NCMA TEK

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PRESCRIPTIVE SEISMIC REINFORCEMENT REQUIREMENTS FOR MASONRY STRUCTURES

TEK 14-18A
Structural (2003)

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INTRODUCTION

Historically, the degree of seismic risk and the resulting design loads were linked to seismic zones, where the higher seismic zones were associated with higher anticipated ground motion. In recent years, design codes (refs. 1, 2, and 7) have dropped the use of seismic zones and replaced them with Seismic Design Categories (SDCs). While there are similar concepts between seismic zones and design categories, there are unique philosophies present in each. The information that follows outlines the procedure for defining a project's SDC, the permissible design methods that can be used with each SDC, and the prescriptive reinforcement required for these design conditions.

SEISMIC DESIGN CATEGORIES

Seismic Design Categories range from SDC A (lowest seismic risk) through SDC F (highest seismic risk). Several factors contribute to defining the seismic design category for a particular project, including the following.

- Maximum earthquake ground motion. Ground acceleration values are obtained from maps published in the 2003 *International Building Code* (ref. 7) or the ASCE 7 *Minimum Design Loads for Buildings and Other Structures* (ref. 2).
- Local soil profile. Soil profiles are classified as Site Class A (hard rock) through Site Class F (organic or liquefiable soils). When soil properties are not known in sufficient detail to determine the site class, Site Class D (moderately stiff soil) is assumed.
- Use or occupancy of the structure. Each structure is assigned to one of three seismic use groups corresponding to its use or occupancy. Seismic Use Group III structures include essential facilities (such as hospitals and fire stations) and structures that contain substantial quantities of hazardous materials. Seismic Use Group II structures include those that would present a substantial public hazard, including schools, jails and buildings with an occupancy load greater than 5,000. Seismic Use Group I structures are those not included in Seismic Use Groups II and III.

Figures 1 and 2 define specific SDCs for 0.2 and 1 second spectral response acceleration, respectively. Each figure is based on Site Class D (the default class when the soil profile is not known) and is applicable to seismic use group I and II structures (buildings other than high hazard exposure structures). Note that if the soil profile is known and is lower

Table 1—Permitted Design Procedures for Seismic Design Categories (ref. 1)[a]

	Design method:				
	Empirical	Allowable stress design		Strength design	
SDC	design	Unreinforced	Reinforced	Unreinforced	Reinforced
A	✓	✓	✓	✓	✓
B		✓	✓	✓	✓
C		✓	✓	✓	✓
D			✓	✓	✓
E			✓	✓	✓
F			✓	✓	✓

[a] These limitations apply only to a structure's lateral force-resisting system (i.e., shear walls). No such restrictions are placed on partition walls and other nonloadbearing elements.

Table 2—Permitted Shear Wall Types for Seismic Design Categories (ref. 1)

	Type of shear wall:				
	Ordinary	Detailed	Ordinary	Intermediate	Special
SDC	plain	plain	reinforced	reinforced	reinforced
A	✓	✓	✓	✓	✓
B	✓	✓	✓	✓	✓
C			✓	✓	✓
D					✓
E					✓
F					✓

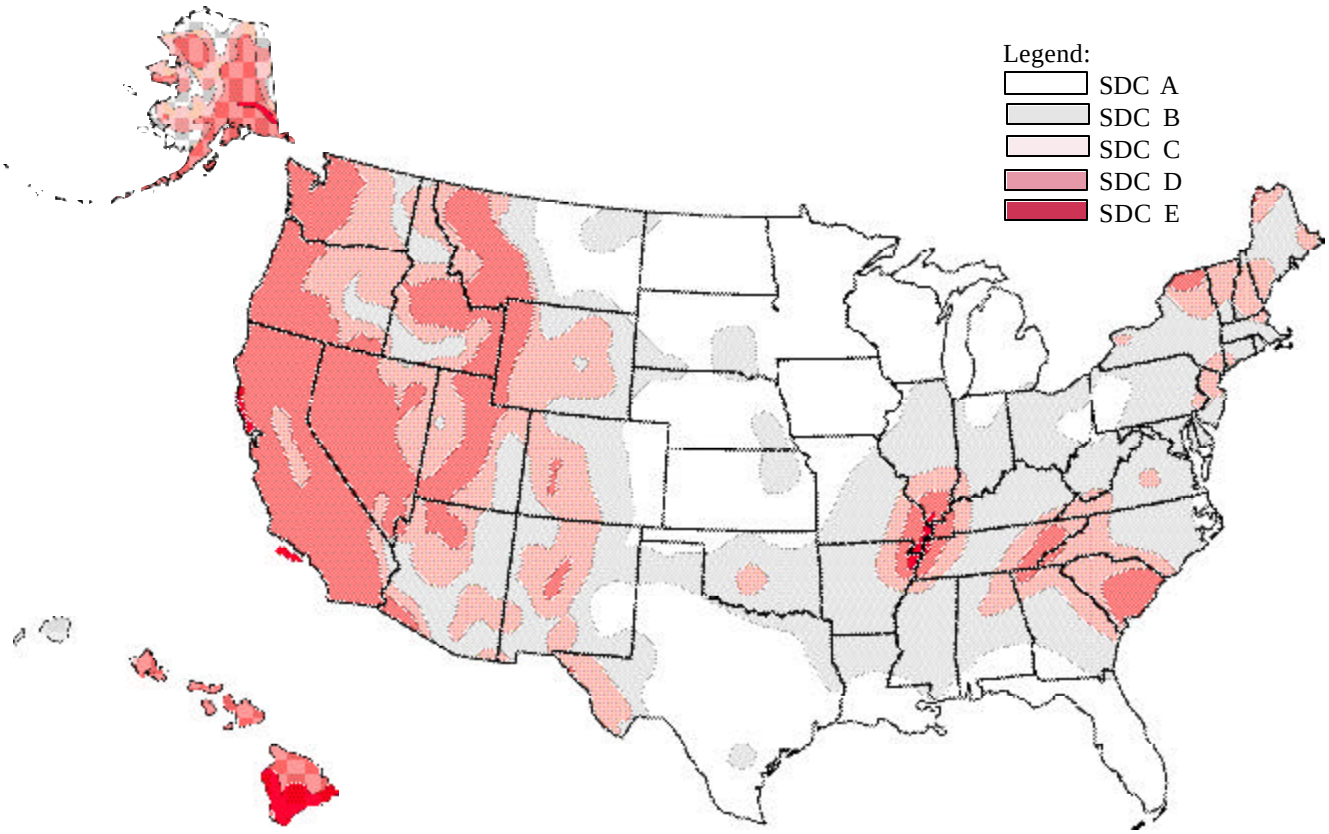


Figure 1—Seismic Design Categories for Site Class D, Seismic Use Group I and II, for a 0.2-Second Spectral Response Acceleration

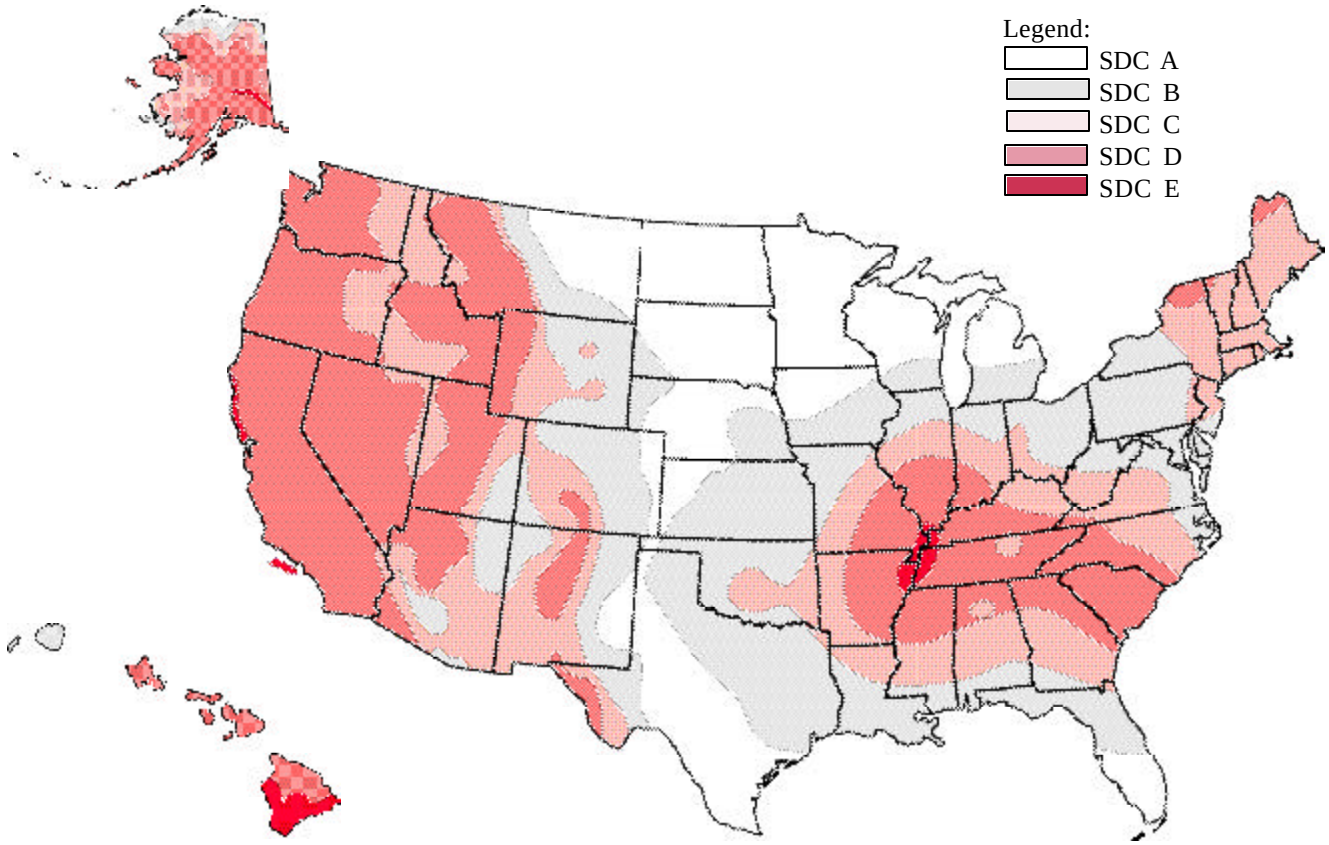


Figure 2—Seismic Design Categories for Site Class D, Seismic Use Group I and II, for a 1-Second Spectral Response Acceleration

than D, a correspondingly lower SDC may be realized.

Structures are assigned to the highest SDC obtained from either Figure 1 or Figure 2. Section 1616.3 of the 2003 IBC (ref. 7) does, however, permit the SDC to be determined based solely on Figure 1 (0.2 second spectral response acceleration) for relatively short, squat structures (common for masonry buildings) meeting the requirements of that section.

DESIGN PROVISIONS

The design provisions described in the following two sections apply to all masonry elements with the exception of glass unit masonry and masonry veneer. Seismic design provisions for masonry veneer are covered at the end of this TEK.

The requirements listed below for the various Seismic Design Categories (SDCs) are cumulative. That is, masonry in buildings assigned to SDC B must meet the requirements for SDC A as well as those for B. Buildings assigned to SDC C must meet the requirements for Categories A, B and C, and so on.

General

Designers have the option of using several design methods for masonry structures: empirical design (ref. 3); allowable stress design (ref. 4); or strength design (ref. 5). There are, however, restrictions placed on the use of both empirical design and unreinforced masonry. Table 1 summarizes the design procedures which may be used for the various SDCs.

SHEAR WALL PRESCRIPTIVE SEISMIC DETAILING

Ordinary Plain (Unreinforced) Shear Walls

Ordinary plain masonry shear walls are designed as unreinforced elements, and as such rely entirely on the masonry to carry and distribute the anticipated loads. Note that ordinary plain masonry shear walls do not require any prescriptive reinforcement and are permitted to be used in Seismic Design Categories A and B.

Detailed Plain (Unreinforced) Shear Walls

Detailed plain masonry shear walls are also designed as unreinforced elements, however some prescriptive reinforcement is mandated by *Building Code Requirements for Masonry Structures* (ref. 1) to help ensure a minimum level of inelastic deformation capacity and energy dissipation in the event of an earthquake. As the anticipated seismic risk increases (which corresponds to higher seismic design categories), the amount of prescriptive reinforcement also increases. The minimum prescriptive reinforcement for detailed plain masonry shear walls is shown in Figure 3.

Ordinary Reinforced Masonry Shear Walls

Ordinary reinforced masonry shear walls, which are designed using reinforced masonry procedures, rely on the reinforcement to carry and distribute anticipated tensile stresses, while the masonry carries the compressive stresses. Although such walls contain some reinforcement, prescriptive reinforcement is also mandated by *Building Code Requirements for Masonry Structures* (ref. 1) to ensure a minimum level of performance during a design level earthquake. The reinforcement required by design may also serve as the minimum prescriptive reinforcement.

The minimum prescriptive vertical and horizontal reinforcement requirements are identical to those for detailed plain masonry shear walls as shown in Figure 3.

Intermediate Reinforced Masonry Shear Walls

Intermediate reinforced masonry shear walls are designed using reinforced masonry design procedures. Intermediate reinforced shear wall reinforcement requirements differ from those for ordinary reinforced in that the maximum spacing of vertical reinforcement is reduced from 120 in. (3,048 mm) to 48 in. (1,219 mm) (see Figure 4).

Special Reinforced Masonry Shear Walls

Prescriptive reinforcement for special reinforced masonry shear walls must comply with the requirements for intermediate reinforced masonry shear walls and the following (see also Figure 5):

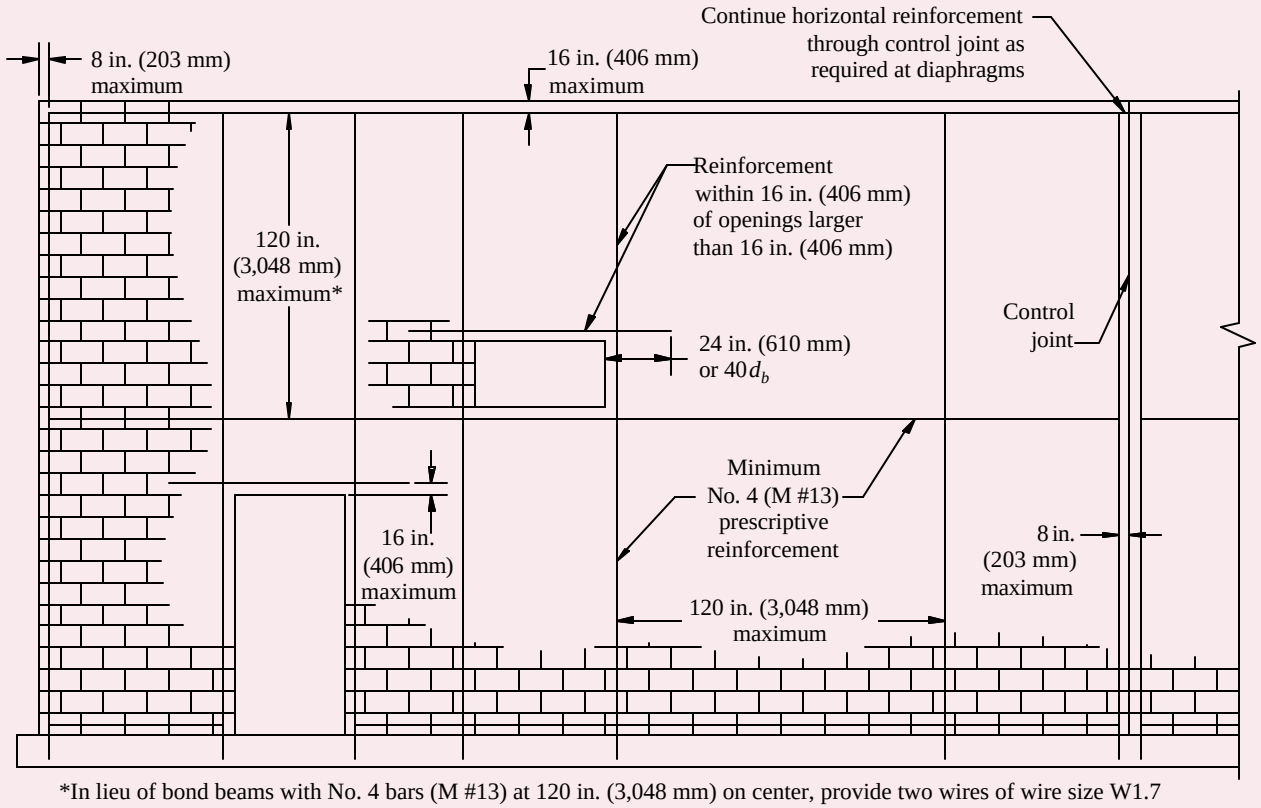
- The sum of the cross-sectional area of horizontal and vertical reinforcement must be at least 0.002 times the gross cross-sectional wall area.
- The minimum cross-sectional area in each direction must be at least 0.0007 times the gross cross-sectional wall area.
- The maximum spacing of vertical and horizontal reinforcement is the smaller of one-third the length of the shear wall, one-third the height of the shear wall or 48 in. (1,219 mm).
- The vertical and horizontal reinforcement must be uniformly distributed.
- The minimum cross-sectional area of vertical reinforcement must be one-third of the required horizontal reinforcement.
- All horizontal reinforcement must be anchored around the vertical reinforcement with a standard hook.

The following additional requirements pertain to stack bond masonry shear walls assigned to SDC D, E or F. These walls must be constructed of fully grouted open-end units, fully grouted hollow units laid with full head joints or solid units. The maximum reinforcement spacing for stack bond masonry shear walls assigned to SDC D is 24 in. (610 mm). For stack bond masonry shear walls assigned to SDC E or F, the cross-sectional area of horizontal reinforcement must be at least 0.0025 times the gross cross-sectional area of the masonry, and be spaced at 16 in. (406 mm) on center, maximum.

PRESCRIPTIVE SEISMIC DETAILING OF NONLOADBEARING ELEMENTS

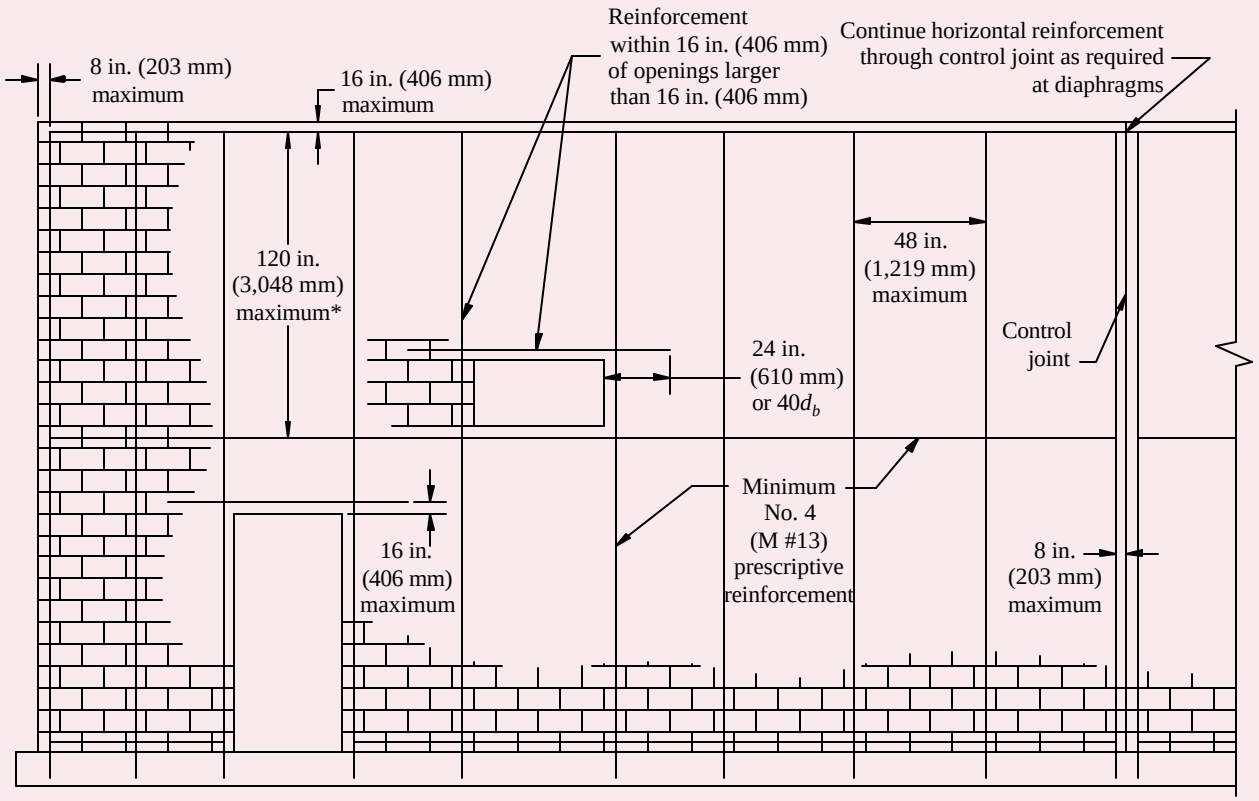
When incorporated into structures assigned to SDC C, D, E or F, masonry partition walls and other nonloadbearing masonry elements (i.e., those not designed to resist loads other than those induced by their own mass) must be isolated from the lateral force-resisting system. This helps ensure that forces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

Nonstructural elements, such as partition walls, assigned to SDC C and above must be reinforced in*either* the horizontal or vertical direction (see Figure 6).



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

Figure 3—Prescriptive Seismic Detailing for Detailed Plain (Unreinforced) Masonry Shear Walls and for Ordinary Reinforced Masonry Shear Walls



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

Figure 4—Prescriptive Seismic Detailing for Intermediate Reinforced Masonry Shear Walls

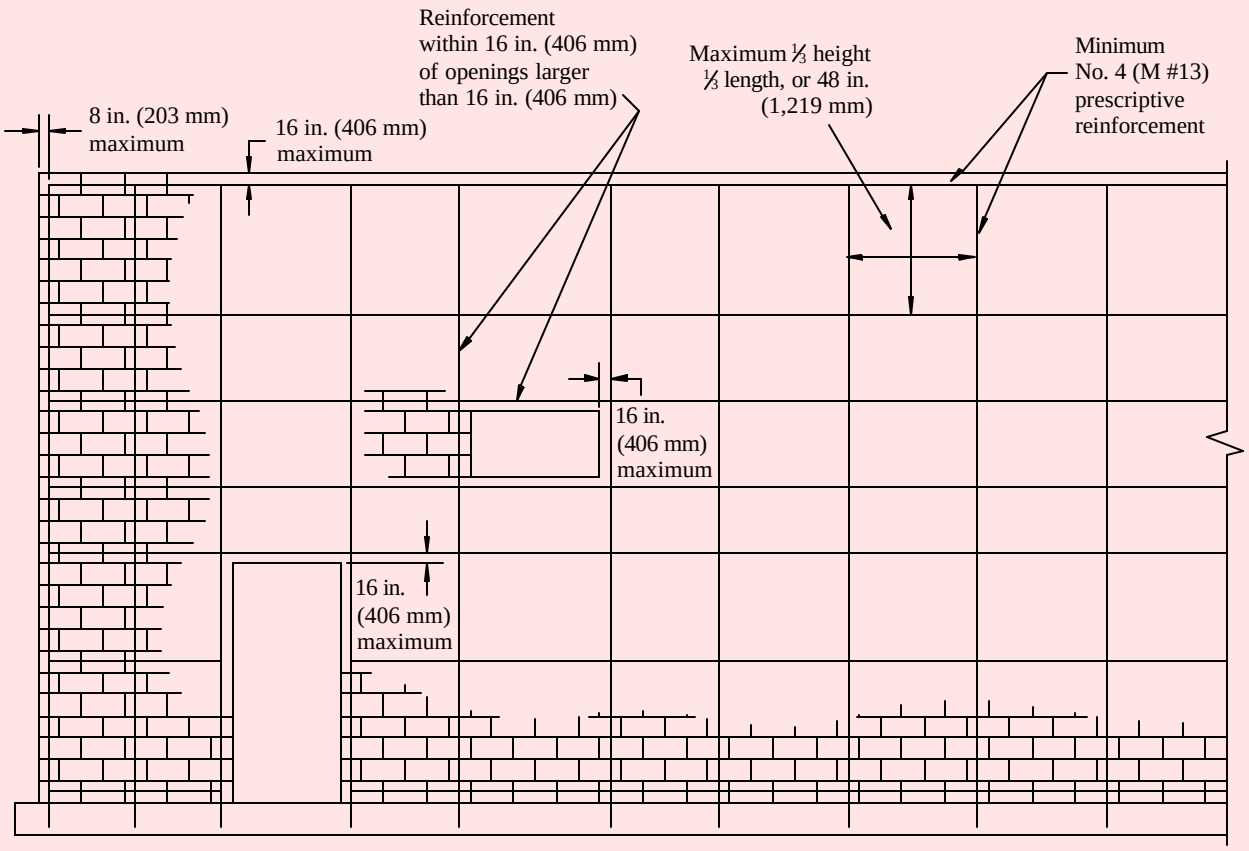
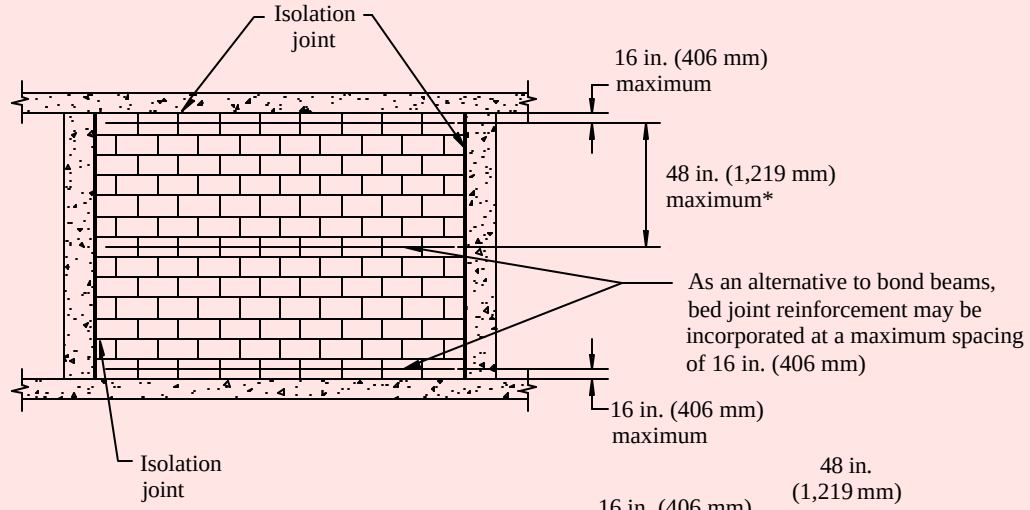
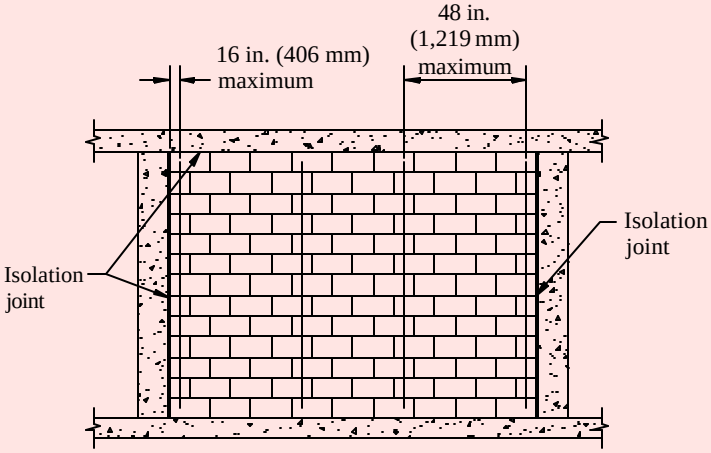


Figure 5—Prescriptive Seismic Detailing for Special Reinforced Masonry Shear Walls





*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.

Figure 6—Horizontal and Vertical Reinforcement Options for Nonloadbearing Elements

When reinforced with horizontal reinforcement, the minimum horizontal joint reinforcement for walls thicker than 4 in. (102 mm) is two longitudinal W1.7 (MW 11) wires. For walls 4-in. (102-mm) thick or less, only one W1.7 (MW 11) wire is required. The maximum joint reinforcement spacing is 16 in. (406 mm) for either case. As an alternative to the wire, bond beams with at least one No. 4 bar (M #13) and spaced at 48 in. (1,219 mm) maximum may be used. Horizontal reinforcement must be provided within 16 in. (406 mm) of the top and bottom of these masonry walls.

For vertically reinforced walls, the minimum vertical reinforcement is one No. 4 (M #13) bar spaced no more than 48 in. (1,219 mm) on center. Vertical reinforcement must be located within 16 in. (406 mm) of the ends of the masonry wall.

VENEER DESIGN PROVISIONS

In addition to the other requirements for installing and constructing anchored masonry veneer (see ref. 1 Chapter 6 and ref. 6), Code Section 6.2.2.10 (ref. 1) includes requirements for masonry veneer anchored to buildings assigned to SDC C, D, E or F. As with the wall requirements, these requirements are cumulative.

Anchored veneer on buildings assigned to SDC C must be isolated from the structure at the sides and top so that vertical and lateral seismic forces resisted by the structure are not imparted to the veneer wythe. This isolation reduces accidental loading and permits larger building deflections to occur without damaging the veneer.

In addition to the general requirements and those for SDC C above, the following requirements must be met for veneer anchored to structures assigned to SDC D:

- The weight of the anchored veneer for each story must be supported independently of other stories to reduce the size of potentially damaged areas.
- To increase veneer stability and reduce the possibility of falling debris, the maximum area of veneer supported by each anchor must be reduced by 75% as follows (the maximum horizontal and vertical spacings are, however, unchanged).
  - 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 ft^2 (0.19 m^2) of wall area, and
  - for all other anchors, provide at least one anchor for each 2.63 ft^2 (0.24 m^2) of wall area.
- The anchored veneer must also have continuous single-wire joint reinforcement of minimum wire size W1.7 (MW 11) at a maximum spacing of 18 in. (457 mm) on center vertically to provide ductility and post-cracking strength.

In addition to these requirements, anchored veneer for buildings assigned to SDC E or F must also have vertical expansion joints at all returns and corners as further protection against building deflections. Anchors must be mechanically attached to the required joint reinforcement with clips or hooks.

REFERENCES

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