaks at the top and bottom of the band is preferred, as shown in (b). A local masonry industry representative should be contacted for further information on which detail has been more successful in a given location.

Detail (b) shows a slip plane in the interfaces between the concrete and clay masonry to allow unrestrained longitudinal movement between the two materials. This can be accomplished by placing building paper, polyethylene, flashing or a similar material in the horizontal bed joints above and below the band. When hollow masonry units are used for the band, the slip plane below the band should incorporate flashing, so that any water draining down the cores of the band can be directed out of the wall at that point.

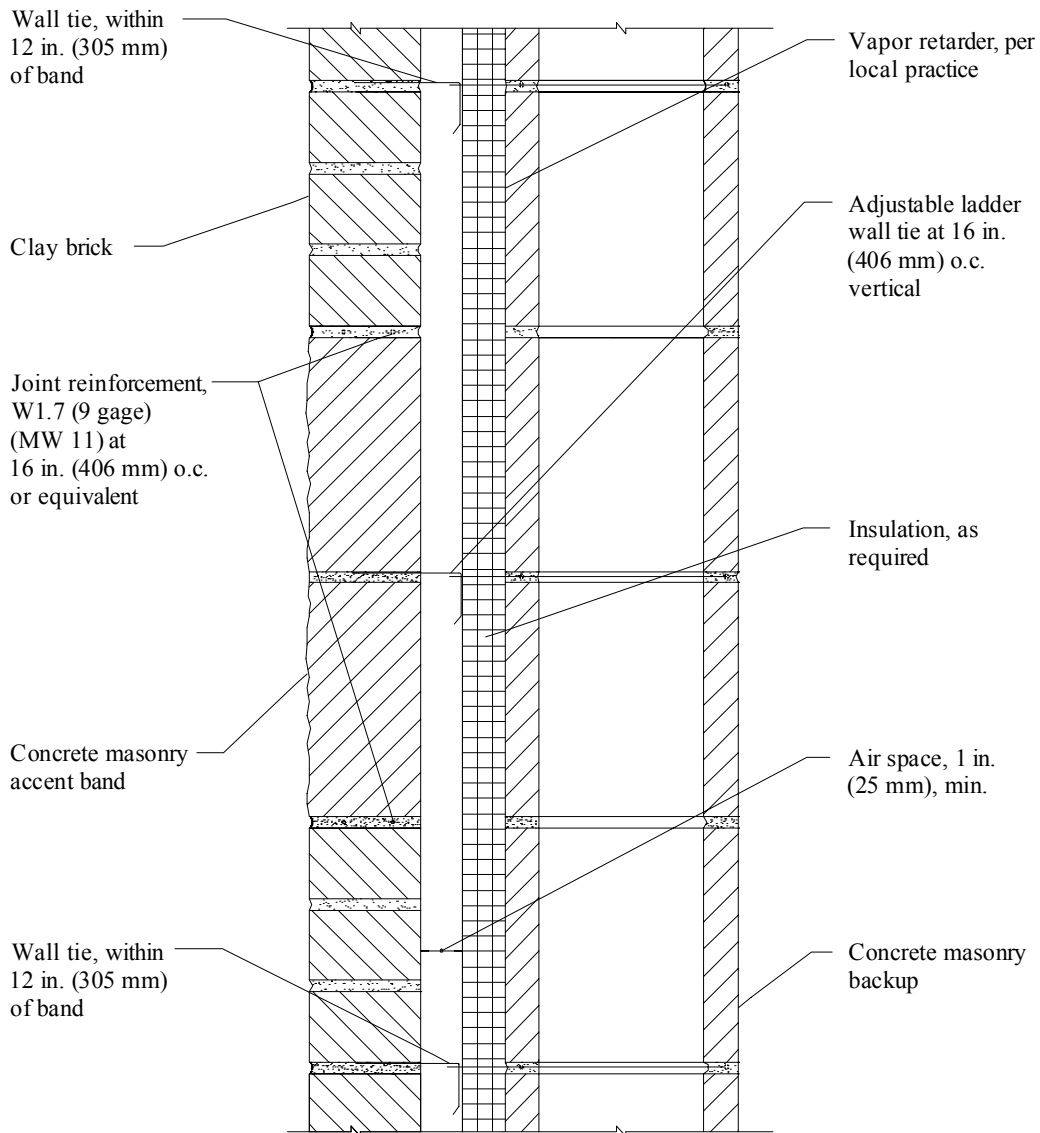
When slip planes are used, joint reinforcement should be placed in the concrete masonry band. The exposed mortar joint at the top and bottom of the band should be raked back and sealed with an appropriate sealant to prevent water penetration at these joints. Note that this construction is typically more expensive than the detail shown in (a).

In addition to joint reinforcement, reduced spacing of expansion joints in the wall is recommended to reduce the potential for cracking. Experience has shown that vertical expansion joints in clay masonry should extend through the concrete masonry band as well, and be placed at a maximum of 20 feet (6.10 m) along the length of the wall. Although concrete masonry construction typically requires control joints rather than expansion joints, control joints should not be used in the concrete masonry band at the expansion joint locations.

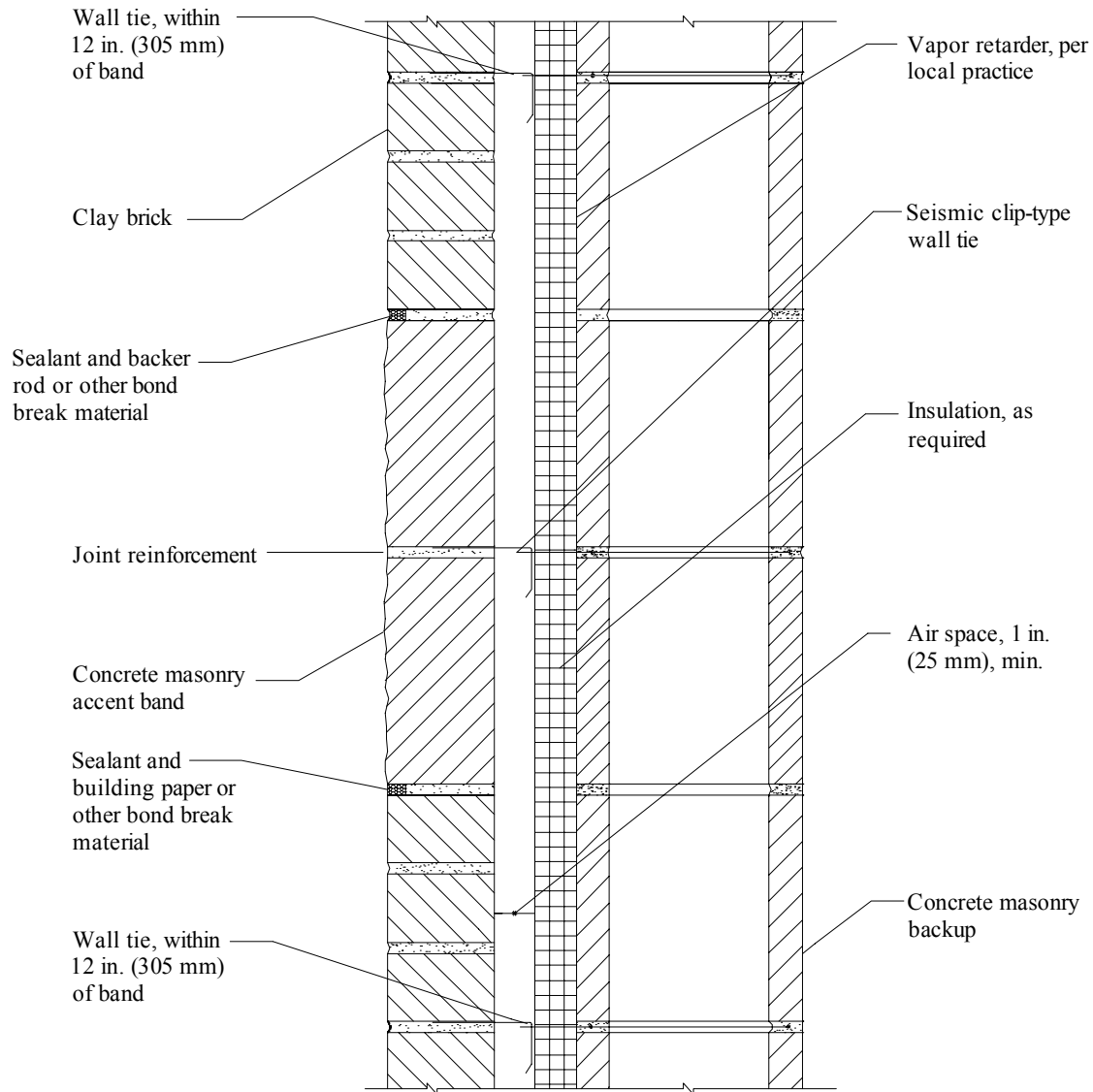
Note that local experience may require reducing the expansion joint spacing to 16 feet (4.88 m). If brick vertical expansion joint spacing does exceed 20 feet (6.10 m), consider placing an additional vertical movement joint through the concrete masonry accent band near mid-panel with joint reinforcement continuous through that joint. The continuous joint reinforcement in this location helps keep the clay brick above and below the band from cracking as the concrete masonry shrinks.

A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) air space is preferred. Proprietary insulating drainage products can be used without the need for a clear air space.

Multi-Course Concrete Masonry Band in Clay Brick Veneer With Joint Reinforcement at Top and Bottom of Band



Multi-Course Concrete Masonry Band in Clay Brick Veneer With Slip Planes at Top and Bottom of Band

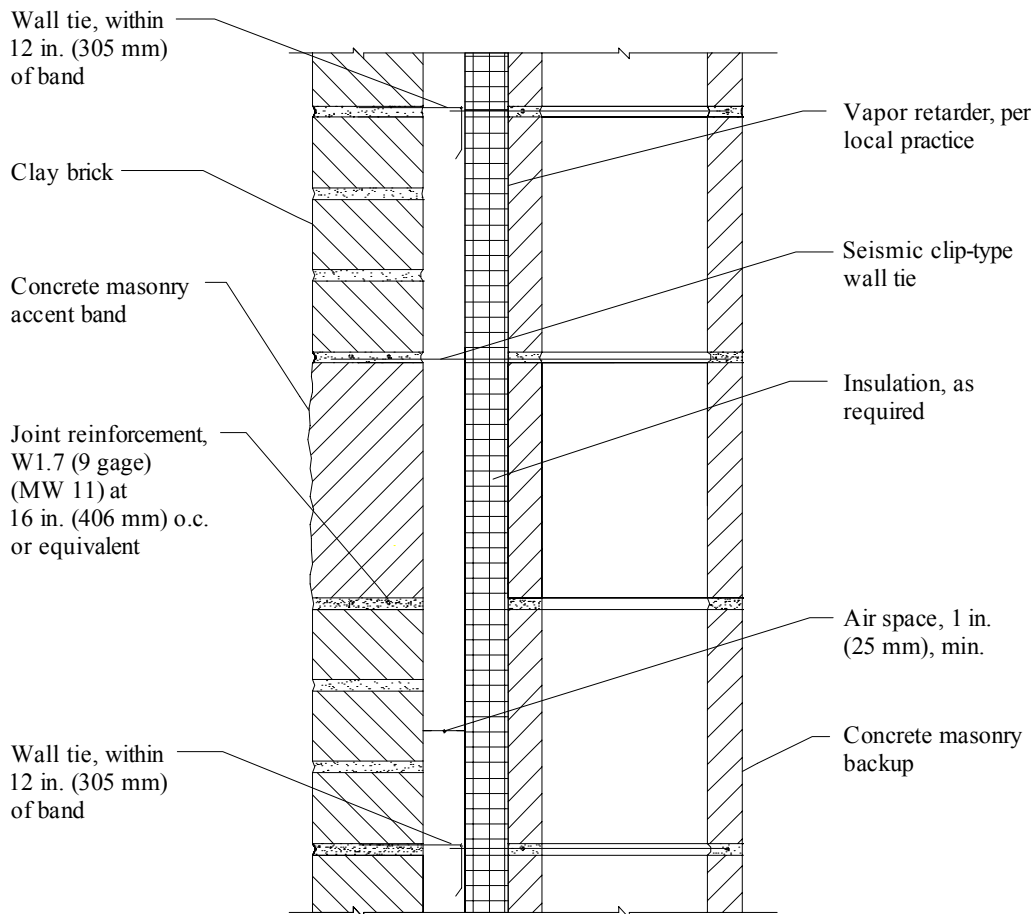


Last Modified: December, 2002

Single-Course Concrete Masonry Band in Clay Brick Veneer

Bands only one course high must be detailed to incorporate joint reinforcement and wall ties in the joints above and below the band. See also the notes to Figure 9D.1.

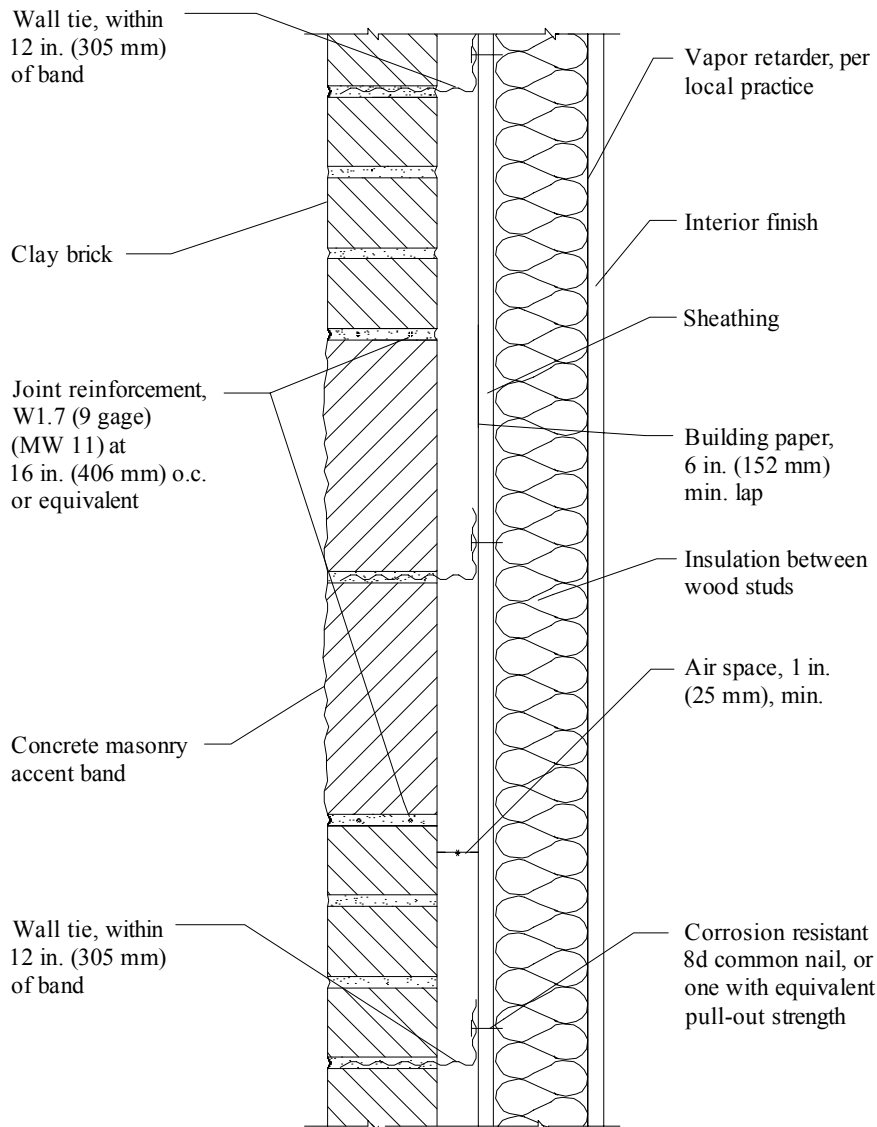
A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as beveling the mortar bed away from the cavity or carefully pulling a piece of wood up the cavity to collect mortar droppings as veneer construction proceeds). Otherwise, a 2 inch (51 mm) air space is preferred. Proprietary drainage products can be used to create a drainage cavity, which takes the place of the clear air space.



Concrete Masonry Band in Clay Brick Veneer Over Wood Framing Backup

When concrete masonry banding is used over a wood framing backup, it is imperative that joint reinforcement be used in the concrete masonry band, even if it is not used in the surrounding clay brick masonry. See also the notes to Figure 9D.1.

A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as beveling the mortar bed away from the cavity or carefully pulling a piece of wood up the cavity to collect mortar droppings as veneer construction proceeds). Otherwise, a 2 inch (51 mm) air space is preferred. Proprietary drainage products can be used to create a drainage cavity, which takes the place of the clear air space.



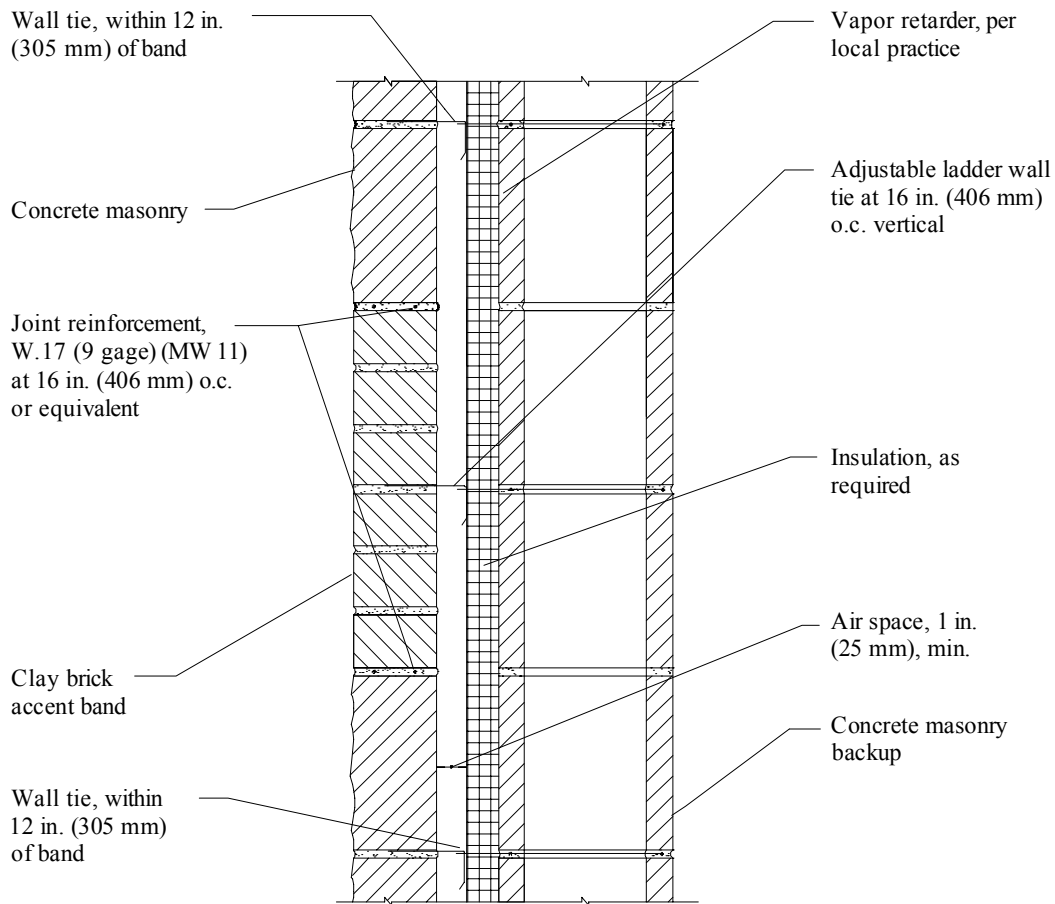
Last Modified: December, 2002

Multi-Course Clay Brick Band in Concrete Masonry Veneer

The recommendations to control differential movement for clay brick masonry bands in concrete masonry are very similar to those for a concrete masonry band in clay brick veneer: joint reinforcement above and below the band and wall ties within the band. Seismic clip-type wall ties are recommended, as they provide an adjustable wall tie and joint reinforcement in one assembly.

With this construction, it is imperative that the veneer control joint not contain mortar as it goes through the clay brick band. Mortar in this joint will restrict brick expansion, reducing the movement joint's effectiveness. Note that although control joints in structural masonry walls must permit free longitudinal movement while resisting lateral or out-of-plane shear loads, veneers are laterally supported by the backup and do not require a shear key.

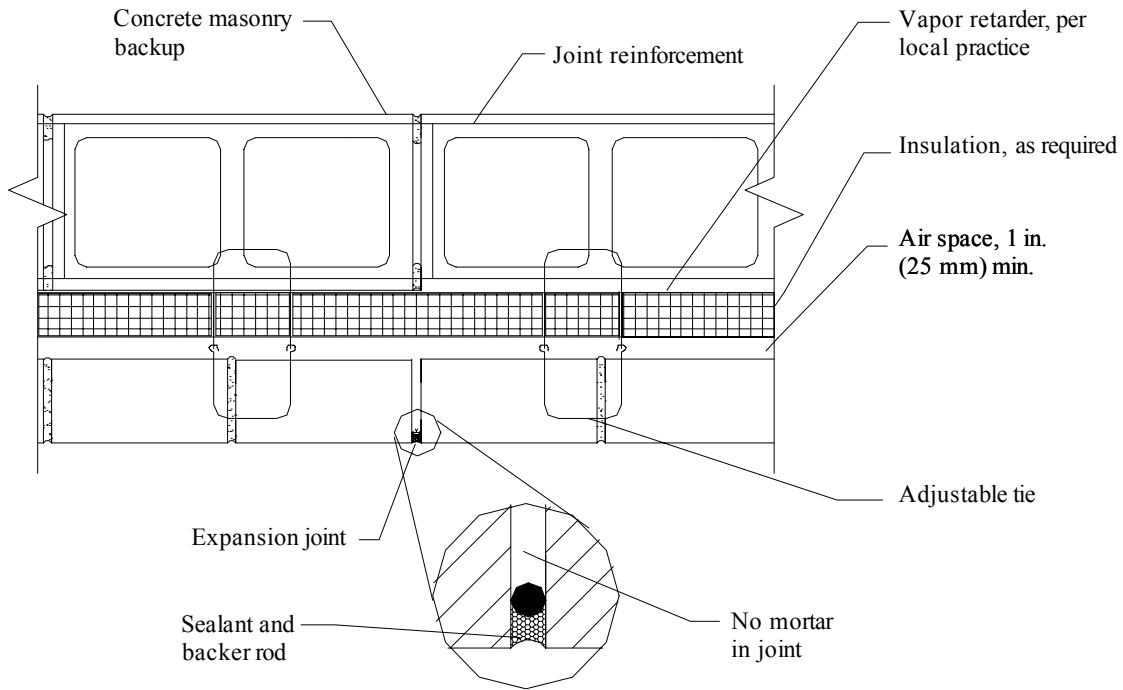
A 1 inch (25 mm) air space between wythes is considered appropriate if special precautions are taken to keep the air space clean (such as by beveling the mortar bed away from the cavity or drawing a piece of wood up the cavity to collect mortar droppings). Otherwise, a 2 inch (51 mm) air space is preferred. Proprietary insulating drainage products can be used without the need for a clear air space.



(a) Section

Last Modified: December, 2002

Multi-Course Clay Brick Band in Concrete Masonry Veneer



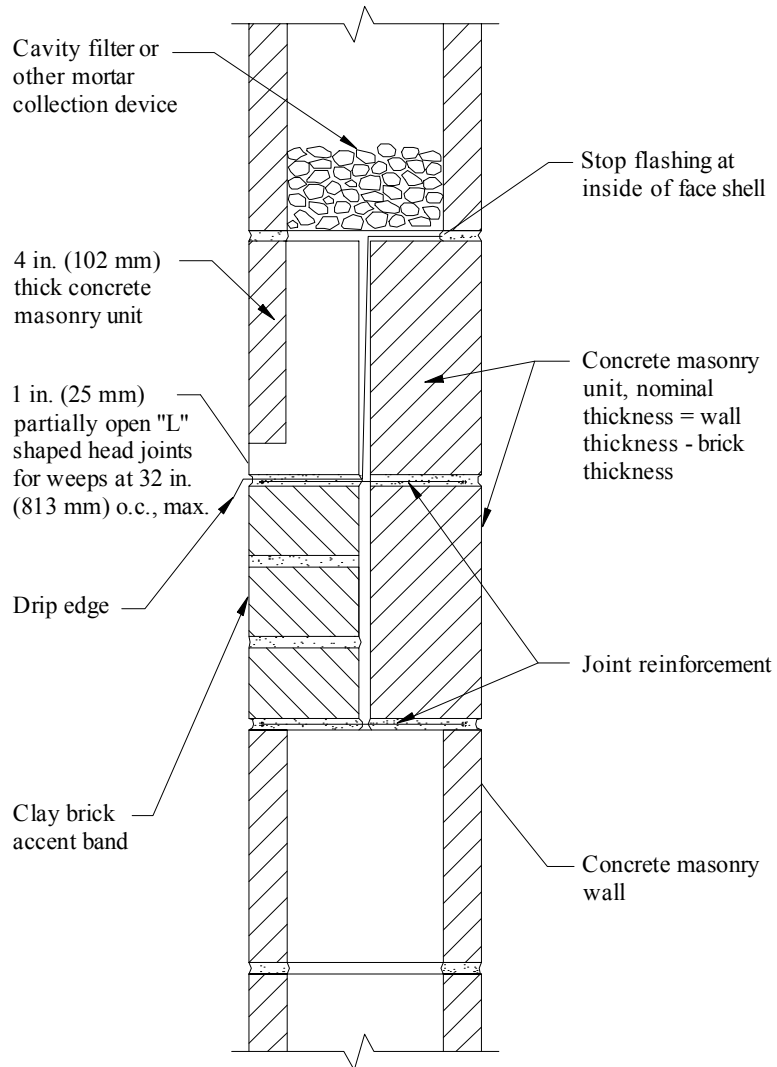
(b) Expansion Joint Plan View for Clay Brick
(Control joint in concrete masonry is similar,
except it may contain a raked out mortar joint)

Multi-Course Clay Brick Band in Loadbearing Concrete Masonry Wall

In single wythe construction, flashing and weep holes are used above the accent band to help remove any water that may accumulate in the wall. The use of two reduced thickness concrete masonry units allows flashing to be placed within the wall without causing a complete horizontal bond break at the flashing.

In reinforced walls, as shown in (b), flashing and weeps are also used. On the wall interior, rather than using reduced thickness units, a full size unit is cut to fit to allow adequate space for the reinforcement and grout.

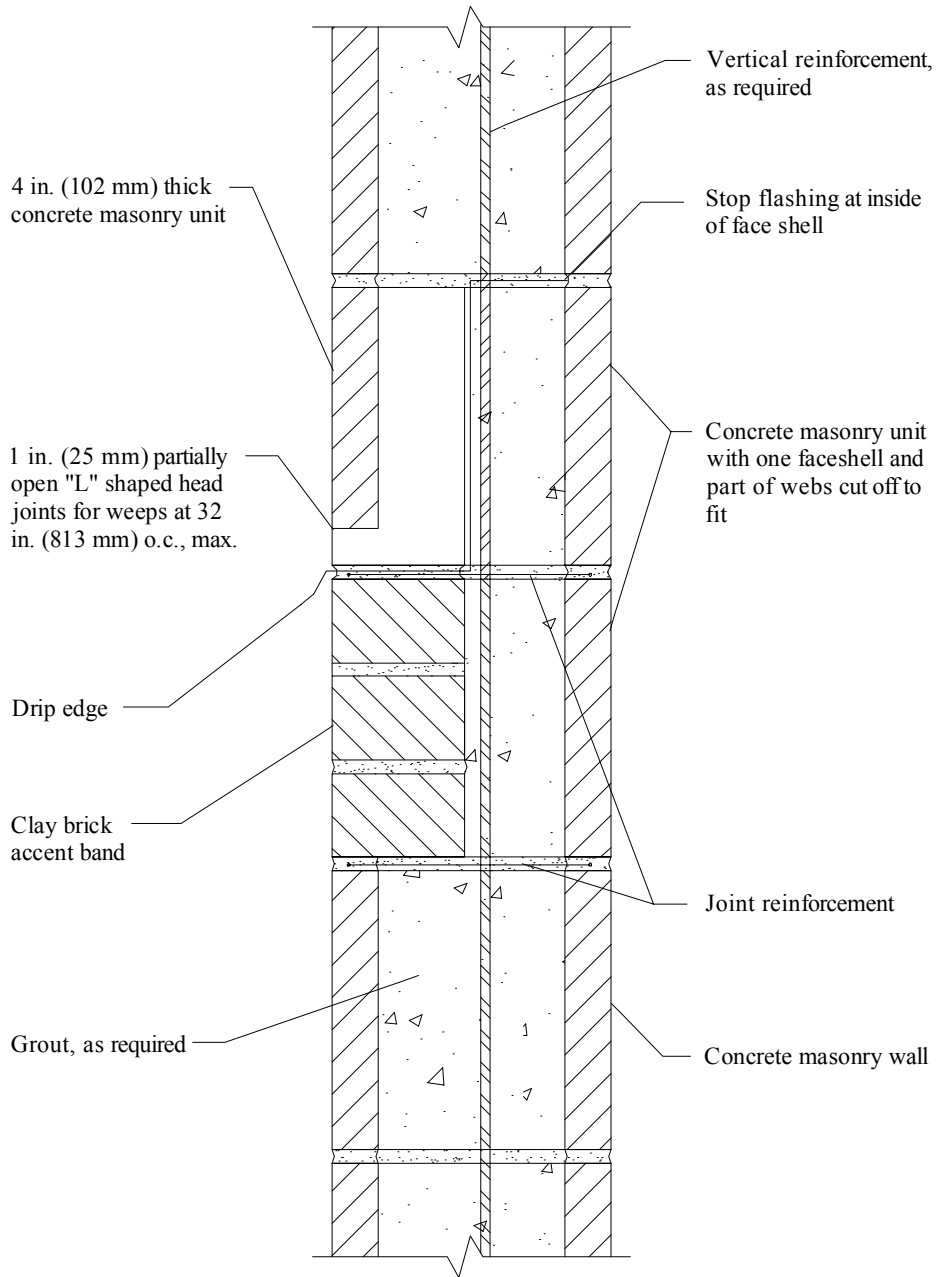
A cavity filter is any material used to prevent mortar droppings from clogging weeps, such as 2 inches (51 mm) of washed pea stone. This should be accompanied by a means of intercepting or dispersing mortar droppings, such as using proprietary devices at regular intervals or filling the cells with loose fill insulation a few courses at a time as the wall is laid up. As an alternative, every other veneer unit can be left out on top of the flashing to serve as cleanouts until the wall is completed.



(a) Unreinforced Wall

Last Modified: December, 2002

Multi-Course Clay Brick Band in Loadbearing Concrete Masonry Wall



(b) Reinforced Wall

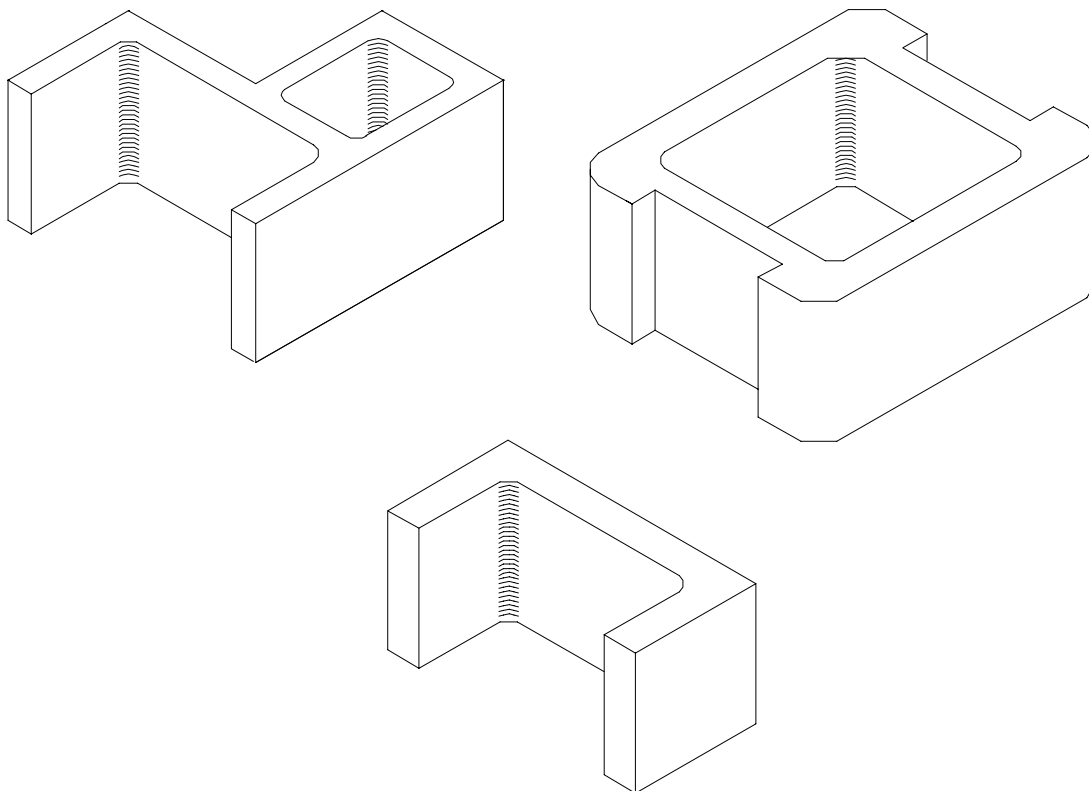
9E — Pilasters

A pilaster is a thickened wall section which projects beyond one or both wall faces, providing lateral stability to the masonry wall it is a part of. A pilaster may be constructed as an integral part of the wall or, where provision for crack control is desired such as at control joints, it may be constructed as an unbonded structural member where lateral support is provided by using suitable connections.

When subjected to little or no vertical load other than their own weight, pilasters serve as flexural members or vertical beams. In this application, pilasters must be able to resist bending while transferring applied loads from the walls to the roof and foundation systems. Lateral ties in the pilaster may not be necessary, although they will help hold the masonry units together during grouting and help the pilaster perform as an integrated assembly.

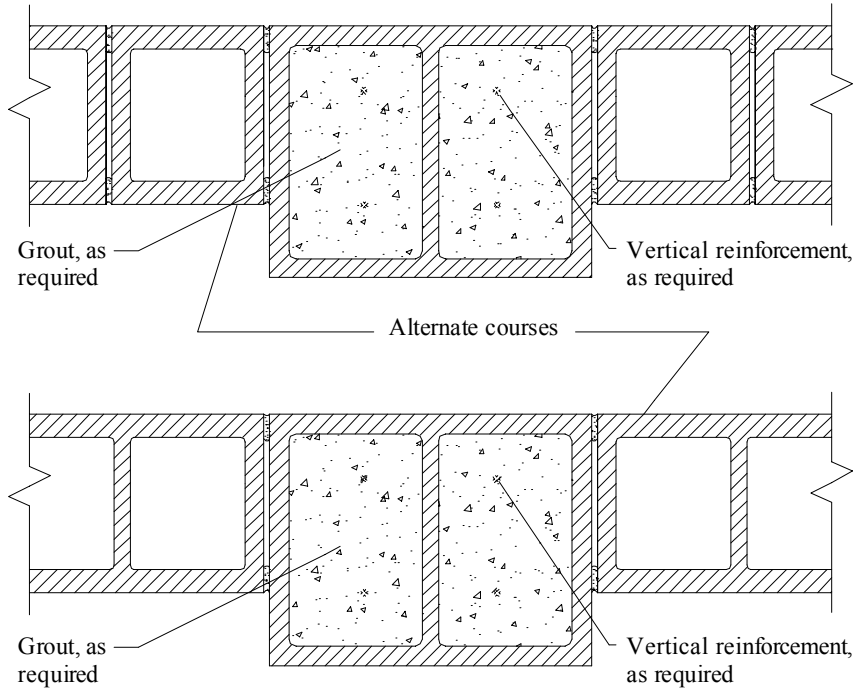
While the primary purpose of a pilaster is to provide lateral support, in some cases it may also need to support vertical loads, such as those imposed by beams or other framing members.

In addition to conventional concrete masonry units, other concrete masonry unit shapes may be available specifically for pilaster construction (shown below).

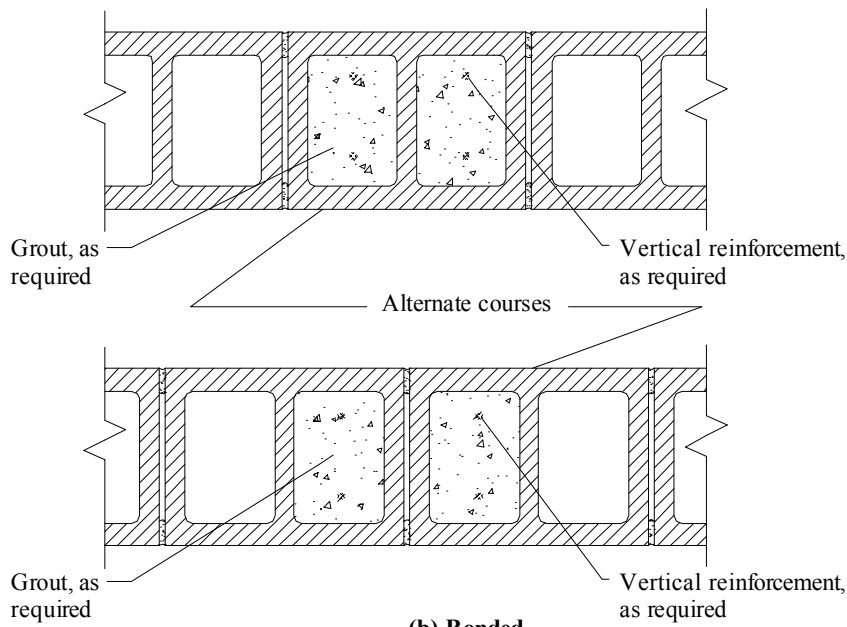


Pilaster Units

16 x 12 Inch (406 x 305 mm) Pilasters

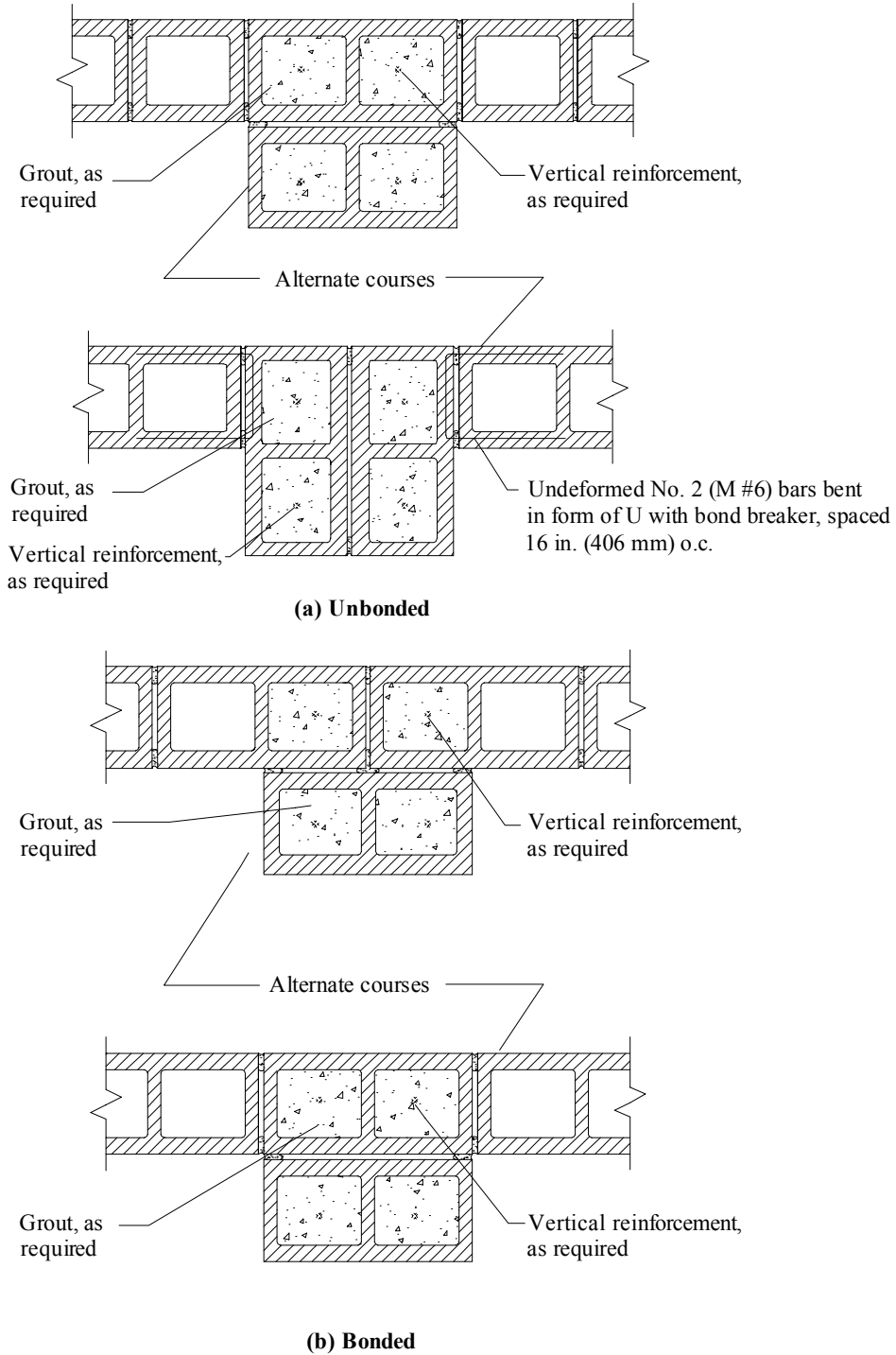


(a) Unbonded



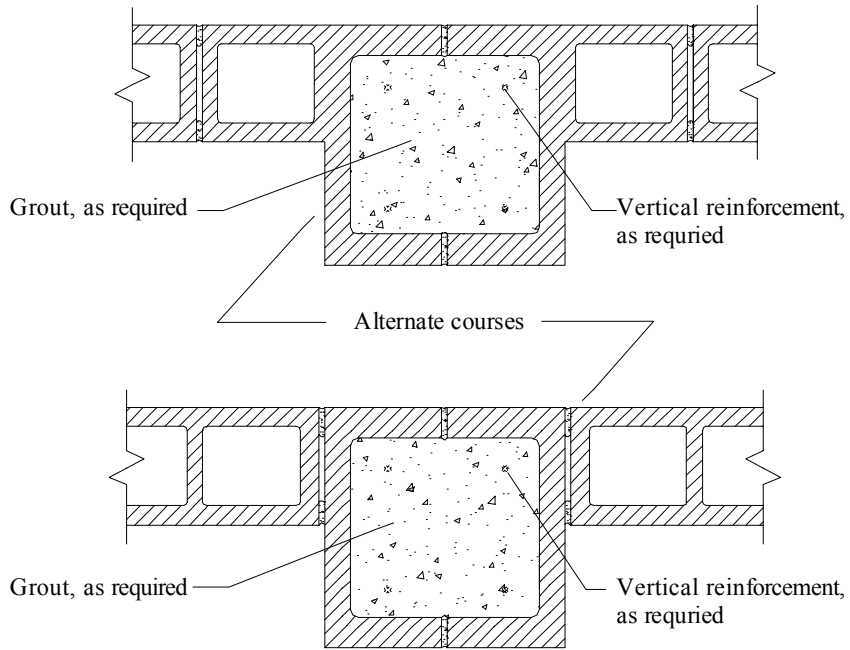
(b) Bonded

16 x 16 Inch (406 x 406 mm) Pilasters



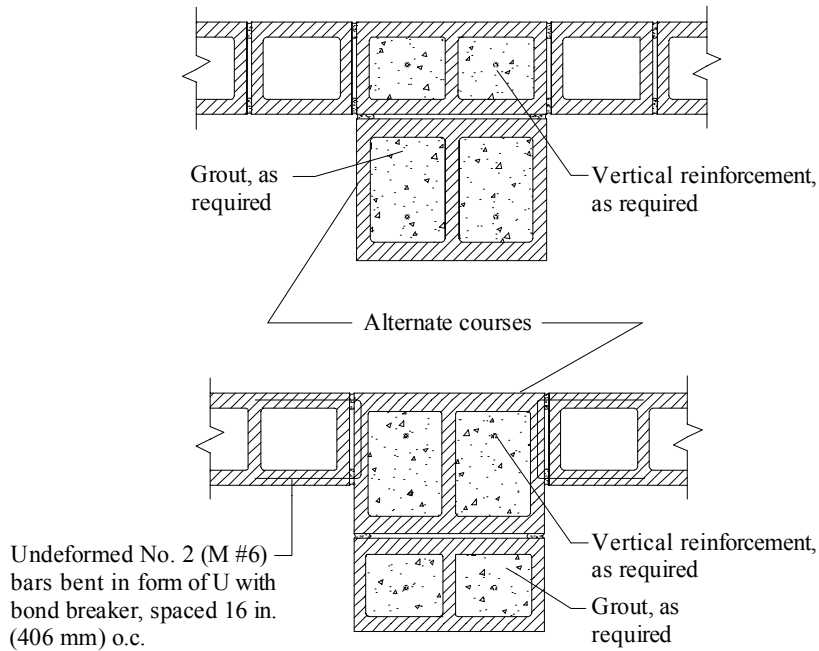
Last Modified: December, 2002

16 x 16 Inch (406 x 406 mm) Pilasters

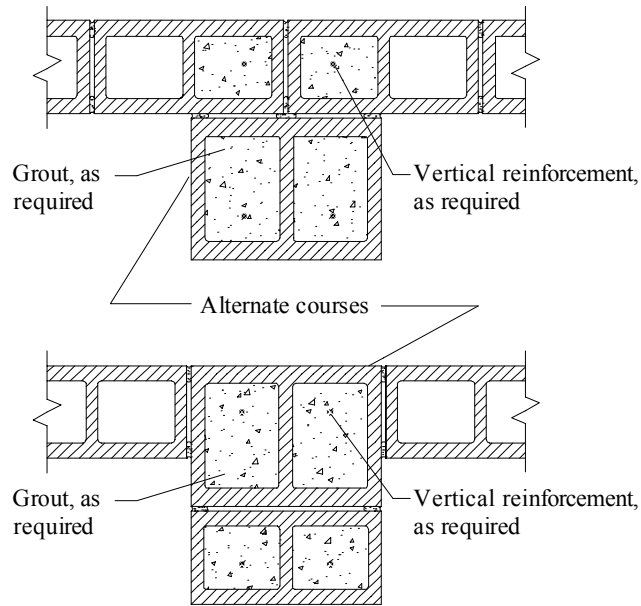


(c) Bonded, Alternate Using Special Units

16 x 20 Inch (406 x 508 mm) Pilasters



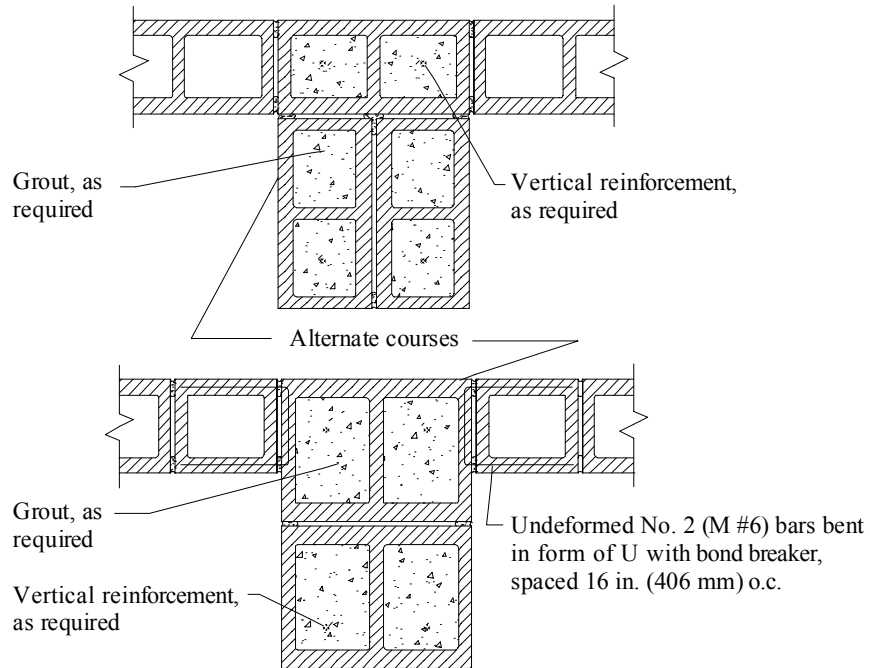
(a) Unbonded



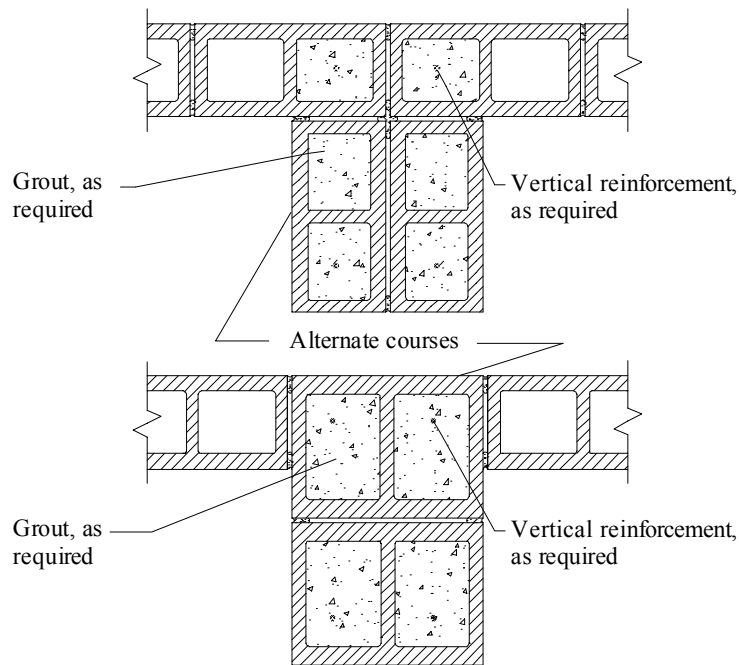
(b) Bonded

Last Modified: December, 2002

16 x 24 Inch (406 x 610 mm) Pilasters



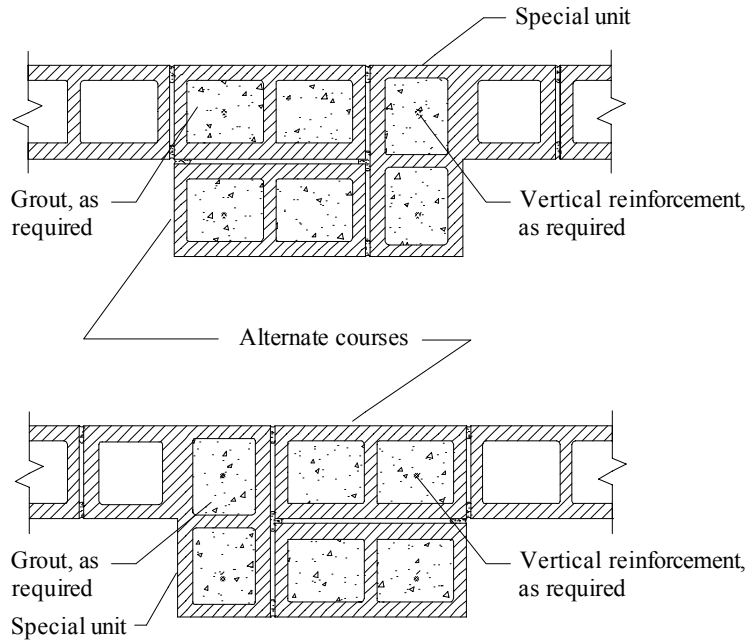
(a) Unbonded



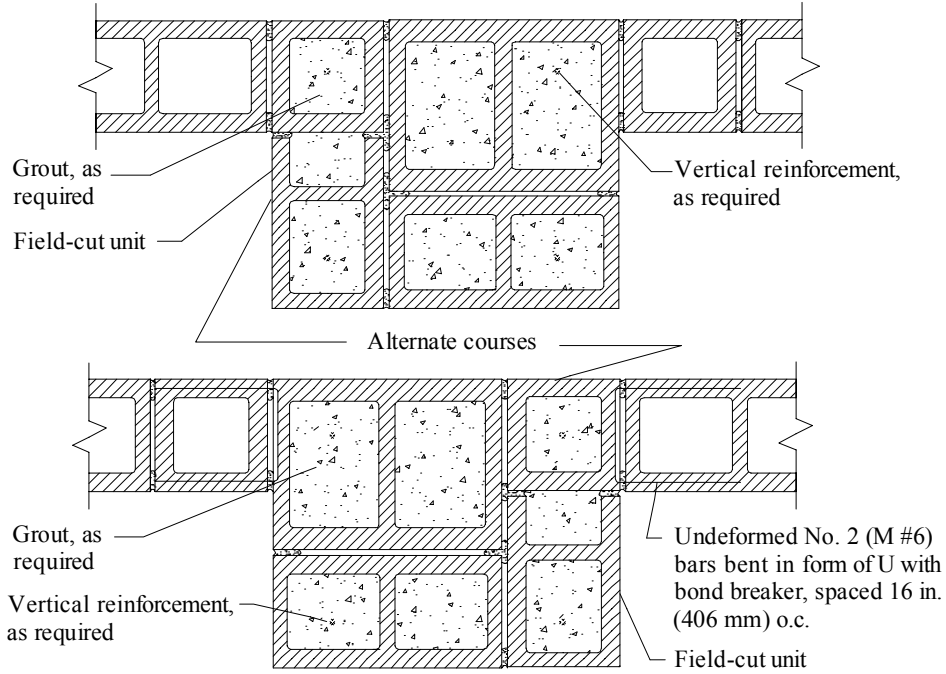
(b) Bonded

Last Modified: December, 2002

24 x 16 Inch (610 x 406 mm) Bonded Pilasters



24 x 20 Inch (610 x 508 mm) Pilasters

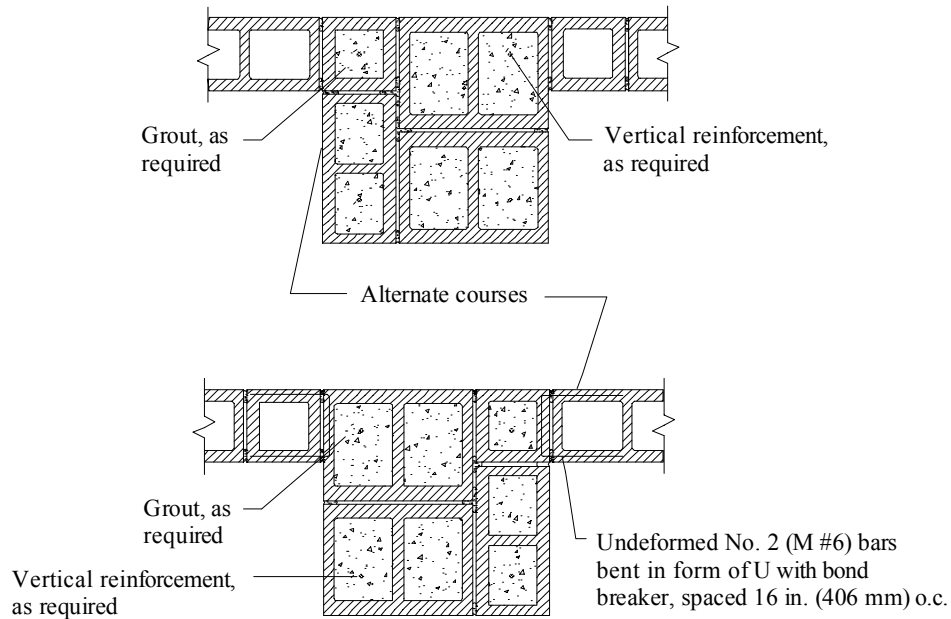


(a) Unbonded

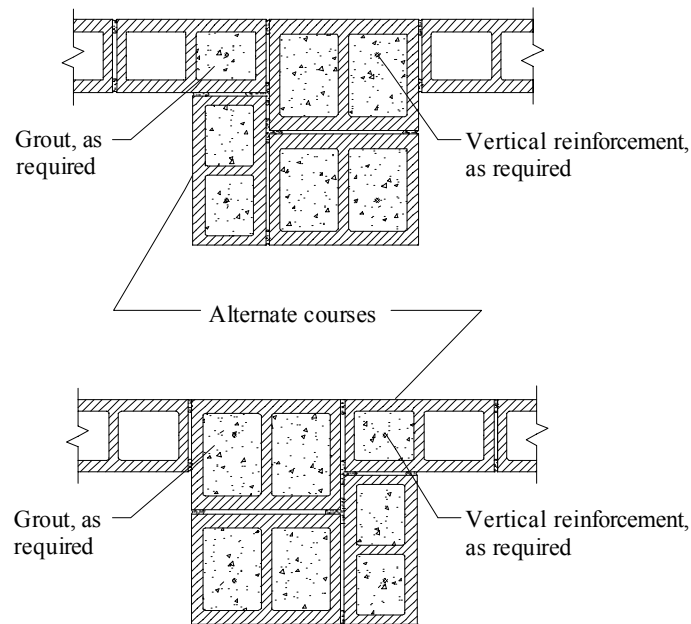
(b) Bonded

Last Modified: December, 2002

24 x 24 Inch (610 x 610 mm) Pilasters



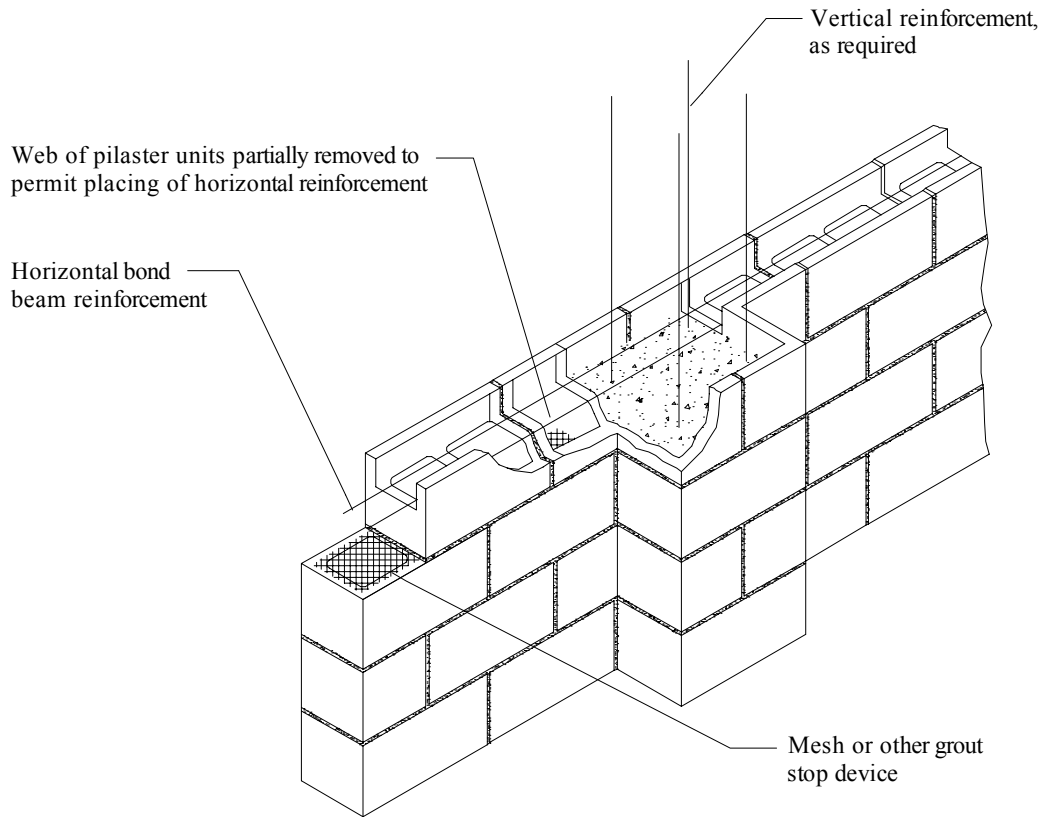
(a) Unbonded



(b) Bonded

Last Modified: December, 2002

Pilaster with Continuous Bond Beam



9F — Glass Unit Masonry

Glass unit masonry can be used as nonloadbearing walls, windows or as partitions. *Building Code Requirements for Masonry Structures* (Ref. 9.1) contains prescriptive requirements that govern panel size, panel support, expansion joints, mortar and joint reinforcement.

Because they are nonloadbearing, glass unit masonry panels must be structurally isolated from the surrounding wall to prevent structural loads from being imparted to the panel. Lateral support is provided along the top and sides of each panel using either channel-type restraints or panel anchors (see Figures 9F.1 and 9F.2). However, when the glass unit masonry panel is only one unit high or one unit long, lateral support is not required at the sides or top, respectively.

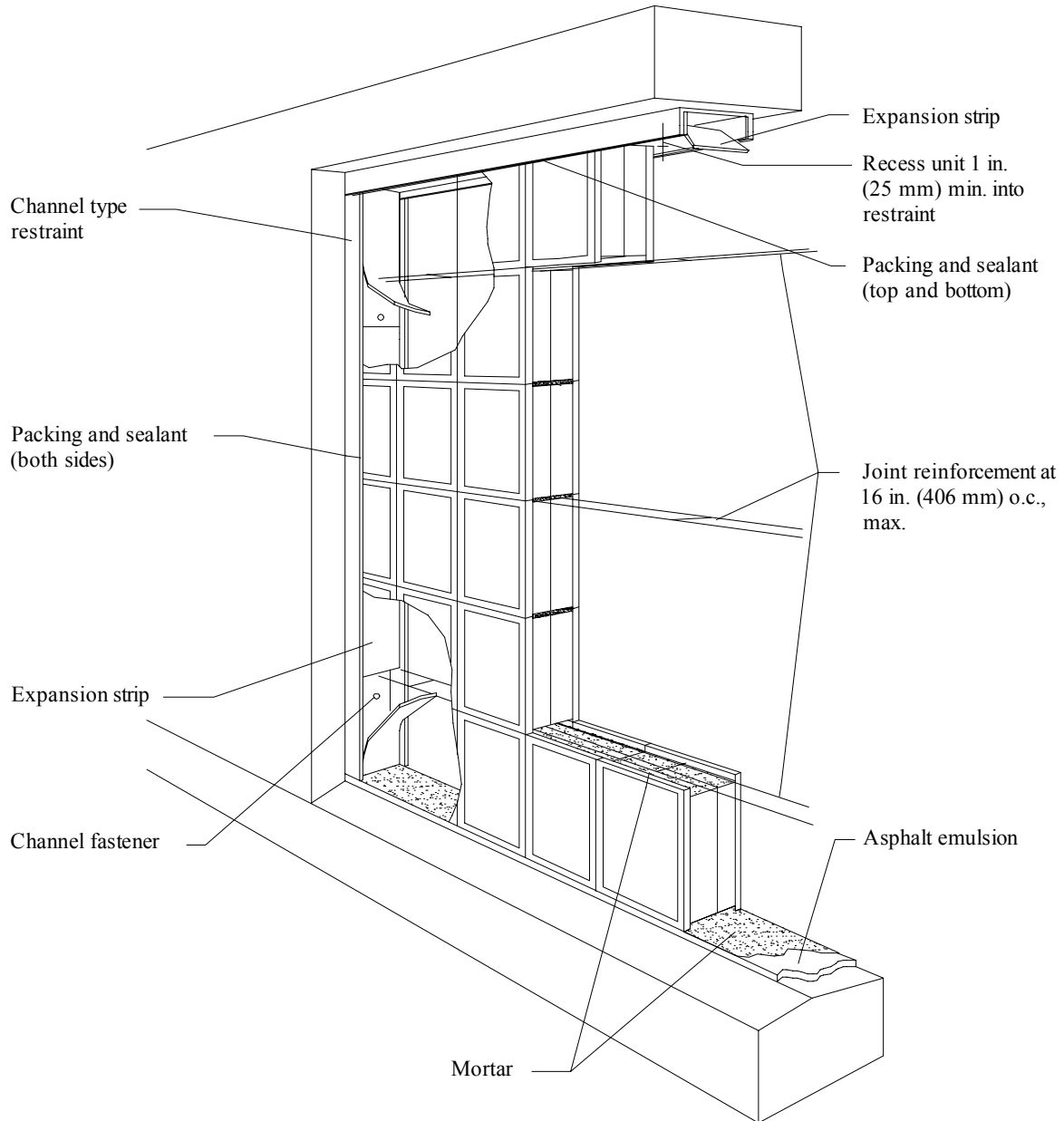
Expansion joints are required along the top and sides of glass unit masonry panels to accommodate movement of the surrounding materials. Horizontal joint reinforcement, spaced at 16 inches (406 mm) o.c. maximum, is also important to control cracking due to expansion and contraction. As with concrete masonry, the joint reinforcement should not extend across movement joints.

Glass unit masonry is typically constructed in stack bond (with vertical mortar joints aligned) with nominal $\frac{1}{4}$ inch (6.4 mm) thick mortar joints, using full mortar beds and Type N or S mortar. Because glass is not absorptive, mortar for glass units should be mixed drier than for other masonry materials. In addition, mortar should not be retempered after initial set, and should be discarded if not used within $1\frac{1}{2}$ hours after initial mixing.

Curved panels can be constructed using either rectangular units or radial units which are tapered to allow smaller radii. Curved panels require additional support where the curved sections abut straight sections and at inflection points in multicurved walls.

Glass Unit Masonry With Channel-Type Restraints

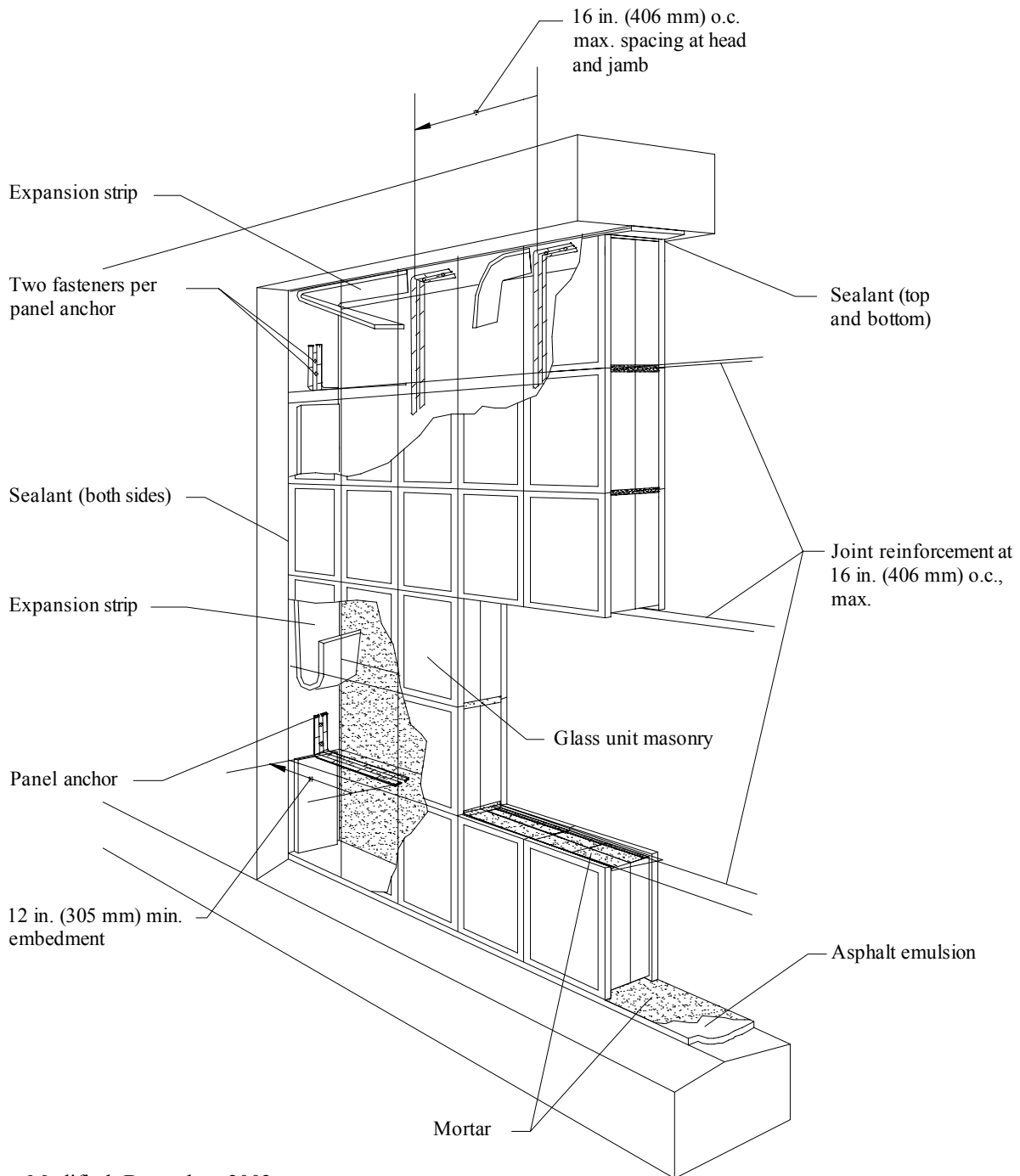
Channel-type restraints provide a physical chase which holds the glass units. The channel must be sized to accommodate expansion material between the panel and the restraint in addition to the minimum 1 inch (25 mm) recess for the glass units. If the glass unit masonry panel is made up of a single glass unit, channel-type restraints must be used. Channels may be constructed of concrete, masonry, metal or wood.



Last Modified: December, 2002

Glass Unit Masonry With Panel Anchors

Panel anchors are perforated steel straps which are fastened to the building frame on one end, while the other end is embedded into the mortar joint between two units. Panel anchors are typically 1 3/4 inch (19 mm) wide, 24 inch (610 mm) long 20 gage steel strips, punched with three staggered rows of elongated holes. The holes provide a mechanical bond between the mortar and the anchor. Galvanizing, applied after manufacture, provides corrosion protection.



Last Modified: December, 2002

9G — Fire Wall Construction

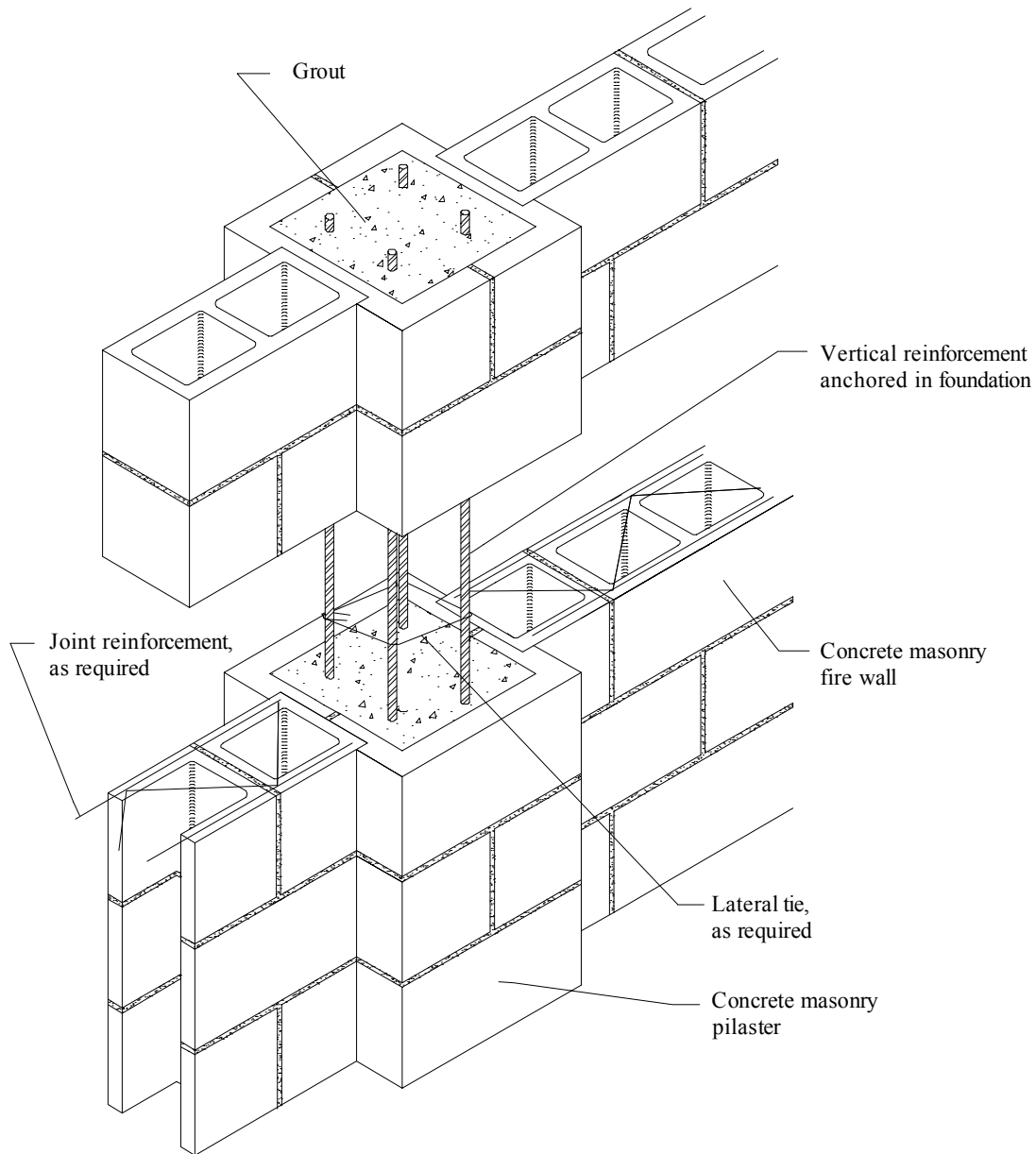
Fire walls are designed to keep fire from spreading from one compartment or building to another. While building codes differ slightly on the definition and the minimum fire resistance ratings of fire walls, the following general principles apply. First, the wall is constructed of noncombustible materials and all openings are protected. It must extend continuously from the foundation to or through the roof, and be strong enough during a fire to allow collapse of construction on either side without collapse of the wall.

Types of fire walls include free standing, cantilevered, tied and double wall construction. The types of walls are distinguished from each other by the method used to support the fire wall.

For details of fire rated control joints, see Section 2C.

Free-Standing Fire Wall

Free-standing walls are unsupported at the top and do not rely on the building frame for structural stability. Stability may be provided in the horizontal span by pilasters, which are designed as reinforced cantilever beams.



Laterally Supported Fire Wall

Laterally supported fire walls utilize typical break-away connectors manufactured with metals having melting points lower than structural steel (generally about 800° F (427 C)) so that they will give way in the event of fire.

Cantilevered walls are identical except without the break-away connectors at the top. Stability in this case is provided by vertical reinforcement and cantilever support at the base of the wall.

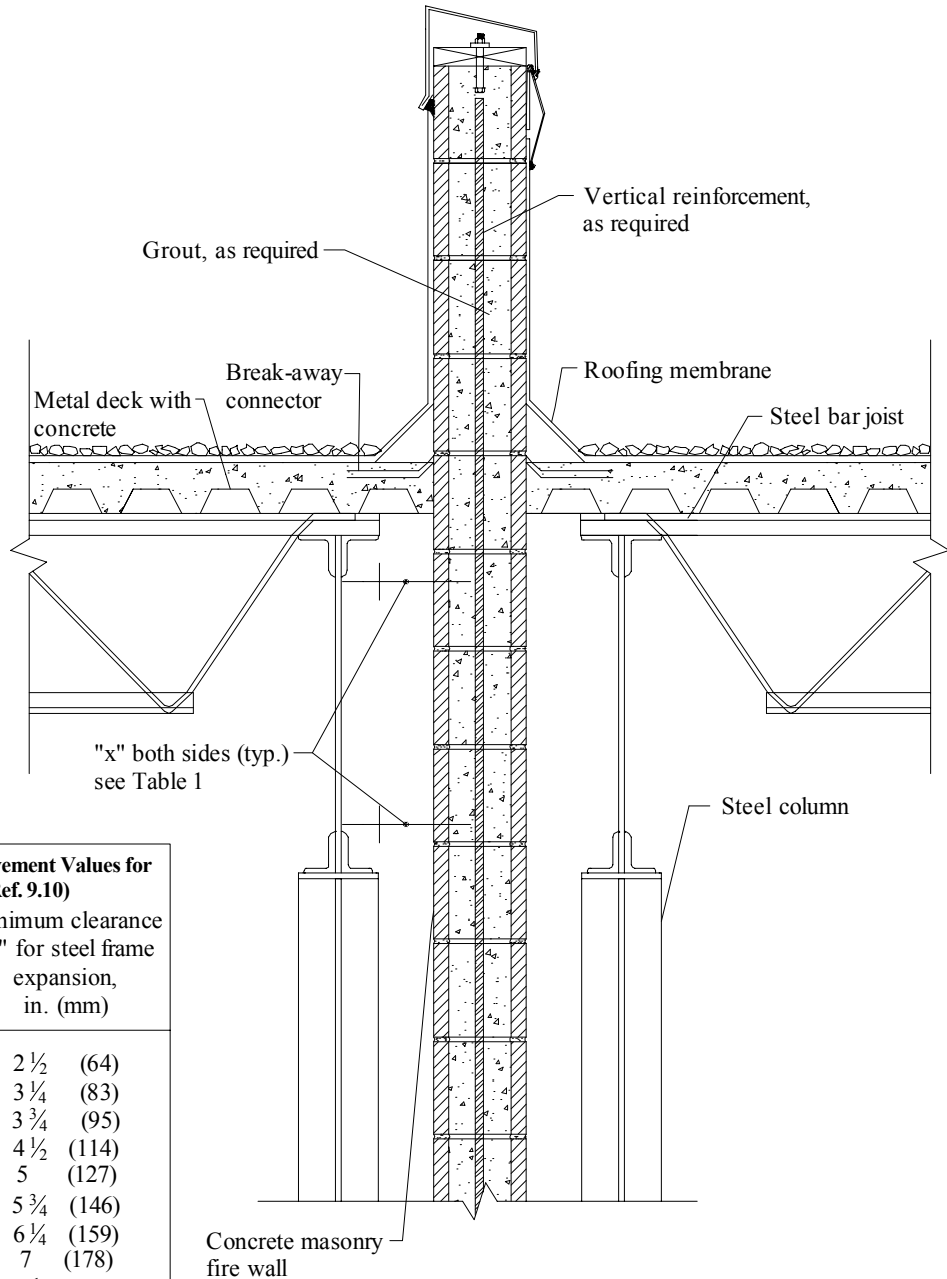


Table 1 — Thermal Movement Values for Steel Frames (Ref. 9.10)

Length of bay perpendicular to fire wall ft (m)	Minimum clearance "x" for steel frame expansion, in. (mm)
20 (6.10)	2 ½ (64)
25 (7.62)	3 ¼ (83)
30 (9.14)	3 ¾ (95)
35 (10.67)	4 ½ (114)
40 (12.19)	5 (127)
45 (13.72)	5 ¾ (146)
50 (15.24)	6 ¼ (159)
55 (16.76)	7 (178)
≥60 (18.29)	7 ½ (191)

Last Modified: December, 2002

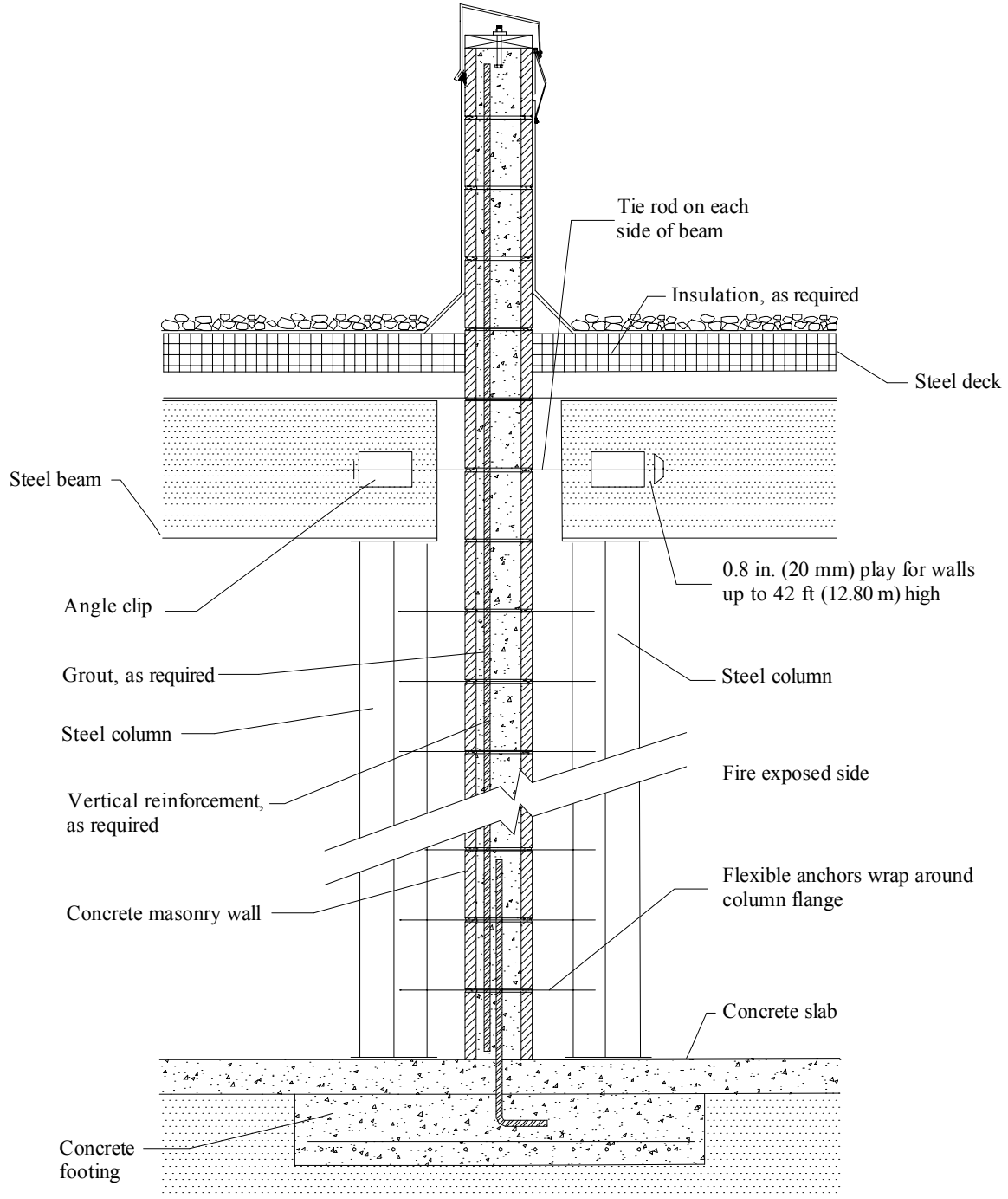
Tied Fire Wall

Tied walls rely on the building frame for lateral stability. The framework is tied together such that forces due to the collapse of the structure on one side of the fire wall are resisted by the structural framework on the other side of the wall. It is important that framing members immediately adjacent to the wall are protected to the required fire resistance rating period to ensure they will not collapse during the fire. Adequate clearance between the framing steel and the concrete masonry fire wall is necessary to allow steel expansion without exerting pressure on the wall.

Detail (a) shows a tied wall between two rows of steel columns and beams or trusses which are aligned both vertically and horizontally on both sides of the wall. Lateral support for the fire wall is provided by flexible metal anchors which wrap around the column flanges, and by through-wall ties at the beam level. These anchors and ties are shown in Figure 9G.4.

As an alternative, (b) shows the fire wall constructed in a single column line by tying the top of the wall to horizontal steel framing located directly over the top of the wall and spanning in the same direction. In this case the fire wall will also be tied to, and completely encase, the steel columns.

Tied Fire Wall

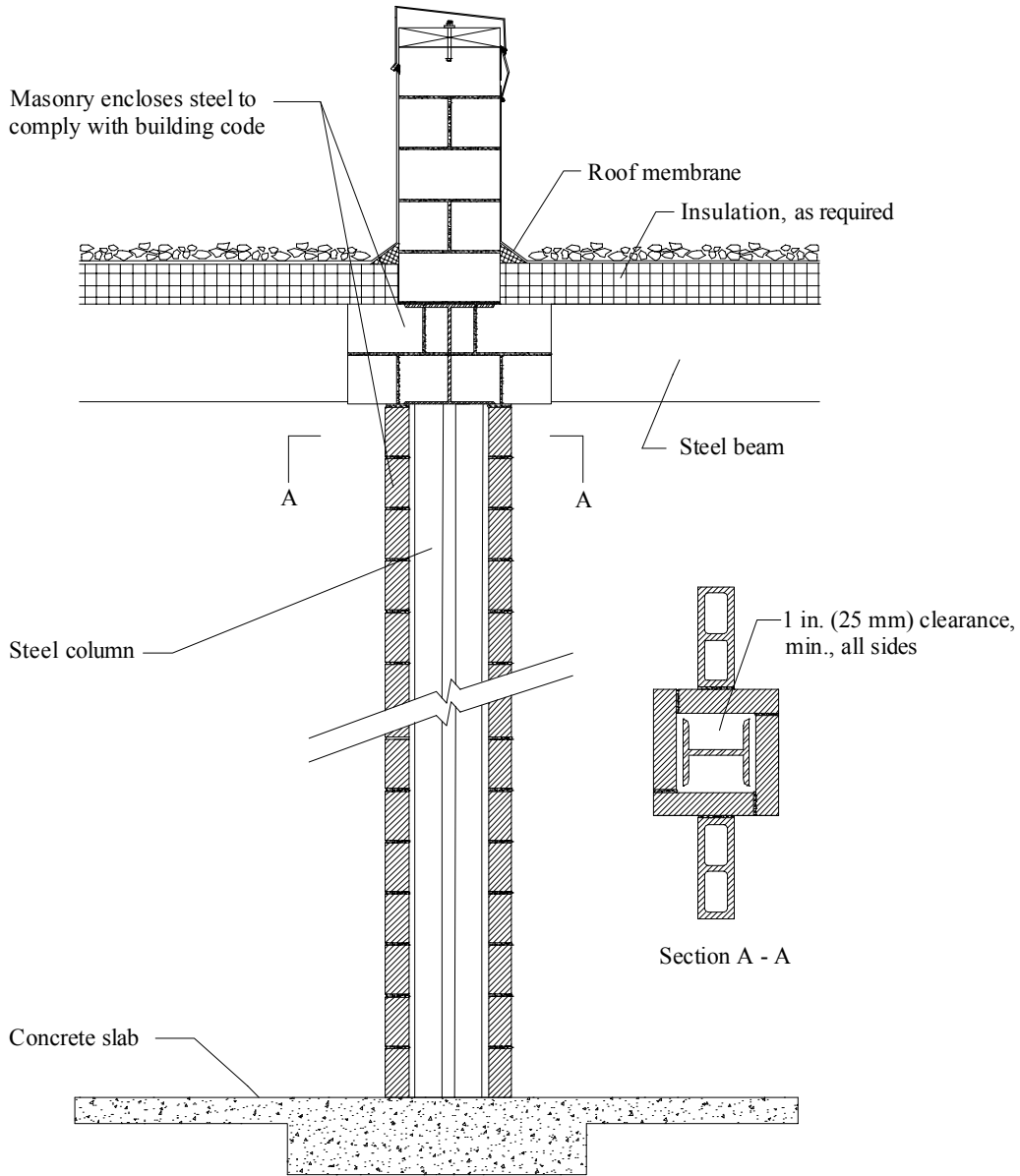


(a) Double Column Method

Last Modified: December, 2002

Tied Fire Wall

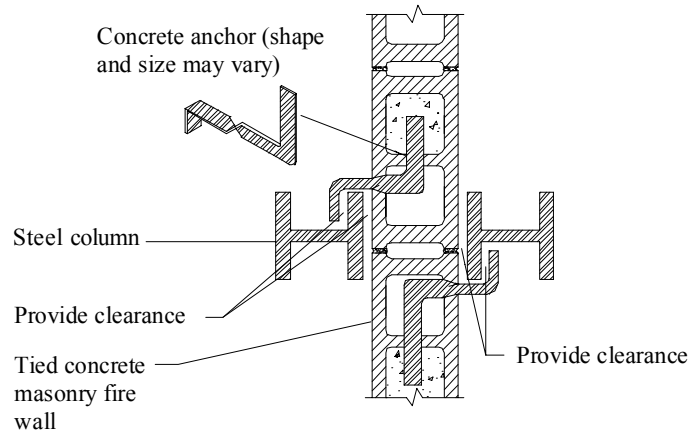
At the steel beam, detailing to enable the support of the concrete masonry, and thus complete the integrity of the fire wall, will depend on the framing layout.



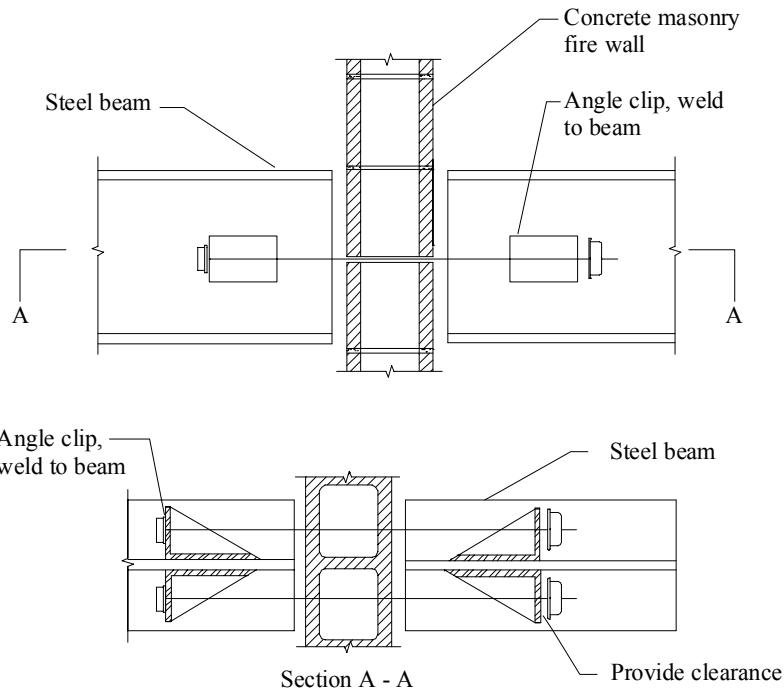
(b) Single Column Method

Anchors and Ties for Tied Fire Walls

The maximum clearance for flexible anchors should be 0.8 inches (20 mm) for walls up to 40 feet (12.19 m) high and an additional 0.2 inches (5.1 mm) for every additional 10 feet (30.48 m) of wall height. For through-wall ties, the clearance should be 0.8 inches (20 mm) for walls up to 42 feet (12.80 m) high.



(a) Flexible Anchors

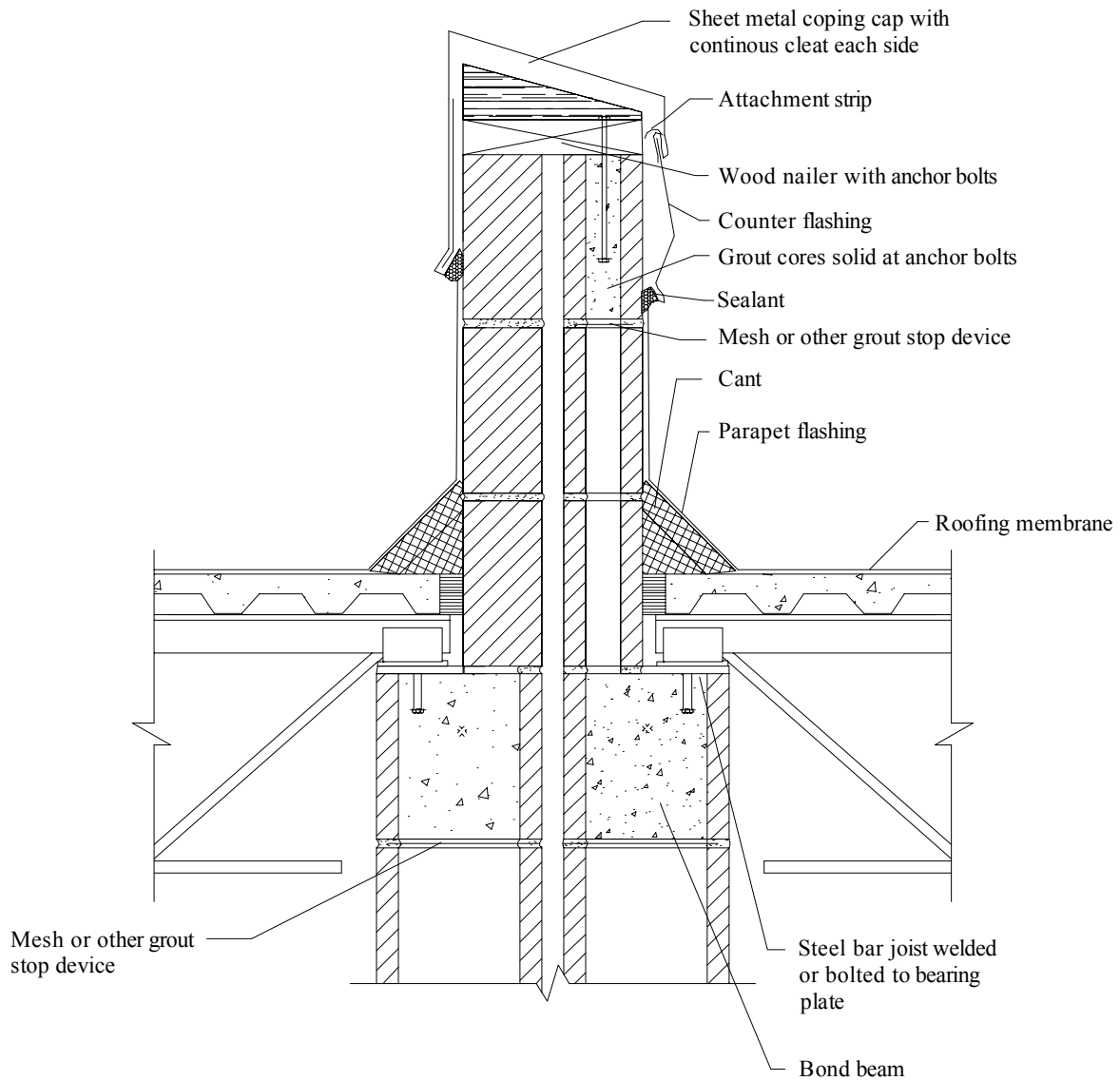


(b) Through-Wall Ties

Last Modified: December, 2002

Double Wall Fire Wall

Double wall construction uses two independent concrete masonry wythes side by side. In the event one wall is pulled down due to fire, the other wall remains intact, preventing fire spread. Floor and roof connections to each wythe are the same as for conventional concrete masonry construction (see Chapter 6).



Last Modified: December, 2002

9H — Sound Wall Construction

Concrete masonry controls noise in two ways: by reducing the amount of sound coming through the wall from an outside source and by absorbing noise generated within a room. For sound absorption, performance is measured using a Noise Reduction Coefficient (NRC), which varies with the porosity and surface texture of the concrete masonry wall. Walls with more porous and open-textured surfaces are able to absorb more sound and hence have higher NRC values.

For sound isolation, higher density concrete materials tend to be more effective. This effectiveness is measured by the Sound Transmission Class (STC), with higher STC values indicating better sound insulation.

Building design and layout significantly affect sound transmission as well. Strategies which provide a longer path length for sound travel (such as spacing adjacent exterior windows farther apart) and which force sound diffusion by changing its direction (such as using offset hallway doors, rather than having them directly across from each other) will diminish sound transmission as well.

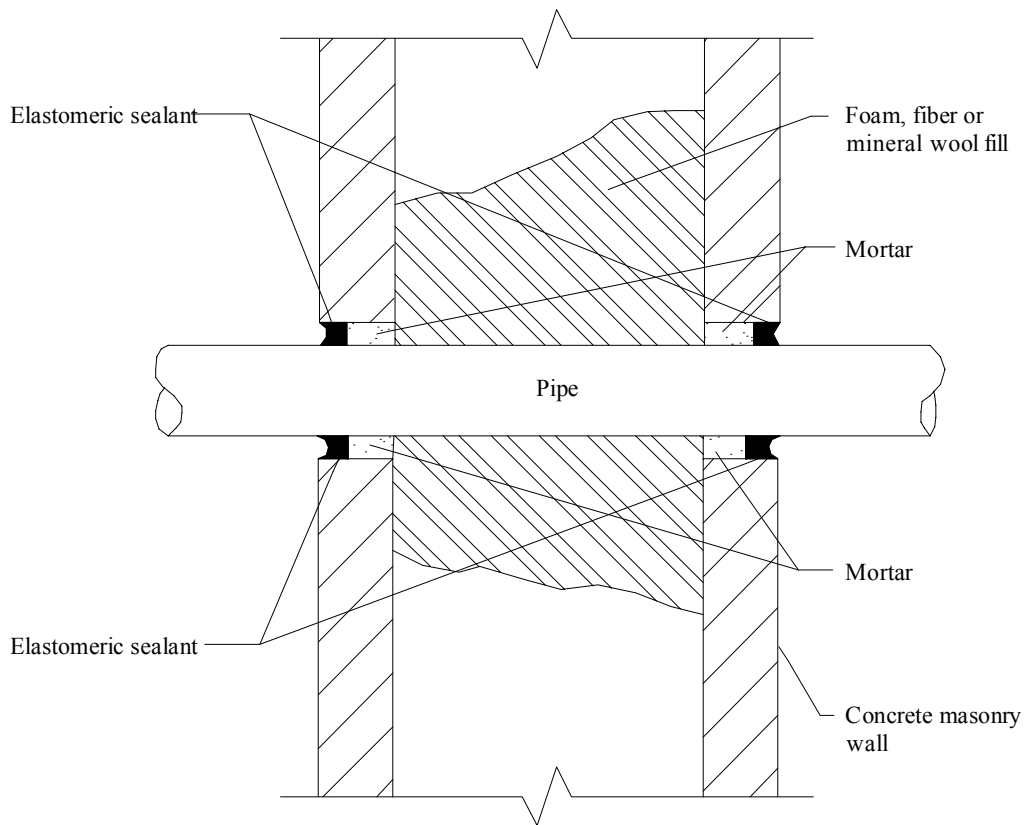
Any open area in the wall is vulnerable to sound transmission. Because the impact of these openings on the overall sound transmission is difficult to quantify, it is prudent to seal all holes, cracks, voids and wall penetrations to maintain the rated STC.

Walls rated for fire resistance must also meet the fire resistive construction requirements of the building code, including fire stopping of through-wall penetrations and using fire resistive sealing materials.

Wall Penetrations

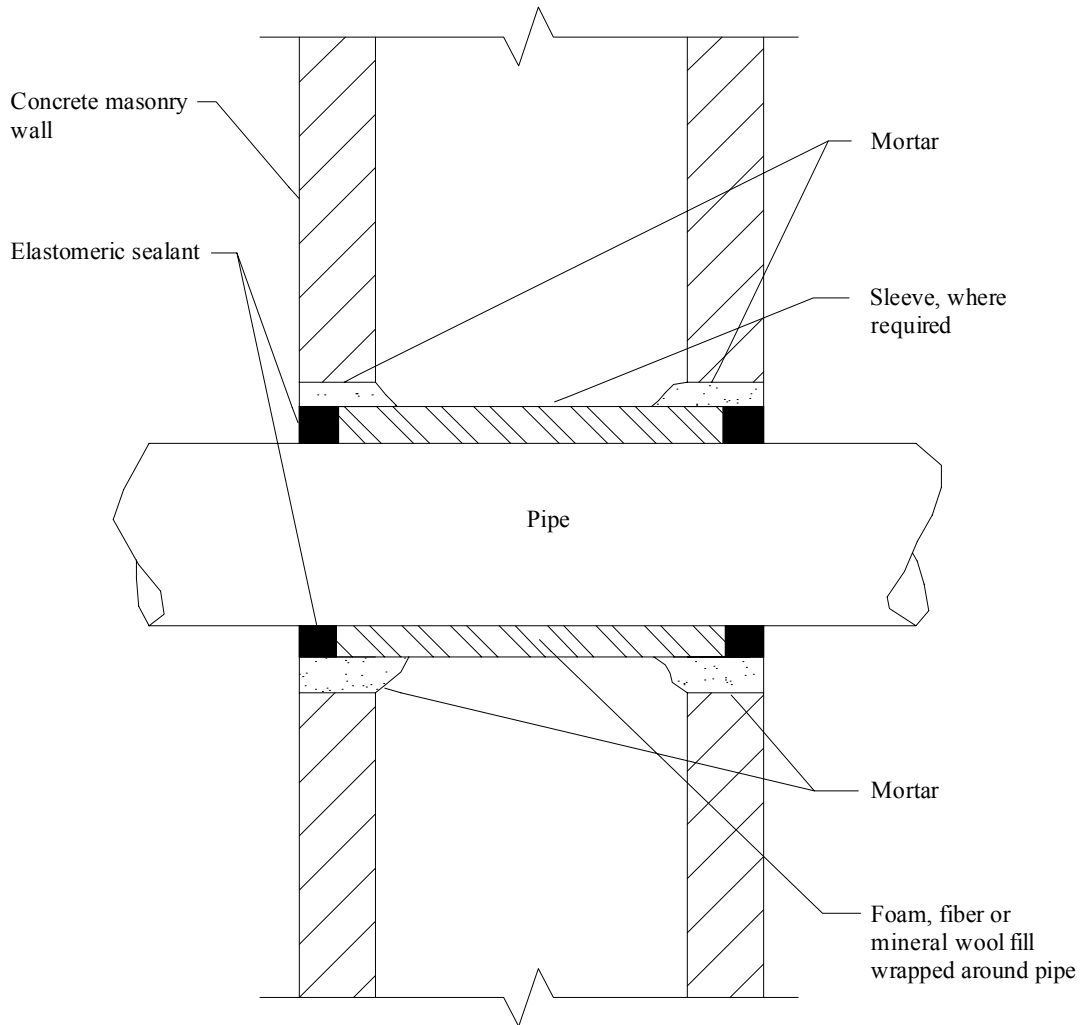
Through-wall openings and partial wall penetrations should be completely sealed, after first filling gaps with foam, cellulose fiber, glass fiber, ceramic fiber or mineral wool.

At control joints, the joint space behind the sealant backing should also be filled with mortar, grout, foam, cellulose fiber, glass fiber or mineral wool.



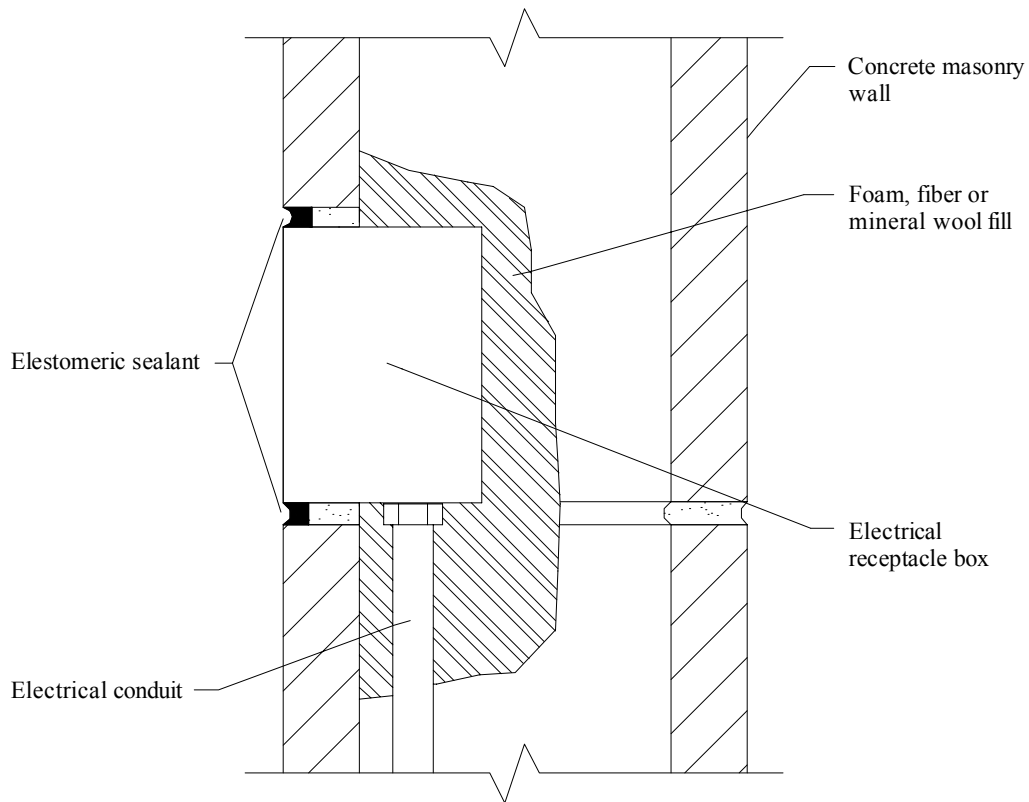
(a) Pipe Penetration

Wall Penetrations



(b) Pipe Penetration, Alternate

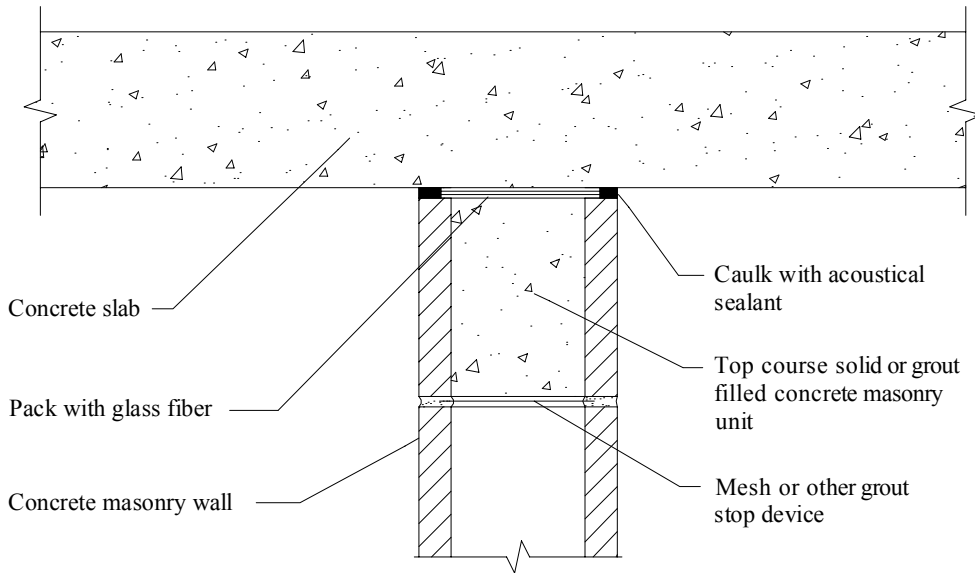
Wall Penetrations



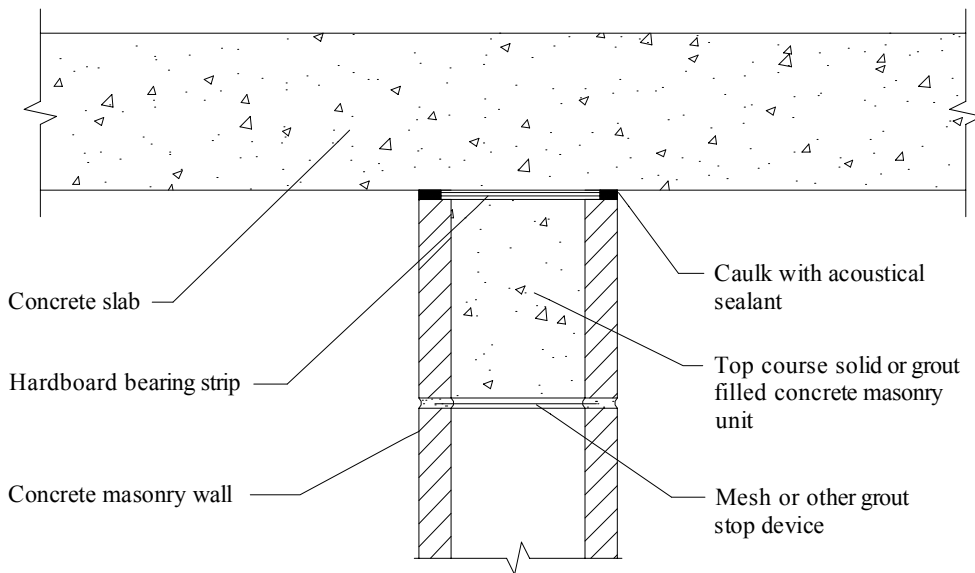
(c) Utility Box Penetration

Tops of Walls

Any gaps between a concrete masonry sound wall and the floor or roof above can allow sound transmission across the sound wall. Partitions should be carried to the underside of the structural slab. The joint between the two should provide for slab deflection and be sealed against sound transmission.



(a) Nonbearing Wall



(b) Bearing Wall

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9I — Arches

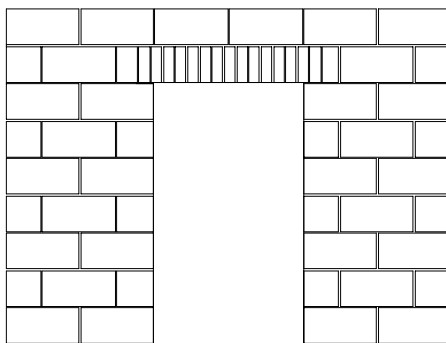
A masonry arch is as a rigid span typically curving upward between two support points. Arches are used in a wide variety of structures ranging from the purely decorative triumphal arch to the masonry arch bridge, where they sustain large loads. Arches are classified as either minor or major (see figure, below). Minor arches have spans of up to 6 feet (1.83 m) and rise-to-span ratios not exceeding 0.15.

Since any section of an arch may be subjected to shear, moment and thrust, it is important that arches be constructed with high quality materials and good workmanship. Concrete masonry units for arch construction should be either 100 percent solid units or should be filled solid. Bond is an important factor in building arches with sufficient shear resistance to withstand the imposed loads. To obtain good bond, all mortar joints in the arch need to be completely filled. This is sometimes difficult to achieve, especially where the concrete masonry units are laid in soldier bond or rowlock header bond. It may also be difficult where the arch has a tight curvature, and mortar joints of varying thickness are used. However, completely filled joints are paramount to a strong arch, and can be achieved with quality workmanship.

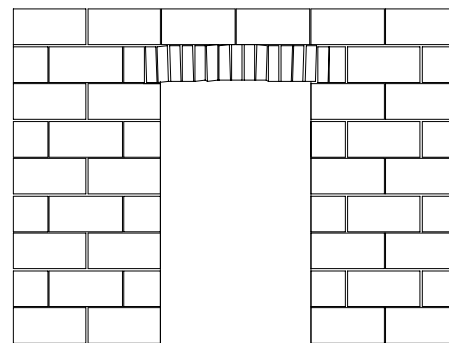
Concrete masonry arches are constructed using a form or temporary support. After construction, the form is kept in place until the arch is strong enough to carry the design loads. For unreinforced concrete masonry arches, the form should remain in place for about one week after construction.

Care should be taken when placing control joints adjacent to arches. If the arch is structural, control joints should be located so that they do not affect the integrity of the arch, which requires sufficient masonry mass to resist the horizontal thrust. Vertical control joints should not be placed in the masonry directly above a structural arch.

Minor Arches:

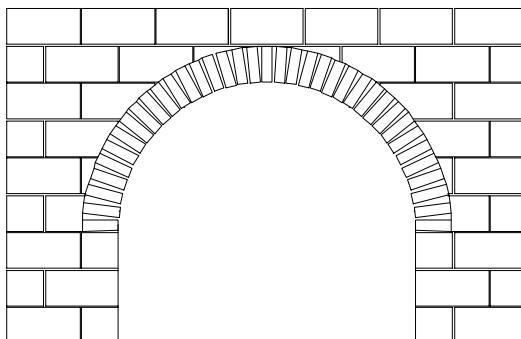


Flat or Jack

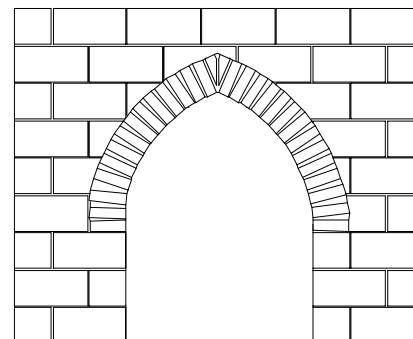


Segmental

Major Arches:



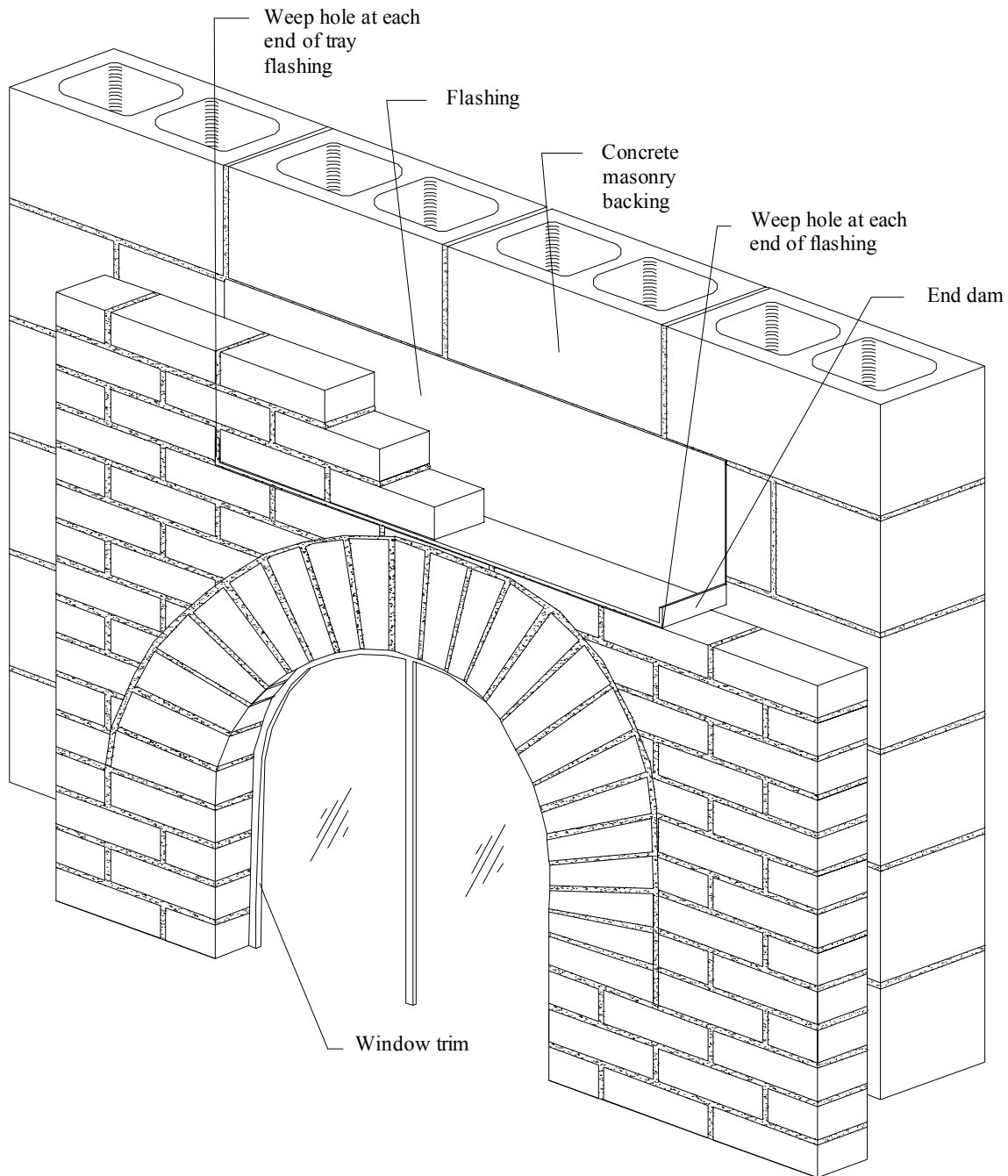
Round or Semicircular



Pointed or Gothic

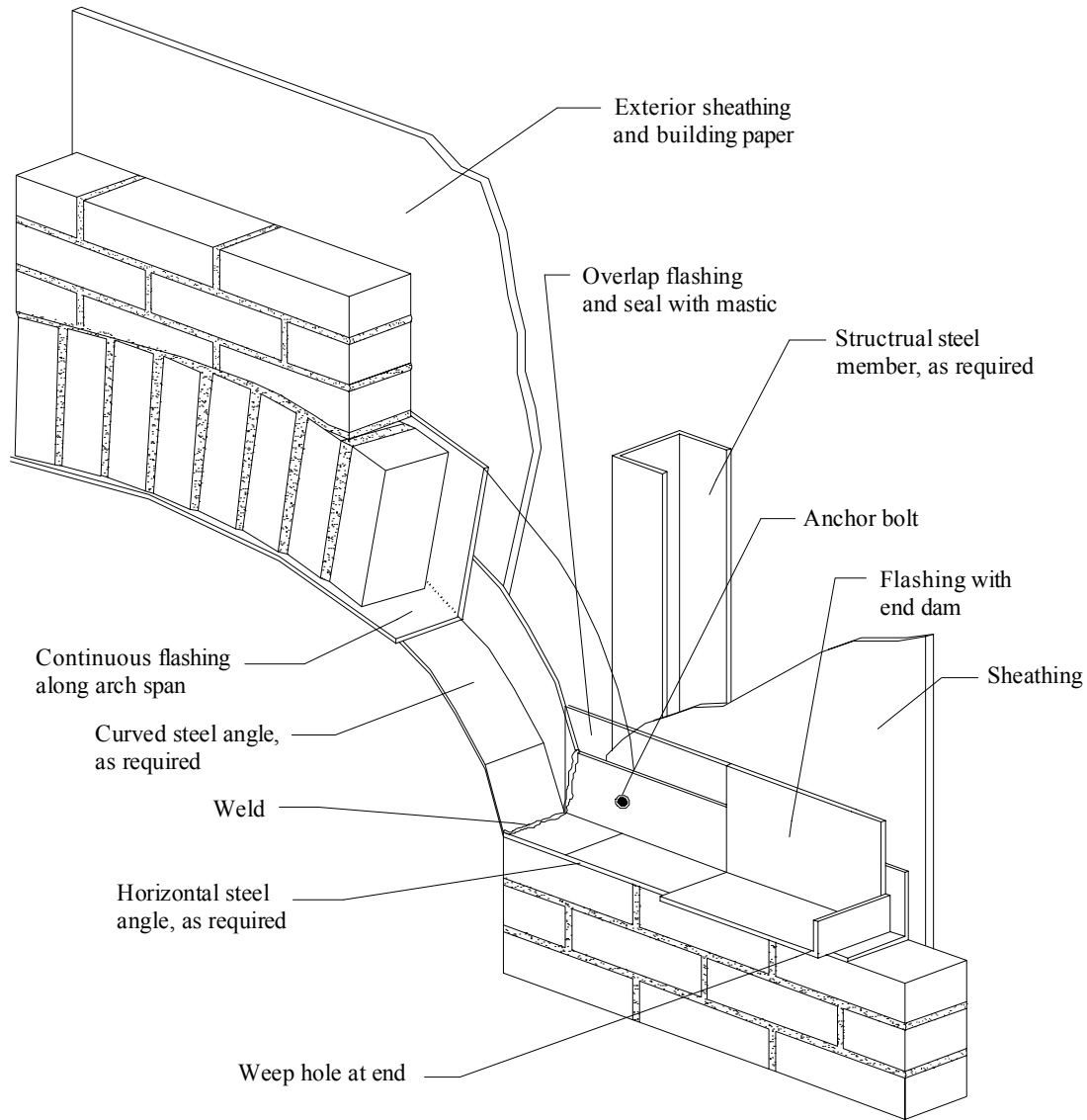
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Flashing Arches



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Steel Angle Support for Arch



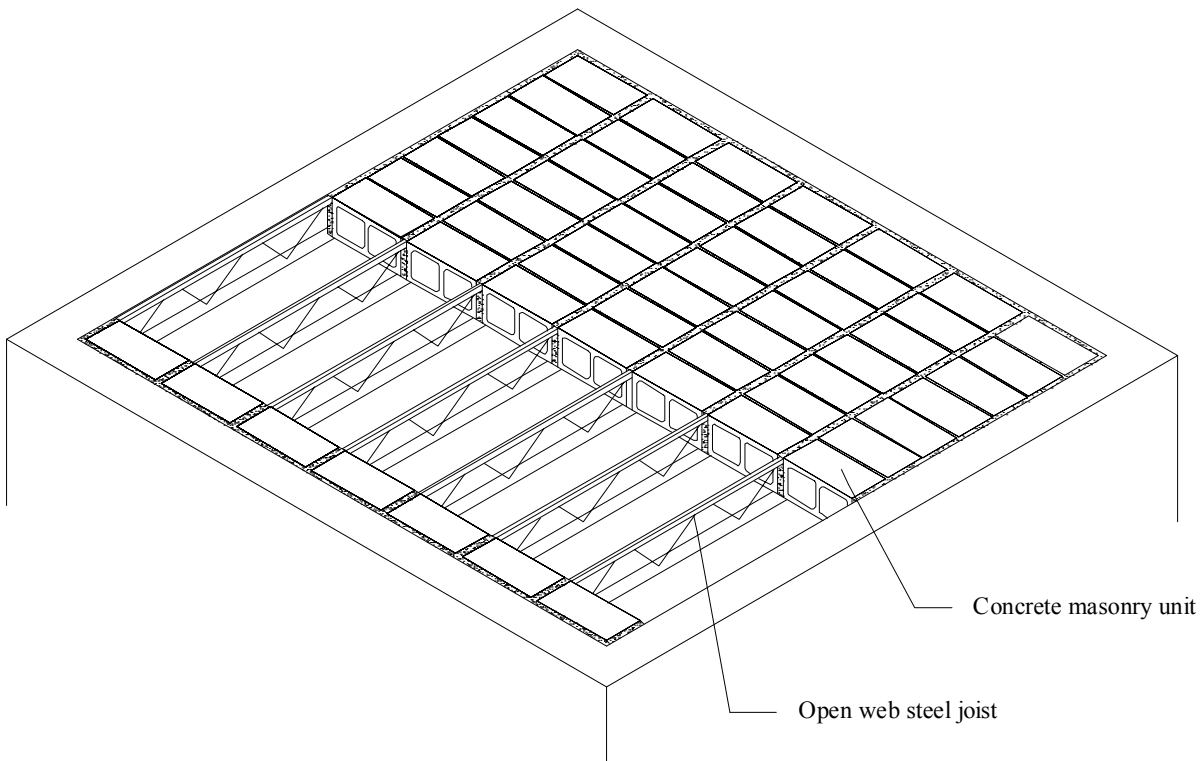
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9J — Masonry Floor System

Proprietary systems are available which utilize concrete masonry units for floor construction.

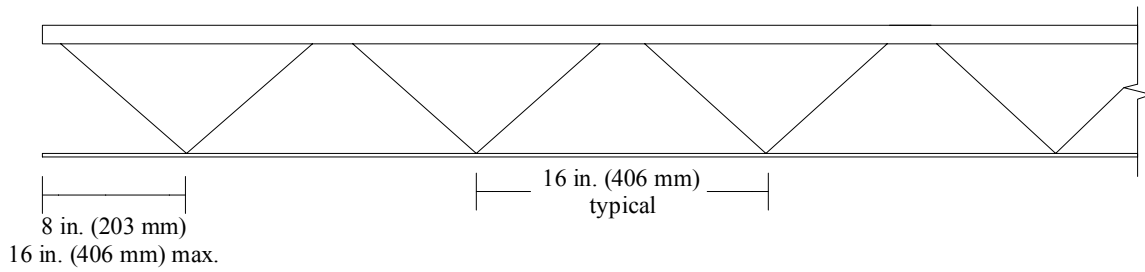
Concrete Masonry Floor System

The composite system shown is constructed by placing conventional concrete masonry units on steel bar joists which rest on a ledge within the wall. This system can be used for either floors or roofs. The patented open-web steel joists (see detail (b)) have a cross section detailed to support conventional concrete masonry units on the joists' bottom flanges. Laborers set individual units between pairs of joists then cap the surface with grout to form a finished surface and fill voids around the joists. The thickness of the grout can be increased to increase the assembly's fire resistance rating.

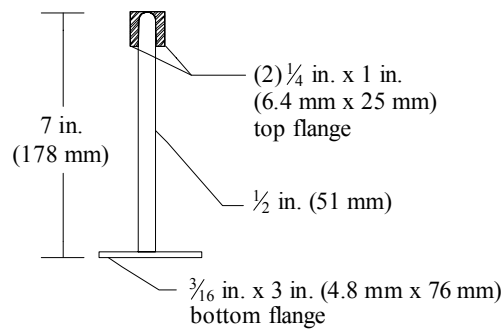


(a) Isometric

Concrete Masonry Floor System



Side Elevation



End Elevation

(b) Detail of Steel Joist

References:

- 9.1 *Building Code Requirements for Masonry Structures*, ACI 530-99/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
- 9.2 *Allowable Stress Design of Concrete Masonry Columns*, TEK 17-3A. National Concrete Masonry Association, 2001.
- 9.3 *Concrete Masonry Radial Walls*, TEK 5-10. National Concrete Masonry Association, 1988.
- 9.4 *Allowable Stress Design of Concrete Masonry Pilasters*, TEK 17-4A. National Concrete Masonry Association, 1995.
- 9.5 *Glass Unit Masonry*, TEK 2-2A. National Concrete Masonry Association, 1998.
- 9.6 *Details for Concrete Masonry Fire Walls*, TEK 5-8A. National Concrete Masonry Association, 1996.
- 9.7 *Sound Transmission Class Ratings for Concrete Masonry Walls*, TEK 13-1A. National Concrete Masonry Association, 2000.
- 9.8 *Building Code Requirements for Structural Concrete*, ACI 318-95. American Concrete Institute, 1995.
- 9.9 *Brick Masonry Arches*, Technical Notes 31. Brick Industry Association, 1995.
- 9.10 *Criteria for Maximum Foreseeable Loss Fire Walls and Space Separation, Loss Prevention Data, Factory Mutual Engineering Corp., 1985.*
- 9.11 *Concrete Masonry Walls for Metal Buildings*, TR 149. National Concrete Masonry Association, 1996.
- 9.12 *International Building Code*, International Code Council, 2000.

"A" block

Hollow masonry unit with one end closed by a cross web and the opposite end open or lacking an end cross web. Used with reinforced masonry construction. (See "Open end block.")

Absorption

The amount of water that a concrete masonry unit absorbs when immersed in water for a specified length of time, expressed as a percentage of the dry unit weight or as pounds of water per cubic foot of concrete. Usually, the lower the absorption, the more dense the masonry unit.

Accelerator

A liquid or powder ingredient added to a cementitious paste to speed hydration and promote early strength development. Accelerator materials include calcium chloride and compositions predominately of calcium chloride. Care should be taken when using accelerators as they may promote corrosion of any steel present.

Actual dimensions

(See "Dimensions, actual.")

Adhesion (bond)

(See "Bond.")

Adhesive anchor

An anchoring device that is placed in a pre-drilled hole and secured using a chemical compound.

Admixture

Substances other than water, aggregate, lime, or cement added to concrete, mortar or grout to improve one or more chemical or physical properties.

Aggregate gradation

(See "Gradation.")

Aggregate

An inert granular material such as natural sand, manufactured sand, gravel, crushed stone, vermiculite, perlite and air cooled blast furnace slag, which, when bound together by a cementitious matrix forms concrete, grout or mortar.

Air entraining

The capability of a material or process to develop a system of uniformly distributed spherical microscopic air bubbles in a cementitious paste to increase the workability or durability of the resulting product. Some admixtures act as air entraining agents.

Anchor

Metal rod, tie, bolt or strap used to secure masonry to other structural elements. May be cast, adhered, expanded or fastened into masonry.

Angle

A structural steel section that has two legs joined at 90 degrees to one another. Used as a lintel to support masonry over openings such as doors or windows in lieu of a masonry arch or reinforced masonry lintel. Also used as a shelf to vertically support masonry veneer. Sometimes referred to as a relieving angle.

Arch

A vertically curved compressive structural member spanning openings or recesses. May also be built flat by using special masonry shapes or specially placed units.

Area, gross cross-sectional

(See "Cross-sectional area, gross.")

Area, net cross-sectional

(See "Cross-sectional area, net.")

Autoclave

In the production of concrete masonry units, a type of curing system chamber that utilizes super heated steam under pressure to promote or enhance specific properties of manufactured units.

Axial load

The load exerted on a wall or other structural element and acting parallel to the element's axis. Axial loads typically act in a vertical direction, but may be otherwise depending on the type and orientation of the element.

Backing

The surface to which a non-structural finish material is secured. The backing material may be concrete, masonry, steel framing or wood framing.

Backup

(See "Backing.")

Beam

A structural member, typically horizontal, primarily designed to resist flexure.

Bearing partition

An interior wall that supports a vertical load in addition to its own weight.

Bed joint

(See "Mortar joint, bed.")

Burnished block
(See "Ground block.")

Bedded area
The surface area of a masonry unit that is in contact with mortar in the plane of the mortar joint.

Block
A solid or hollow manufactured concrete masonry unit larger than brick-sized units.

Block machine
Equipment used to mold, consolidate and compact shapes when manufacturing concrete masonry units.

Bond
(1) The arrangement of units to provide strength, stability or a unique visual effect created by laying units in a prescribed pattern. (2) The physical adhesive or mechanical binding between masonry units, mortar, grout and reinforcement. (3) To connect wythes or masonry units.

Bond beam
(1) The grouted course or courses of masonry units reinforced with longitudinal bars and designed to take the longitudinal flexural and tensile forces that may be induced in a masonry wall. (2) A horizontal grouted element within masonry in which reinforcement is embedded.

Bond beam block
A hollow unit with depressed web portions to form a continuous channel or channels for reinforcing steel and grout. U-shaped block are sometimes used to form bond beams, especially over openings. Also called channel block.

Bond breaker
A material used to prevent adhesion between two surfaces.

Bond, running
The placement of masonry units such that head joints in successive courses are horizontally offset at least one-quarter the unit length. Centering head joints over the unit below, called center or half bond, is the most common form of running bond. A horizontal offset between head joints in successive courses of one-third and one-quarter the unit length is called third bond and quarter bond, respectively.

Bond, stack
For structural design purposes, *Building Code Requirements for Masonry Structures* considers all masonry not laid in running bond as stack bond. In common use, stack bond typically refers to masonry laid so head joints in successive courses form a continuous vertical line. Also called plumb joint bond, straight stack, jack bond, jack-on-jack and checkerboard bond.

Bond strength
The resistance to separation of mortar from masonry units and of mortar and grout from reinforcing steel and other materials with which it is in contact.

Bonding
(See "Bond.")

Brick
A solid or hollow manufactured masonry unit of either concrete or clay.

Cantilever
A member structurally supported at only one end through a fixed connection. The opposite end has no structural support.

Cap
(See "Coping.")

Cap block
A solid slab used as a coping unit. May contain ridges, bevels or slopes to facilitate drainage. (See also "Coping block.")

Carbonation
A reaction between carbon dioxide and calcium compounds, especially in cement paste, mortar, grout, or concrete, that produces calcium carbonate. The result is an irreversible volumetric shrinkage of the cementitious material.

Caulking
Sealing joints in masonry with a resilient compound such as a silicone material.

Cavity
A continuous air space between wythes of masonry or between masonry and its backup system. Typically greater than 2 inches (51 mm) in thickness. (See "Collar joint.")

Cavity wall
(See "Wall, cavity.")

Cavity wall tie
(See "Wall tie, cavity.")

Cell

The hollow space within a concrete masonry unit formed by the face shells and webs. Also called cores.

Cement

A powdered substance made of burned lime and clay mixed with water and sand to make mortar or mixed with water, sand and gravel to make concrete or grout. The mixture hardens due to a chemical reaction during curing.

Cementitious material

(1) When proportioning masonry mortars, the following are considered cementitious materials: portland cement, blended hydraulic cement, masonry cement, mortar cement, lime putty and hydrated lime. (2) A generic term for any inorganic material or mixture of inorganic materials that sets and develops strength by chemical reaction with water.

Cinder

An aggregate usually produced from the combustion of coal, and sometimes used in the manufacture of concrete masonry units.

Cleanout/cleanout hole

A small opening, typically located in the first course of masonry, for removing mortar droppings prior to grout placement in grouted masonry.

Coating

A material applied to a surface to preserve, protect, decorate, seal or smooth the substrate.

Cold weather construction

Procedures used to construct masonry when ambient air temperature or masonry unit temperature is below 40°F (4.4°C).

Collar joint

A continuous air space between wythes of masonry, which is permitted to be filled with mortar or grout. Typically less than 2 inches (51 mm) in thickness. (See also "Cavity.")

Color (pigment)

A powdered liquid or granular substance that when blended with a liquid vehicle, gives a cementitious matrix its coloring.

Column

(1) In structures, a relatively long, slender structural compression member such as a post, pillar, or strut. Usually vertical, a column supports loads that act primarily in the direction of its longitudinal axis. (2) For the purposes of design, an isolated vertical member whose horizontal dimension measured at right angles to the thickness does not exceed three times its thickness and whose height is greater than four times its thickness.

Composite action

A masonry member designed so that the combined components act together as a single member to resist loads by transferring stresses between components. (See also "Noncomposite action.")

Compressive strength

The maximum compressive load that a specimen will support divided by the net cross-sectional area of the specimen.

Compressive strength of masonry

Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by the testing of masonry prisms or as a function of individual masonry units and mortar in accordance with the provisions of *Specification for Masonry Structures*. (See also "Specified compressive strength of masonry.")

Concrete

A composite material that consists essentially of a binding medium and aggregate (usually a combination of fine aggregate and coarse aggregate). In portland cement concrete, the binder is a mixture of portland cement and water.

Concrete block

A hollow or solid unit consisting of portland cement and suitable aggregates combined with water with or without the inclusion of other materials. Larger in size than a concrete brick.

Concrete brick

A hollow or solid unit consisting of portland cement and suitable aggregates combined with water with or without the inclusion of other materials. Smaller in size than a concrete block.

Concrete masonry unit

Generic term for a hollow or solid masonry unit made from cementitious materials, aggregates and water.

Connector

A mechanical device for securing two or more pieces, parts or members together; includes anchors, wall ties and fasteners. May be either structural or nonstructural.

Connector, tie

A metal device used to join wythes of masonry in a multiwythe wall or to attach a masonry veneer to its backing. (See also "Anchor.")

Control joint

A continuous unbonded masonry joint that is formed, sawed or tooled in a masonry structure to regulate the location and amount of cracking and separation resulting from dimensional change of different parts of the structure, thereby avoiding the development of high stresses.

Coping

The materials or masonry units used to form the finished top of a wall, pier, chimney or pilaster to protect the masonry below from water penetration. Masonry coping units are commonly extended beyond the wall face and cut with a drip.

Coping block

A solid concrete masonry unit intended for use as the top and finished course in wall construction.

Core

(See "Cell.")

Corrosion

Destruction of metal by chemical, electrochemical or electrolytic reaction with its environment or other materials.

Corrosion resistant

A material that is treated or coated to retard corrosive action. An example is steel that is galvanized after fabrication.

Course

A horizontal layer of masonry units in a wall or, much less commonly, curved over an arch.

Crack control

Methods used to control the extent, size and location of cracking in masonry including reinforcing steel, control joints and dimensional stability of masonry materials.

Crack

A complete or incomplete separation of masonry into two or more parts produced by breaking or fracturing.

Cross-sectional area, gross

The area delineated by the out-to-out dimensions of masonry in the plane under consideration. This includes the total area of a section perpendicular to the direction of the load, including areas within cells and voids.

Cross-sectional area, net

The area of masonry units, grout and mortar crossed by the plane under consideration, removing the area of all voids such as ungrouted cores, open spaces, or any other area devoid of masonry.

Cull

A masonry unit that does not meet the standards or specifications and therefore has been rejected.

Curing

(1) The maintenance of proper conditions of moisture and temperature during initial set to develop a required strength and reduce shrinkage in products containing portland cement. (2) The initial time period during which cementitious materials gain strength.

Curtain wall

(See "Wall, curtain.")

Damp-proofing

The treatment of masonry to retard the passage or absorption of water or water vapor, either by application of a suitable coating or membrane to exposed surfaces or by use of a suitable admixture or treated cement.

Damp check

An impervious horizontal layer to prevent vertical penetration of water in a wall or other masonry element. A damp check consists of either a course of solid masonry, metal or a thin layer of asphaltic or bituminous material. It is generally placed near grade to prevent upward migration of moisture by capillary action.

Density

The ratio of the mass of a concrete masonry unit to its net volume.

Diaphragm

A roof or floor system designed to transmit lateral forces to shear walls or other lateral load resisting elements.

Dimension, actual

The actual measured size of a concrete masonry unit or assemblage.

Dimension, nominal

The specified dimension plus an allowance for mortar joints, typically $\frac{3}{8}$ inch (9.5 mm). Nominal dimensions are usually stated in whole numbers. Width (thickness) is given first, followed by height and then length.

Dimension, specified

The dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure. Unless otherwise stated, all calculations are based on specified dimensions.

Dowel

A straight metal bar used to connect masonry to masonry or to concrete.

Drip

A groove or slot cut beneath and slightly behind the forward edge of a projecting unit or element, such as a sill, lintel or coping, to cause rainwater to drip off and prevent it from penetrating the wall.

Drying shrinkage

The volumetric change in dimension of a concrete masonry wall or unit due to drying.

Dry stack

Masonry work laid without mortar.

Eccentricity

The distance between the resultant of an applied load and the centroidal axis of the masonry element under load.

Effective height

The assumed height of a member used to calculate the slenderness ratio.

Effective thickness

The assumed thickness of a member used to calculate the slenderness ratio.

Efflorescence

A deposit or encrustation of soluble salts (generally white), that may form on the surface of stone, brick, concrete or mortar when moisture moves through and evaporates on the masonry. Often caused by free alkalis leached from mortar, grout, adjacent concrete or clays and deposited on the surface of the masonry.

Equivalent thickness

The solid thickness to which a hollow unit would be reduced if the material in the unit were recast into a unit with the same face dimensions (height and length) but without voids. Determined by multiplying the decimal value of the percent solid volume by the actual width. Used to determine masonry fire resistance ratings.

Expansion anchor

An anchoring device (based on a friction grip) in which an expandable socket expands, causing a wedge action, as a bolt is tightened into it.

Exterior wall

(See "Wall, exterior.")

Face

(1) The surface of a wall or masonry unit. (2) The surface of a unit designed to be exposed in the finished masonry.

Face shell

The side (typically exposed) of a hollow concrete masonry unit.

Face shell mortar bedding

Hollow masonry unit construction where mortar is applied only to the horizontal surface of the unit face shells and in the head joints to a depth equal to the thickness of the face shell. No mortar is applied to the unit cross webs. (See also "Full mortar bedding.")

Facing

Any material forming a part of a wall and used as a finished surface.

Fastener

A device used to attach components to masonry, typically nonstructural in nature.

Fire resistance

A rating assigned to walls indicating the length of time a wall performs as a barrier to the passage of flame, hot gases and heat when subjected to a standard fire and hose stream test in accordance with ASTM E 119. For masonry, fire resistance is most often determined based on the masonry's equivalent thickness.

Fire wall

Any wall that subdivides a building so as to resist the spread of fire.

Flashing

A thin impervious material placed in mortar joints and through air spaces in masonry to prevent water penetration and to facilitate water drainage.

Fluted block

Block with surface grooves in a visual pattern. For example, the grooves may simulate raked joints. Also referred to as scored block.

Fly ash

The finely divided residue resulting from the combustion of ground or powdered coal. Sometimes used as a cementitious material.

Footing

A structural element that transmits loads directly to the soil.

Foundation wall

(See "Wall, foundation.")

Freeze-thaw

The cyclic freezing and thawing of moisture in materials and the resultant effects on the materials and on the structures of which they are a part.

Full mortar bedding

Masonry construction where mortar is applied to the entire horizontal surface of the masonry unit. (See also "Face shell mortar bedding.")

Furring

A method of finishing the interior face of a masonry wall to provide space for insulation, to prevent moisture transmittance or to provide a smooth or plane surface for finishing.

Gradation

The particle size distribution of aggregate as determined by separation with standard screens. Aggregate gradation is expressed in terms of the individual percentages passing standard screens. Sieve analysis and screen analysis are synonymous when referring to aggregate gradation.

Ground block

A concrete masonry unit in which the surface is ground to a smooth finish exposing the internal matrix of the unit. Also called ground face, burnished or honed block.

Grout

(1) A mixture of cementitious material and aggregate to which sufficient water is added to produce desired consistency without segregation of the constituents during placement. (2) The hardened equivalent of such mixtures.

Grout lift

An increment of grout height within the total grout pour. A grout pour consists of one or more grout lifts.

Grout pour

The total height of masonry to be grouted prior to erection of additional masonry. A grout pour consists of one or more grout lifts.

Grouted masonry

(1) Concrete masonry construction of hollow units where hollow cells are filled with grout, or multi-wythe construction in which the space between wythes is solidly filled with grout. (2) Masonry construction made with solid masonry units where the interior joints and voids are filled with grout.

Grouting, high lift

The technique of grouting masonry in lifts for the full height of the wall.

Grouting, low lift

The technique of grouting as the wall is constructed, usually to scaffold or bond beam height, but not greater than 4 feet (1,219 mm) to 6 feet (1,829 mm), depending on Code limitations.

Gypsum

A soft mineral consisting of hydrous calcium sulfate. The raw material from which plaster is made (by heating).

"H" block

Hollow masonry unit lacking cross webs at both ends forming an "H" in cross section. Used with reinforced masonry construction. (See also "Open end block.")

Header

A masonry unit that overlaps two or more adjacent wythes of masonry to tie them together. Also called a bonder.

Head joint

(See "Mortar joint, head.")

Height of wall

(1) The vertical distance from the foundation wall or other similar intermediate support to the top of the wall. (2) The vertical distance between intermediate supports.

Height-thickness ratio

The height of a masonry wall divided by its nominal thickness. The thickness of cavity walls is taken as the overall thickness minus the width of the cavity.

High lift grouting

(See "Grouting, high lift.")

Hollow masonry unit

A masonry unit whose net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

Honed block

(See "Ground block.")

Hot weather construction

Procedures used to construct masonry when ambient air temperature exceeds 100 °F (37.8 °C) or temperature exceeds 90 °F (32.2 °C) with a wind speed greater than 8 mph (13 km/h).

Inspection

The observation to verify that the masonry construction meets the requirements of the applicable design standards and contract documents.

Jamb block

A block specially formed for the jamb of windows or doors, generally with a vertical slot to receive window frames, etc. Also called sash block.

Joint

The surface at which two members join or abut. If they are held together by mortar, the mortar-filled volume is the joint.

Joint reinforcement

Steel wires placed in mortar bed joints (over the face shells in hollow masonry). Multi-wire joint reinforcement assemblies have cross wires welded between the longitudinal wires at regular intervals.

Lap

- (1) The distance two bars overlap when forming a splice.
- (2) The distance one masonry unit extends over another.

Lap splice

The connection between reinforcing steel generated by overlapping the ends of the reinforcement.

Lateral support

The means of bracing structural members in the horizontal span by columns, buttresses, pilasters or cross walls, or in the vertical span by beams, floors, foundations, or roofs.

Lightweight aggregate

Aggregate of low density, such as expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, slag, natural pumice, volcanic cinders, diatomite, sintered fly ash or industrial cinders.

Lightweight concrete masonry unit

A unit whose oven-dry density is less than 105 lb/ft³ (1,680 kg/m³).

Lime

Calcium oxide (CaO), a general term for the various chemical and physical forms of quicklime, hydrated lime and hydraulic hydrated lime.

Lintel

A beam placed or constructed over a wall opening to carry the superimposed load.

Lintel block

A masonry unit consisting of one core with one side open. Usually placed with the open side up, like a trough, to be reinforced and grouted to form a continuous beam.

Loadbearing

(See "Wall, loadbearing.")

Loads, allowable

The permitted safe load carrying capacity determined through testing or calculation of a given structural element or combination of elements. Includes an acceptable safety factor of a given material and loading condition.

Low lift grouting

(See "Grouting, low lift.")

Maintenance

Efforts to limit the deterioration of an element's physical appearance or structural integrity.

Masonry

An assemblage of masonry units and mortar with or without the inclusion of grout and reinforcing steel and other accessories.

Masonry Cement

(1) A mill-mixed cementitious material to which sand and water is added to make mortar. (2) Hydraulic cement produced for use in mortars for masonry construction where greater plasticity and water retention are desired than is obtainable by the use of portland cement alone. Such cements always contain one or more of the following materials: portland cement, portland-pozzolan cement, natural cement, slag cement, hydraulic lime and usually contain one or more of the following: hydrated lime, pulverized limestone, chalk, talc, pozzolan, clay or gypsum.

Masonry unit

Natural or manufactured unit of burned clay, concrete, stone, glass, gypsum, etc.

Masonry veneer

(See "Veneer, masonry.")

Medium weight concrete masonry unit

A unit whose oven-dry density is at least 105 lb/ft³ (1,680 kg/m³) but less than 125 lb/ft³ (2,000 kg/m³).

Metric

The Modern Metric System (SI) is the standard international system of measurement. The system that has been mandated for use in all United States Federal Buildings.

Mix design

The proportions of ingredients used to produce mortar, grout or concrete.

Mixer

A machine employed for blending the constituents of concrete, grout, mortar or other mixtures.

Modular coordination

The designation of masonry units, door and window frames, and other construction components that fit together during construction without customization.

Modular design

Construction with standardized units or dimensions for flexibility and variety in use.

Modulus of elasticity

The ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of the material.

Moisture content

The amount of water contained at the time of sampling expressed as a percentage of the total absorption.

Mortar

A plastic mixture of cementitious materials, fine aggregate and water used to bond masonry, connectors, or other structural units. May contain portland cement, mortar cement or masonry cement.

Mortar bed

A horizontal layer of mortar used to seat a masonry unit.

Mortar bond

(See "Bond".)

Mortar joint, bed

The horizontal mortar joint between masonry units.

Mortar joint, head

The vertical mortar joint between masonry units.

Movement joint, control

(See "Control joint.")

Net area

(See "Cross-sectional area, net.")

Net section

The minimum cross section of the member under consideration.

Net cross-sectional area

(See "Cross-sectional area, net.")

Nominal dimension

(See "Dimension, nominal.")

Noncombustible

Any material that will neither ignite nor actively support combustion in air at a temperature of 1,200°F (648.9°C) when exposed to fire.

Nonloadbearing

(See "Wall, nonloadbearing.")

Normal weight concrete masonry unit

A unit whose oven-dry density is 125 lb/ft³ (2000 kg/m³) or greater.

Open end block

A hollow unit, with one or both ends open. Used with reinforced masonry construction. (See "A" block and "H" block.)

Parging

(1) A coating of mortar, which may contain damp-proofing ingredients, over the back of masonry veneer, the face of the backup or over below-grade exterior masonry. (2) The process of applying such a coating.

Perlite

A volcanic glass having a perlitic structure, usually having higher water content than obsidian. Used as an insulating material and as a lightweight aggregate in concretes, mortars and plasters.

Pier

An isolated column of masonry or a bearing wall not bonded at the sides to associated masonry. For design, a vertical section of masonry whose horizontal dimension measured at right angles to its thickness is not less than three times its thickness nor greater than six times its thickness and whose height is less than five times its length.

Pigment

(See "Color.")

Pilaster

A bonded or keyed column of masonry built as part of a wall. It may be flush or projected from either or both wall surfaces. It has a uniform cross section throughout its height and serves as a vertical beam, a column or both.

Pilaster block

Concrete masonry units designed for use in the construction of plain or reinforced concrete masonry pilasters and columns.

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Plain masonry

(See "Unreinforced masonry.")

Plasticizer

A substance incorporated into a cementitious material to increase its workability, flexibility or extensibility.

Portland cement

An hydraulic cement produced by pulverizing clinker consisting of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground material.

Pozzolan

A siliceous or a siliceous and aluminum material, which in itself possesses little or no cementitious value, but in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Prestressed

(See "Wall, prestressed.")

Prism

A small assemblage made with masonry units and mortar and sometimes grout. Primarily used to predict the strength of full-scale masonry members or as part of a quality assurance program.

Prism strength

Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by testing masonry prisms.

Project specifications

The written documents that specify project requirements in accordance with the service parameters and other specific criteria established by the owner or owner's agent.

Pumice

A volcanic material with a cellular structure, which is highly porous. Is sometimes used as an aggregate for lightweight concrete masonry units.

Quality assurance

The administrative and procedural requirements established by the contract documents and by code to assure that constructed masonry is in compliance with the contract documents.

Quality control

The planned system of activities used to provide a level of quality that meets the needs of the users and the use of such a system. The objective of quality control is to provide quality that is safe, adequate, dependable and economic. The overall system involves integrating factors including: the proper specification; production to meet the full intent of the specification; inspection to determine whether the resulting material, product and service is in accordance with the specifications; and review of usage to determine any necessary revisions to the specifications.

R-value

The thermal resistance that is an indication of the steady state heat flow through an assembly.

Radon

A gaseous element produced by the radioactive decay of radium.

Rain penetration

Water migration into a material.

Raked joint

A mortar joint where $\frac{1}{4}$ to $\frac{1}{2}$ inch (6 to 13 mm) of mortar is removed from the outside of the joint.

Reinforced masonry

(1) Masonry containing reinforcement in the mortar joints or grouted cores used to resist stresses. (2) Unit masonry in which reinforcement is embedded in such a manner that the component materials act together in resisting applied forces.

Reinforcing steel

Steel embedded in masonry in such a manner that the two materials act together to resist forces.

Retarding agent

A chemical additive in mortar that slows setting or hardening, most commonly in the form of finely ground gypsum.

Running bond

(See "Bond, running.")

Sash block

(See "Jamb block.")

Scored block

A block with grooves that are in a visual pattern. For example, the grooves may simulate raked joints.

Screen block

An open-faced masonry unit used for decorative purposes or to partially screen areas from the sun or from view.

Sealant

A material of plastic consistency laid over a joint surface or the outside of a joint filler to prevent water entry.

Shell

(See "Face shell.")

Shoring and bracing

The props or posts used to temporarily support members during construction.

Shrinkage

The volume change due to moisture loss, decrease in temperature or carbonation of a cementitious material.

Sill block

A solid concrete masonry unit used for the sills of a wall opening.

Sill

A flat or slightly beveled unit set horizontally at the base of an opening in a wall.

Simply supported

A member structurally supported at top and bottom or both sides through a pin-type connection, which assumes no moment transfer.

Slag, air-cooled blast-furnace

The material resulting from solidification of molten blast-furnace slag under atmospheric conditions.

Slag, blast-furnace

The nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.

Slag, expanded blast-furnace

The lightweight cellular material obtained by controlled processing of molten blast-furnace slag with water, or water and other agents.

Slag, granulated blast-furnace slag

The glassy granular material formed when molten blast furnace slag is rapidly chilled, as by immersion in water.

Slenderness ratio

The ratio of a member's effective height to radius of gyration.

Slump

(1) The drop in the height of a wet cementitious material from its original shape when in a plastic state. (2) A standardized measurement of a plastic cementitious material to determine its flow and workability.

Slump block

A concrete masonry unit produced so that it slumps or sags in irregular fashion before it hardens.

Slushed joint

A mortar joint filled after units are laid by "throwing" mortar in with the edge of a trowel.

Solid masonry unit

A unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane.

Spall

To flake or split away through frost action or pressure.

Specified dimensions

(See "Dimension, specified.")

Specified compressive strength of masonry

Minimum compressive strength required of the masonry by the contract documents, and upon which the project design is based (expressed in terms of force per unit of net cross-sectional area).

Split block

A concrete masonry unit with one or more faces purposely fractured to expose the rough aggregate texture to provide architectural effects in masonry wall construction. Also called a split-faced block.

Stack bond

(See "Bond, stack.")

Strike

To finish a mortar joint with a stroke of the trowel or special tool, simultaneously removing extruded mortar and smoothing the surface of the mortar remaining in the joint.

Struck joint

A joint from which excess mortar has been removed by a stroke of the trowel, leaving an approximately flush joint.

Temper

To moisten and mix mortar to a proper consistency.

Thermal expansion

The expansion of a material due to an temperature increase.

Thermal movement

The change of dimension resulting from a temperature change.

Tie

(See "Connector, tie.")

Ties, veneer

(See "Wall tie, veneer.")

Tolerance

The specified allowance in variation from a specified size, location, or placement.

Tooling

Compressing and shaping the face of a mortar joint with a tool other than a trowel.

Unit

(See "Masonry unit.")

Unreinforced masonry

Masonry in which the tensile resistance of the masonry is taken into consideration and the effects of stresses in reinforcement, if present, are neglected. Also called plain masonry.

Veneer, adhered

Masonry veneer secured to and supported by the backing through adhesion.

Veneer, anchored

Masonry veneer secured to and supported laterally by the backing through anchors and supported vertically by the foundation or other structural elements.

Veneer, masonry

A masonry wythe that provides the exterior finish of a wall system and transfers out-of-plane load directly to a backing, but is not considered to add load resisting capacity to the wall system.

Wall, bonded

A masonry wall in which two or more wythes are bonded to act as a structural unit.

Wall, cavity

A multi-wythe noncomposite masonry wall with a continuous air space within the wall (with or without insulation), which is tied together with metal ties.

Wall, composite

A multi-wythe wall where the individual masonry wythes act together to resist applied loads. (See also "Composite action.")

Wall, curtain

(1) A nonloadbearing wall between columns or piers. (2) A nonloadbearing exterior wall vertically supported only at its base, or having bearing support at prescribed vertical intervals. (3) An exterior nonloadbearing wall in skeleton frame construction. Such walls may be anchored to columns, spandrel beams or floors, but not necessarily built between columns.

Wall, exterior

Any outside wall or vertical enclosure of a building.

Wall, faced

A wall in which the masonry facing and backing are bonded to act as a complete system under load.

Wall, foundation

A wall below the floor nearest grade serving as a support for a wall, pier, column or other structural part of a building and in turn supported by a footing.

Wall, loadbearing

A wall carrying vertical loads greater than 200 lb/ft (2.9 kN/m) in addition to its own weight. Also, any wall that supports vertical load in addition to its own weight.

Wall, multi-wythe

A wall composed of two or more masonry wythes.

Wall, nonloadbearing

Typically, wall that supports no vertical load other than its own weight. Could also be a wall carrying vertical loads less than 200 lb/ft (2.9 kN/m) in addition to its own weight.

Wall, panel

(1) An exterior nonloadbearing wall in skeleton frame construction, wholly supported at each story. (2) A nonloadbearing exterior masonry wall having bearing support at each story.

Wall, partition

An interior separation wall without structural function.

Wall, prestressed

A masonry wall in which internal compressive stresses have been introduced to reduce potential tensile stresses in the wall resulting from imposed loads.

Wall, reinforced

(1) A masonry wall reinforced with steel embedded so that the two materials act together in resisting forces. (2) A wall containing reinforcement used to resist shear and tensile stresses.

Wall, retaining

A wall designed to prevent the movement of soils and structures placed behind the wall.

Wall, screen

A masonry wall constructed with more than 25% open area intended for decorative purposes, typically to partially screen an area from the sun or from view.

Wall, shear

A wall which resists lateral load in its own plane resulting from wind, blast, earthquake, or other lateral loads.

Wall, single wythe

A wall of one masonry unit thickness.

Wall, solid masonry

A wall built of solid masonry units.

Wall tie

A rigid, corrosion-resistant metal tie that bonds two wythes of a cavity wall.

Wall tie, veneer

A wall tie used to connect a facing veneer to the backing.

Wall, veneer

(See "Veneer, masonry.")

Water permeance

The ability of water to penetrate through a substance such as mortar or brick.

Waterproof

(1) Impervious to water. (2) Covered or treated with a material or materials to prevent water penetration.

Waterproofing

(1) The methods used to prevent moisture flow through masonry. (2) The materials used to prevent moisture flow through masonry.

Watertight

Impermeable to water except when under sufficient pressure to produce structural discontinuity.

Weathering

(1) The action of weather in altering the color, texture, composition or form of exposed objects. (2) The effects of nature physically and chemically upon masonry construction.

Web

The portion of a hollow concrete masonry unit connecting the face shells.

Weep hole

An opening left (or cut) in mortar joints or masonry face shells to allow moisture to exit the wall. Usually located immediately above flashing.

Workability

The ability of mortar or grout to be easily placed and spread.

Workmanship

(1) The art or skill of a workman. (2) Craftsmanship; the quality imparted to a masonry element.

Wythe

Each continuous vertical section of a wall, one masonry unit in thickness.

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