Chapter 21: Masonry

General Comments

Masonry construction has been used for at least 10,000 years in a variety of structures—homes, private and public buildings and historical monuments. The masonry of ancient times involved two major materials: brick manufactured from sun-dried mud or burned clay and shale; and natural stone.

The first masonry structures were unreinforced and intended to support mainly gravity loads. The weight of these structures stabilized them against lateral loads from wind and earthquakes.

Masonry construction has progressed through several stages of development. Fired clay brick became the principal building material in the United States during the middle 1800s. Concrete masonry was introduced to construction during the early 1900s and, along with clay masonry, expanded in use to all types of structures.

Historically, “rules of thumb” (now termed “empirical design”) were the only available methods of masonry design. Only in recent times have masonry structures been engineered using structural calculations. In the last 45 years, the introduction of engineered reinforced masonry has resulted in structures that are stronger and more stable against lateral loads, such as wind and seismic.

Masonry consists of a variety of materials. Raw materials are made into masonry units of different sizes and shapes, each having specific physical and mechanical properties. Both the raw materials and the method of manufacture affect masonry unit properties.

The word “masonry” is a general term that applies to construction using hand-placed units of clay, concrete, structural clay tile, glass block, natural stones and the like. One or more types of masonry units are bonded together with mortar, metal ties, reinforcement and accessories to form walls and other structural elements.

Proper masonry construction depends on correct design, materials, handling, installation and workmanship.

With a fundamental understanding of the functions and properties of the materials that comprise masonry construction and with proper design and construction, quality masonry structures are not difficult to obtain.

During the pioneer era of U.S. history, the fireplace was the central focus of residential cooking and heating. Today, the fireplace is essentially a decorative feature of residential construction. For energy conservation, existing fireplaces are sometimes converted and new fireplaces are designed to provide supplemental heat.

Of the many types of fireplaces, the most common are single face. Multifaced fireplaces, such as a corner fireplace with two adjacent open sides, fireplaces with two opposite faces open (common exposure to two rooms) or fireplaces with three or all faces open also occur, but are less common.

While the provisions of this chapter are for single-faced fireplaces, almost all types of masonry fireplaces include the same basic construction features: the base assembly, which consists of a foundation and hearth support; the firebox assembly, which consists of a fireplace opening, a hearth, a fireplace or combustion chamber and the throat and the smoke chamber, which supports the chimney liner.

Masonry fireplaces are made primarily of clay brick or natural stones, but also of concrete masonry or cast-in-place concrete. Chimneys for medium- and high-heat appliances require special attention for fire safety.

Purpose

Chapter 21 provides comprehensive and practical requirements for masonry construction, based on the latest state of technical knowledge. The provisions of Chapter 21 require minimum accepted practices and the use of standards for the design and construction of masonry structures and elements of structures. The provisions address: material specifications and test methods; types of wall construction; criteria for engineered design (by working stress and strength design methods); criteria for empirical design; required details of construction and other aspects of masonry, including execution of construction. The provisions are intended to result in safe and durable masonry. The provisions of Chapter 21 are also intended to prescribe minimum accepted practices for the design and construction of glass unit masonry, masonry fireplaces, masonry heaters and masonry chimneys.
SECTION 2101
GENERAL

2101.1 Scope. This chapter shall govern the materials, design, construction and quality of masonry.

Section 2101 prescribes general requirements for masonry designed in accordance with Chapter 21 of the code. It identifies masonry design methods and the conditions required for the use of each method. The methods are intended as a practical means for safety under a variety of potential service conditions.

Minimum requirements for construction documents and fireplace drawings are also included in Section 2101.

Chapter 21 contains the minimum code requirements for acceptance of masonry design and construction by the building official. Compliance with these requirements is intended to result in masonry construction with the minimum required structural adequacy and durability. Requirements more stringent than these are appropriate where mandated by sound engineering and judgement. Less restrictive requirements, however, are not permitted.

2101.2 Design methods. Masonry shall comply with the provisions of one of the following design methods in this chapter as well as the requirements of Sections 2101 through 2104. Masonry designed by the working stress design provisions of Section 2101.2.1, the strength design provisions of Section 2101.2.2 or the prestressed masonry provisions of Section 2101.2.3 shall comply with Section 2105.

This section requires masonry to comply with one of six design methods and the requirements contained in Sections 2101 through 2104 for construction documents, materials and construction.

The six design methods listed in Sections 2101.2.1 through 2101.2.6 can be categorized into two general design approaches for masonry. The first approach, engineered design, encompasses working stress, prestressed masonry and strength design. Use of these design methods necessitates a quality assurance program in accordance with Section 2105. The second approach, prescriptive design, includes the empirical design method, provisions for glass unit masonry and provisions for masonry veneer. Prescriptive design is permitted only under limited conditions as noted in Section 2109.1.1.

When the design professional chooses engineered design, the prescriptive masonry requirements of this chapter do not apply. For example, Section 2109 does not apply to engineered masonry.

Other provisions of the code also apply to masonry. For example, fire-resistant construction using masonry is required to comply with Chapter 7. Design loads and related requirements, including seismic forces and detailing, are required to comply with Chapter 16. Masonry foundations are required to comply with the provisions of Chapter 18. Special inspections of masonry construction are required in Chapter 17. Masonry veneer is addressed in Chapter 14.

2101.2.1 Working stress design. Masonry designed by the working stress design method shall comply with the provisions of Sections 2106 and 2107.

This section requires that masonry designed by the working stress design method meets both the working stress design requirements in Section 2107 and the seismic design requirements in Section 2106. Section 2107 requires working stress design to comply with Chapters 1 and 2 of ACI 530/ASCE 5/TMS 402 with minor exceptions. Additional information on these procedures is given in the commentaries to Section 2107 and ACI 530/ASCE 5/TMS 402.

ACI 530/ASCE 5/TMS 402 and ACI 530.1/ASCE 6/TMS 602 are referenced throughout Chapter 21. A description of these standards is warranted here. Both are joint publications of the American Concrete Institute (ACI), the Structural Engineering Institute of the American Society of Civil Engineers (ASCE) and The Masonry Society (TMS) and are produced through a joint committee of those societies, called the Masonry Standards Joint Committee (MSJC). These standards are typically referred to as the MSJC Code and Specification to reflect their joint authorship and sponsorship of the committee that oversees their development. The standards are developed through an ANSI-regulated consensus process and reflect the current state of technical knowledge on masonry design and construction.

The MSJC Code (ACI 530/ASCE 5/TMS 402) contains minimum requirements for masonry elements of structures. Topics include: construction documents; quality assurance; materials; analysis and design; strength and serviceability; flexural and axial stresses; shear; reinforcement; walls; columns; pilasters; beams and lintels and empirical design.

The engineered method in ACI 530/ASCE 5/TMS 402 is a working stress design method, which assumes linearly elastic material behavior and properties and uses working loads (see Chapter 16). The strength design method is also specified in the standard.

The MSJC Specification (ACI 530.1/ASCE 6/TMS 602) sets minimum acceptable levels of construction. It includes minimum requirements for composition; preparation and placement of materials; quality assurance for materials and masonry; execution of masonry construction; inspection and verification of quality. ACI 530.1/ASCE 6/TMS 602 contains both mandatory and optional requirements. The mandatory requirements are enforceable code requirements; the optional requirements may be invoked by the design professional. The specification is meant to be modified for use with the particular project under design.
2101.2.2 Strength design. Masonry designed by the strength design method shall comply with the provisions of Sections 2106 and 2108.

- Masonry is required to meet the strength design provisions referenced in Section 2108 and the seismic design requirements in Section 2106.

2101.2.3 Prestressed masonry. Prestressed masonry shall be designed in accordance with Chapters 1 and 4 of ACI 530/ASCE 5/TMS 402 and Section 2106. Special inspection during construction shall be provided as set forth in Section 1704.5.

- Prestressed masonry must comply with the applicable chapters of the ACI referenced standard, Building Code Requirements for Masonry Structures. Additional requirements for prestressed masonry shear walls used to resist earthquake loads are found in Section 2106.

2101.2.4 Empirical design. Masonry designed by the empirical design method shall comply with the provisions of Sections 2106 and 2109 or Chapter 5 of ACI 530/ASCE 5/TMS 402.

- This section permits the empirical design of masonry either by the provisions of Sections 2106 and 2109, or Chapter 5 of ACI 530/ASCE 5/TMS 402. This is because nearly all of the requirements in Section 2109 are based on the requirements in Chapter 5 of ACI 530/ASCE 5/TMS 402. Additional information on these provisions is given in the commentaries to Section 2109 and ACI 530/ASCE 5/TMS 402.

2101.2.5 Glass masonry. Glass masonry shall comply with the provisions of Section 2110 or with the requirements of Chapter 7 of ACI 530/ASCE 5/TMS 402.

- Glass masonry must comply with either the provisions of Section 2110 or Chapter 7 of ACI 530/ASCE 5/TMS 402. The provisions in Section 2110 are based on the requirements in Chapter 7 of ACI 530/ASCE 5/TMS 402. Additional information on these provisions is given in the commentaries to Section 2109 and ACI 530/ASCE 5/TMS 402.

2101.2.6 Masonry veneer. Masonry veneer shall comply with the provisions of Chapter 14.

- This section requires masonry veneer to comply with the provisions of Chapter 14; specifically, Sections 1405.5 for anchored masonry veneer and 1405.9 for adhered masonry veneer. These sections reference the provisions in Chapter 6 of ACI 530/ASCE 5/TMS 402. Additional information on these provisions is given in the commentaries to Chapter 14 and ACI 530/ASCE 5/TMS 402.

2101.3 Construction documents. The construction documents shall show all of the items required by this code including the following:

1. Specified size, grade, type and location of reinforcement, anchors and wall ties.
2. Reinforcing bars to be welded and welding procedure.
4. Provisions for dimensional changes resulting from elastic deformation, creep, shrinkage, temperature and moisture.

- Construction requirements must be clearly identified in the contract documents so that the structure is properly constructed using appropriate materials and methods. This section requires that, as a minimum, critical items required by the code and by the particular design be shown in the construction documents. The list is a minimum and should not be considered all-inclusive by the design professional. Both the design professional and the building official are permitted to require additional items as needed for a particular structure.

2101.3.1 Fireplace drawings. The construction documents shall describe in sufficient detail the location, size and construction of masonry fireplaces. The thickness and characteristics of materials and the clearances from walls, partitions and ceilings shall be clearly indicated.

- This section requires the submission of construction documents for all fireplaces so that compliance with appropriate code sections can be properly determined during plan review. The type of information and its format for plan review are established in this section. Construction documents are required showing relationships of components, as well as details related to the specific characteristics of the materials and techniques to be used when erecting the fireplace and chimney system. Such details are to include the type of brick or stone; refractory brick; concrete masonry; mortar requirements; wall thicknesses; clearances; dimensions of openings and dimensions of the firebox and the hearth extension.

SECTION 2102
DEFINITIONS AND NOTATIONS

2102.1 General. The following words and terms shall, for the purposes of this chapter and as used elsewhere in this code, have the meanings shown herein.

- This section contains definitions of terms associated with the subject matter of this chapter. Definitions of terms can help in the understanding and application of code requirements. Definitions are included within this chapter to provide convenient access to them without having to refer back to Chapter 2.

ADOBE CONSTRUCTION. Construction in which the exterior load-bearing and nonload-bearing walls and partitions are of unfired clay masonry units, and floors, roofs and interior framing are wholly or partly of wood or other approved materials.

Adobe, stabilized. Unfired clay masonry units to which admixtures, such as emulsified asphalt, are added during the manufacturing process to limit the units’ water absorption so as to increase their durability.
Adobe, unstabilized. Unfired clay masonry units that do not meet the definition of “Adobe, stabilized.”

Adobe masonry was popular in the southwest United States due to the availability of soil for units, the frequent exposure to intense sunlight to dry the units, the thermal mass provided by the completed adobe structure and the low cost of this form of construction. This form of construction has relatively low strength, a lack of formalized design procedures and labor-intensive manufacture of units and construction of the building, and accordingly, has not been used as much in recent years.

The two types of adobe masonry, stabilized and unstabilized, are briefly described below. Prescriptive design requirements for adobe masonry are contained in Section 2109.8.

Adobe, stabilized. Admixtures are added to the soil to produce more durable units.

Adobe, unstabilized. Unstabilized adobe does not contain stabilizers in the soil and is, therefore, not as durable as stabilized adobe.

ANCHOR. Metal rod, wire or strap that secures masonry to its structural support.

Anchors are fasteners connecting two components. Figure 2102.1(1) shows examples of anchor bolts that can be used in masonry and Figure 2102.1(3) shows some uses of anchor bolts to connect wood floors and masonry walls.

In this chapter, anchors are required where masonry walls meet intersecting walls, floors, roofs or the foundation below. Requirements for strength and durability of metal anchors are given in Section 2103.11.

ARCHITECTURAL TERRA COTTA. Plain or ornamental hard-burned modified clay units, larger in size than brick, with glazed or unglazed ceramic finish.

Architectural terra cotta refers to fired clay units with architectural shape and fired glazed coating. While rarely used today in new construction, repairs to terra cotta in existing building construction are not uncommon. These clay masonry units are usually produced for custom-made, anchored, ornamental veneers.

AREA.

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

Gross cross-sectional. The area delineated by the out-to-out specified dimensions of masonry in the plane under consideration.

Net cross-sectional. The area of masonry units, grout and mortar crossed by the plane under consideration based on out-to-out specified dimensions.

Area. Different areas are used in different calculations throughout this chapter. It is important to use the correct area, as each different area may give dramatically different results that may not be appropriate.

Bedded. The bedded area is simply the area of the unit’s surface on which mortar is placed and through which stresses are transferred to the adjacent work.

Gross cross-sectional. The gross cross-sectional area of the masonry is the specified masonry width (thickness) multiplied by the specified length, as illustrated in Figure 2102.1(2). While subtraction of core areas of the masonry unit is not required, subtraction of the space between wythes is required in noncomposite walls. Empirical compressive stress design is based on the gross cross-sectional area of the masonry.

Net cross-sectional. The net cross-sectional area encompasses the area of units, grout and mortar contained within the plane under consideration. For ungouted masonry, this area is sometimes equal to the bedded area, or more often to the minimum specified area of the face shells. For grouted masonry, this also includes that area of cores, cells or spaces filled with grout.
**BED JOINT.** The horizontal layer of mortar on which a masonry unit is laid.

- This is a horizontal mortar joint [see Figure 2102.1(4)] that separates a course of masonry units from the ones above and supports the weight of the masonry. Unlike the head or collar joint, it is easily closed when the masonry unit is placed. For a masonry unit in the typical (stretcher) orientation, the bed joint faces are the top and bottom, while the bed surface of the masonry unit is the underside. A special type of bed joint is the base-course joint or starting joint placed over foundations. See Section 2104.1.2 for requirements for thicknesses, placement and permitted tolerances for bed joints.

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**BOND BEAM.** A horizontal grouted element within masonry in which reinforcement is embedded.

- Bond beams permit horizontal reinforcement to be placed in masonry. For hollow masonry unit walls, special units can either be manufactured or the webs and end shells can be reduced by saw cutting to allow horizontal reinforcing bars to be placed in the wall.

**BOND REINFORCING.** The adhesion between steel reinforcement and mortar or grout.

- This term describes the adhesion between reinforcing steel and grout or mortar that transfers stresses between those elements.
BRICK.

Calcium silicate (sand lime brick). A masonry unit made of sand and lime.

Clay or shale. A masonry unit made of clay or shale, usually formed into a rectangular prism while in the plastic state and burned or fired in a kiln.

Concrete. A masonry unit having the approximate shape of a rectangular prism and composed of inert aggregate particles embedded in a hardened cementitious matrix.

Brick is composed of masonry units that are generally prismatic (rectangular) in shape.

Calcium silicate brick (sand lime brick). This solid brick unit is made principally from high-silica sand and lime.

Clay or shale. These masonry units are manufactured from surface clay, shale or fire clay. Different manufacturing processes and physical properties are associated with each material. Surface clays are found in sedimentary layers near the surface. Shales are clays subjected to geologic pressure, resulting in a solid state similar to slate. Fire clays are mined from deeper layers, resulting in more uniform properties. These units are formed into the desired shape by extrusion, molding or pressing. They are then fired in a kiln to increase their strength and durability.

Concrete. Concrete brick units are made from a zero-slump mix of portland cement and possibly other cementitious materials, aggregates, water and admixtures. These units are solid or have a shallow depression called a frog. Slump brick, for example, is a decorative concrete brick with bulged sides resulting from the consistency of the mix and the manufacturing process.

BUTTRESS. A projecting part of a masonry wall built integrally therewith to provide lateral stability.

These elements serve one or more purposes and are sometimes called “pilasters.” As secondary structural members, they are used to limit the unbraced horizontal length of walls (and their corresponding length-to-thickness ratios) by providing horizontally spaced points of lateral support. As lateral-load-resisting beam elements, or as vertical-load-resisting beam columns built integrally with the wall, they are primary structural members.

CAST STONE. A building stone manufactured from portland cement concrete precast and used as a trim, veneer or facing on or in buildings or structures.

Cast stone is a simulated stone precast from portland cement concrete. This material is typically used for veneer, but can also be used in other applications.

CELL. A void space having a gross cross-sectional area greater than $1\frac{1}{2}$ square inches (967 mm$^2$).

This term defines a large intentional void within a masonry unit. Grout and reinforcing steel are often placed in cells to form reinforced masonry.

CHIMNEY. A primarily vertical enclosure containing one or more passageways for conveying flue gases to the outside atmosphere.

A chimney is a primarily vertical enclosure containing one or more flues. This chapter regulates masonry chimneys and fireplaces in Sections 2111 through 2113. Chimneys differ from metal vents in the materials from which they are constructed and the type of appliance they are designed to serve. Chimneys can vent much hotter flue gases than metal vents.

CHIMNEY TYPES.

High-heat appliance type. An approved chimney for removing the products of combustion from fuel-burning, high-heat appliances producing combustion gases in excess of 2,000°F (1093°C) measured at the appliance flue outlet (see Section 2113.11.3).
Low-heated appliance type. An approved chimney for removing the products of combustion from fuel-burning, low-heated appliances producing combustion gases not in excess of 1,000°F (538°C) under normal operating conditions, but capable of producing combustion gases of 1,400°F (760°C) during intermittent forces firing for periods up to 1 hour. Temperatures shall be measured at the appliance flue outlet.

Masonry type. A field-constructed chimney of solid masonry units or stones.

Medium-heated appliance type. An approved chimney for removing the products of combustion from fuel-burning, medium-heated appliances producing combustion gases not exceeding 2,000°F (1093°C) measured at the appliance flue outlet (see Section 2113.11.2).

Provisions for several types of chimneys are contained in Chapter 21, as described below.

High-heated appliance type. High-heated chimneys are used in industrial applications, such as incinerators, kilns and blast furnaces. Section 2113.11.3 contains requirements for the construction and installation of chimneys for high-heated appliances.

Low-heated appliance type. Most domestic fuel-burning appliances are low-heated appliances. Low-heated appliances include solid-fuel burning appliances, such as room heaters and wood stoves. Section 2113 contains requirements for the construction and installation of chimneys for low-heated appliances.

Masonry type. Masonry chimneys can have one or more flues and are field constructed of masonry units, stone, concrete and fired-clay materials. Masonry chimneys can stand alone or be part of a masonry fireplace. Section 2113 contains requirements for the construction and installation of masonry chimneys.

Most masonry chimneys require a chimney liner, resistant to heat and the corrosive action of the products of combustion. Chimney liners are generally made of fired-clay tile, refractory brick, poured-in-place refractory materials or stainless steel.

Medium-heated appliance type. Some examples of medium-heated appliances are annealing furnaces, galvanizing furnaces, pulp dryers and charcoal furnaces. Section 2113.11.2 contains requirements for the construction and installation of chimneys for medium-heated appliances.

CLEANOUT. An opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

These openings allow debris to be removed from a space to be grouted. The code references ACI 530.1/ASCE 6/TMS 602 for minimum construction requirements for masonry, including the minimum size and maximum spacing of cleanouts for grouted masonry.

COLLAR JOINT. Vertical longitudinal joint between wythes of masonry or between masonry and backup construction that is permitted to be filled with mortar or grout.

A collar joint is a filled space between masonry wythes [see Figure 2102.1(4)]. Care is necessary for proper construction of collar joints, especially where solid filling is required.

COLUMN, MASONRY. An isolated vertical member whose horizontal dimension measured at right angles to its thickness does not exceed three times its thickness and whose height is at least four times its thickness.

Masonry columns typically resist moment and axial compression and sometimes axial tension from uplift. Masonry elements falling within the dimensional limits for columns must be designed and detailed accordingly, with minimum column ties and minimum vertical reinforcement.

The requirements for masonry columns vary. Some members meeting the geometric requirements for columns do not have significant structural demands placed on them. In light of this, Section 2107.2.2 exempts some column-type elements from these column detailing requirements.

COMPOSITE ACTION. Transfer of stress between components of a member designed so that in resisting loads, the combined components act together as a single member.

This definition is needed in order to fully explain what is meant by composite masonry.

COMPOSITE MASONRY. Multiwythe masonry members acting with composite action.

When masonry wythes are connected or bonded together so that stresses can be transferred adequately between them, the masonry is considered as composite masonry. Section 2.1.3.2 of ACI 530/ASCE 5/TMS 402 provides minimum bonding requirements for masonry to be considered as composite.

COMPRESSION STRENGTH OF MASONRY. Maximum compressive force resisted per unit of net cross-sectional area of masonry, determined by the testing of masonry prisms or a function of individual masonry units, mortar and grout.

The specified compressive strength of masonry, $f_c$, is used for the engineerized design of masonry (working stress design of Section 2107 and strength design of Section 2108). The average compressive strength of masonry, determined by the prism test method or the unit strength method (Section 2105.2), must equal or exceed the specified compressive strength.

CONNECTOR. A mechanical device for securing two or more pieces, parts or members together, including anchors, wall ties and fasteners.

A few types of steel connectors are illustrated in Figures 2102.1(2) and 2102.1(4). Masonry connectors attach
intersecting components and also act as bonding elements. The specified size, grade, type and location of connectors are required on construction documents, in accordance with Section 2101.3.

COVER. Distance between surface of reinforcing bar and edge of member.

- An adequate thickness of masonry materials is needed between reinforcing steel and the surface of the masonry for two important reasons. The first reason is for proper transfer of stresses between the reinforcing steel and the masonry. This cover, often referred to as the "structural cover," is noted by the term K in Equation 21-2. The second reason is so that the reinforcement is protected from corrosion or degradation. Accordingly, larger cover is required in the MSJC standards for masonry with more severe exposure.

DIAPHRAGM. A roof or floor system designed to transmit lateral forces to shear walls or other lateral-load-resisting elements.

- A diaphragm is a planar horizontal structural element (for example, a floor or roof) designed to transmit horizontal forces to vertical resisting elements (for example, shear walls or frames). Diaphragms are essential elements in the lateral-load-resisting system of a structure. Diaphragms are considered as rigid or flexible in their own planes. Flexible diaphragms deflect more than rigid diaphragms under imposed loads.

DIMENSIONS.

- Actual. The measured dimension of a masonry unit or element.
- Nominal. A dimension equal to a specified dimension plus an allowance for the joints with which the units are to be laid. Thickness is given first, followed by height and then length.
- Specified. The dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure.
- Different dimensions are used to designate sizes of masonry units and masonry elements. The terms below denote the common meanings of various types of dimensions used in the chapter.
- Actual. The actual dimensions of a masonry unit are its measured dimensions. Actual dimensions should equal the specified dimensions within the construction or manufacturing tolerances.
- Nominal. The nominal dimensions of a masonry unit are the specified dimensions, plus the specified thickness of one mortar joint. Nominal dimensions are used for architectural layout of masonry structures. Figure 2102.1(5) shows nominal dimensions for a specific concrete masonry unit.
- Specified. The specified dimensions are prescribed in the construction documents. Actual dimensions should equal the specified dimensions, within the construction or manufacturing tolerances. Figure 2102.1(5) shows specified and nominal dimensions for a concrete masonry unit.

EFFECTIVE HEIGHT. For braced members, the effective height is the clear height between lateral supports and is used for calculating the slenderness ratio. The effective height for unbraced members is calculated in accordance with engineering mechanics.

- Effective height is a theoretical distance used to predict the buckling load (compressive capacity as governed by...
stability) of a wall or column. For a braced condition (no sidesway), effective height is conservatively required to be assumed as the clear height between points of lateral support. For an unbraced condition (sidesway permitted), the effective height is greater than the clear height and must be calculated.

**FIREPLACE.** A hearth and fire chamber or similar prepared place in which a fire may be made and which is built in conjunction with a chimney.

- Requirements for masonry fireplaces are contained in Section 2111.

**FIREPLACE THROAT.** The opening between the top of the firebox and the smoke chamber.

- This definition is necessary for proper understanding of the code criteria for location and minimum cross-sectional area. This criterion is based on many years of successful performance and is needed to provide proper construction requirements (see Section 2111.7).

**GROUTED MASONRY.**

- **Grouted hollow-unit masonry.** That form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.
- **Grouted multiwythe masonry.** That form of grouted masonry construction in which the space between the wythes is solidly or periodically filled with grout.
- **Masonry with grout, either in the cells of hollow units or in the collar joint, is considered grouted masonry. Grouted masonry has a greater surface area to resist loads and a better transfer of stresses to reinforcing steel.**
- **Grouted hollow-unit masonry.** Hollow masonry units are often reinforced and grouted to provide stronger elements. Table 7 of ACI 530.1/ASCE 6/TMS 602 provides requirements on fine or coarse grout based on the dimensions of the cell to be grouted.
- **Grouted multiwythe masonry.** The space between wythes of multiwythe masonry can be grouted to provide stronger elements. Table 7 of ACI 530.1/ASCE 6/TMS 602 provides requirements on fine or coarse grout, based on the dimensions of the space to be grouted.

**HEAD JOINT.** Vertical mortar joint placed between masonry units within the wythe at the time the masonry units are laid.

- **Vertically oriented joints between masonry units are head joints [see Figure 2102.1(4)].**

**HEADER (Bonder).** A masonry unit that connects two or more adjacent wythes of masonry.

- **Masonry bond between adjacent masonry wythes, and masonry bond anchorage between intersecting masonry walls, are occasionally accomplished with connecting units called “headers” or “bonders.” The units may be visible on the outside of either wythe, or may not be visible on one or more wythes. If not visible, they are referred to as “blind headers.” Headers must have a minimum embedment in each wythe.**

**HEIGHT, WALLS.** The vertical distance from the foundation wall or other immediate support of such wall to the top of the wall.

- This term means the actual height, measured from the bottom to the top of the wall, for free-standing cantilever walls, or as the vertical distance between points of lateral support for walls spanning between floor or roof levels.

**MASONRY.** A built-up construction or combination of building units or materials of clay, shale, concrete, glass, gypsum, stone or other approved units bonded together with or without mortar or grout or other accepted method of joining.

- **Ashlar masonry.** Masonry composed of various sized rectangular units having sawed, dressed or squared bed surfaces, properly bonded and laid in mortar.
- **Coursed ashlar.** Ashlar masonry laid in courses of stone of equal height for each course, although different courses shall be permitted to be of varying height.
- **Glass unit masonry.** Nonload-bearing masonry composed of glass units bonded by mortar.
- **Plain masonry.** Masonry in which the tensile resistance of the masonry is taken into consideration and the effects of stresses in reinforcement are neglected.
- **Random ashlar.** Ashlar masonry laid in courses of stone set without continuous joints and laid up without drawn patterns. When composed of material cut into modular heights, discontinuous but aligned horizontal joints are discernible.
- **Reinforced masonry.** Masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces.
- **Solid masonry.** Masonry consisting of solid masonry units laid contiguously with the joints between the units filled with mortar.

- The materials (other than gypsum) and elements constructed as stated in this definition are considered masonry construction and are regulated by Chapter 21. This term identifies the building elements of plain (unreinforced) masonry, reinforced masonry, grouted masonry, glass unit masonry and masonry veneer.

- **Ashlar masonry.** Units for ashlar masonry construction are rectangular in shape but variable in size.
- **Coursed ashlar.** In coursed ashlar masonry, all units in one course are the same height, although different courses may have different heights.
- **Glass unit masonry.** Glass unit masonry is required to be designed in accordance with Sections 2101.2.4 and 2110.
- **Plain masonry.** Plain masonry has historically been referred to as “unreinforced masonry.” Since such ma-
MASONRY UNIT. Brick, tile, stone, glass block or concrete block conforming to the requirements specified in Section 2103.

Clay. A building unit larger in size than a brick, composed of burned clay, shale, fired clay or mixtures thereof.

Concrete. A building unit or block larger in size than 12 inches by 4 inches by 4 inches (305 mm by 102 mm by 102 mm) made of cement and suitable aggregates.

Hollow. A masonry unit whose net cross-sectional area in any plane parallel to the load-bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

Solid. A masonry unit whose net cross-sectional area in every plane parallel to the load-bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane.

Masonry units are natural stone units or manufactured units of fired clay, shale, cementitious materials or glass.

Clay. Clay masonry units are manufactured from fired clay or shale (also see the definition of "Brick, clay or shale").

Concrete. Concrete masonry units are manufactured from a zero-slump mixture of portland cement (and possibly other cementitious materials), aggregates, water and sometimes admixtures.

Hollow. Hollow masonry units are those having a specified net cross-sectional area less than 75 percent of their corresponding gross cross-sectional area. Where the specified net cross-sectional area is equal to or greater than 75 percent of the gross cross-sectional area, the unit is considered to be solid.

Solid. Solid masonry units have a specified net cross-sectional area 75 percent or greater of their corresponding gross cross-sectional area. Where the specified net cross-sectional area is less than 75 percent of the gross cross-sectional area, the unit is considered to be hollow.

MEAN DAILY TEMPERATURE. The average daily temperature of temperature extremes predicted by a local weather bureau for the next 24 hours.

This is the predicted average daily temperature to confirm when cold-weather and hot-weather construction techniques are required to be followed.

MORTAR. A plastic mixture of approved cementitious materials, fine aggregates and water used to bond masonry or other structural units.

Mortar is the material that bonds units and accessories together and compensates for dimensional variations of the units. Both the plastic and hardened properties of mortar are important for strong, durable, water-tight construction. Material requirements and referenced standards for several permitted mortar types are given in Section 2103.7.

MORTAR, SURFACE-BONDING. A mixture to bond concrete masonry units that contains hydraulic cement, glass fiber reinforcement with or without inorganic fillers or organic modifiers and water.

This mortar is a packaged, dry, combined material permitted for use in the surface bonding of concrete masonry units that have not been prefaced, coated or painted. Masonry units are stacked without mortar joints and surface-bonding mortar is then applied to both sides of the wall surface, creating a structural element.

PLASTIC HINGE. The zone in a structural member in which the yield moment is anticipated to be exceeded under loading combinations that include earthquakes.

The portion of a member where the yield moment is expected to be exceeded under seismic loads is considered a plastic hinge zone. Location and detailing of plastic hinge zones are a critical part of strength design for seismic loads.

PRESTRESSED MASONRY. Masonry in which internal stresses have been introduced to counteract potential tensile stresses in masonry resulting from applied loads.

This definition provides an understanding of the term "prestressed masonry," which is used to define particular types of shear wall systems recognized under the code.

PRISM. An assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

Compliance with the specified compressive strength of masonry, , can be verified by prism tests. The prism configuration and construction methods for such tests are prescribed in ASTM C 1314.
RUBBLE MASONRY. Masonry composed of roughly shaped stones.

**Coursed rubble.** Masonry composed of roughly shaped stones fitting approximately on level beds and well bonded.

**Random rubble.** Masonry composed of roughly shaped stones laid without regularity of coursing but well bonded and fitted together to form well-divided joints.

**Rough or ordinary rubble.** Masonry composed of unsquared field stones laid without regularity of coursing but well bonded.

- Rubble consists of pieces of stone that are irregular in shape and size. Rubble is often laid to form walls, foundations, and paving.

**Coursed rubble.** Coursed rubble consists of roughly shaped stones that are laid with continuous bed joints.

**Random rubble.** Random rubble has approximately level beds, but discontinuous bed joints because of the varying heights of the individual units.

**Rough or ordinary rubble.** This type of rubble is laid without regular coursing.

RUNNING BOND. The placement of masonry units such that head joints in successive courses are horizontally offset at least one-quarter the unit length.

- Figure 2102.1(6) illustrates the required overlap for running bonds. The minimum overlap is necessary to provide strength between units when masonry spans horizontally. Reinforcement or reinforced bond beams are required in Section 2109.6.5.2 for masonry in other than running bond. Masonry not laid in running bond is often referred to as “stackbonded.”

**SHEAR WALL.**

**Detailed plain masonry shear wall.** A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with Section 2106.1.1.

**Intermediate prestressed masonry shear wall.** A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.1.2.

**Intermediate reinforced masonry shear wall.** A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.1.

**Ordinary plain masonry shear wall.** A masonry shear wall designed to resist lateral forces neglecting stresses in reinforcement, and designed in accordance with Section 2106.1.1.

**Ordinary plain prestressed masonry shear wall.** A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.1.1.

**Ordinary reinforced masonry shear wall.** A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.1.

**Special prestressed masonry shear wall.** A prestressed masonry shear wall designed to resist lateral forces considering stresses in reinforcement and designed in accordance with...
Section 2106.1.1.3 except that only grouted, laterally restrained tendons are used.

**Special reinforced masonry shear wall.** A masonry shear wall designed to resist lateral forces considering stresses in reinforcement, and designed in accordance with Section 2106.1.1.

Shear walls are vertical diaphragms resisting vertical and in-plane lateral loads. They are part of the lateral-force-resisting system and basic seismic-force-resisting system. The various types of shear wall systems defined are necessary to correctly characterize their expected performance level in resisting earthquake forces (also see the definition of “Basic seismic-force-resisting system” in Chapter 16). Shear walls must be adequately connected to floor and roof diaphragms and to the foundation, so that loads can be transferred effectively between these elements.

**Detailed plain masonry shear wall.** Such shear walls are designed as plain (unreinforced) masonry, but contain a minimum amount of reinforcement in the horizontal and vertical directions. Because of this reinforcement, these walls have more favorable seismic design parameters, including higher response modification factors, $R$, than ordinary plain masonry shear walls.

**Intermediate prestressed masonry shear wall.** This definition distinguishes intermediate prestressed masonry shear walls from the other types of prestressed masonry shear walls that are recognized by the code in order to classify the lateral-force-resisting system in determining earthquake loads.

**Intermediate reinforced masonry shear wall.** These shear walls are designed as reinforced masonry and also must contain a minimum amount of prescriptive reinforcement. Because they contain reinforcement, their seismic performance will be better than that of plain masonry shear walls in seismic events and they are accordingly permitted in areas of moderate as well as low seismic risk. These walls have more favorable seismic design parameters, including higher response modification factors, $R$, than plain masonry shear walls and ordinary reinforced masonry shear walls.

**Ordinary plain masonry shear wall.** Such shear walls meet only minimum requirements, without minimum amounts of horizontal and vertical reinforcement. Thus, they may be used only in areas of low seismic risk. Plain masonry walls are designed as unreinforced masonry (by the noted sections), although they may in fact contain reinforcement.

**Ordinary plain prestressed shear wall.** This definition distinguishes ordinary plain prestressed masonry shear walls from the other types of prestressed masonry shear walls that are recognized by the code in order to classify the lateral-force-resisting system in determining earthquake loads.

**Ordinary reinforced masonry shear wall.** These shear walls are designed as reinforced masonry. Because they contain reinforcement, their seismic performance is expected to be better than that of plain masonry shear walls and they are accordingly permitted in areas of moderate as well as low seismic risk. These walls have more favorable seismic design parameters, including higher response modification factors, $R$, than plain masonry shear walls. When used in areas of moderate seismic risk (Seismic Design Category C), however, minimum reinforcement is required as noted in Section 2106.4.

**Special prestressed masonry shear wall.** This definition distinguishes special prestressed masonry shear walls from the other types of prestressed masonry shear walls that are recognized by the code in order to classify the lateral-force-resisting system in determining earthquake loads.

**Special reinforced masonry shear wall.** These shear walls are designed as reinforced masonry and must also meet prescriptive reinforcement limits and material limitations. Because of these requirements, they are permitted to be used in all seismic risk areas. These walls have the most favorable seismic design parameters, including the highest response modification factors, $R$, of any of the masonry shear wall types.

**SHELL.** The outer portion of a hollow masonry unit as placed in masonry.

- The shells of a masonry unit are defined by how the unit is used in construction. They are the portions of a hollow masonry unit exposed on the faces of elements and may include face shells and end webs.

**SPECIFIED.** Required by construction documents.

- The construction documents contain material and construction requirements essential to the proper performance of the structure. These requirements are considered minimums and material or construction that does not comply is not permitted by the code.

**SPECIFIED COMpressive STRENGTH OF MASONRY, $f'_m$.** Minimum compressive strength, expressed as force per unit of net cross-sectional area, required of the masonry used in construction by the construction documents, and upon which the project design is based. Whenever the quantity $f'_m$ is under the radical sign, the square root of numerical value only is intended and the result has units of pounds per square inch (psi) (Mpa).

- Engineered design of structural masonry is based on the specified compressive strength of the masonry, $f'_m$. This strength is required to be shown on the contract documents. Strength of the constructed masonry, determined by the unit strength method or prism strength method, is required to equal or exceed the specified compressive strength of masonry.
STACK BOND. The placement of masonry units in a bond pattern is such that head joints in successive courses are vertically aligned. For the purpose of this code, requirements for stack bond shall apply to masonry laid in other than running bond.

- Figure 2102.1(6) illustrates the required overlap for running bonds. If this required overlap is not provided, the wall is considered to be laid in stack bond. Reinforcement, or reinforced bond beams, are required by Section 2109.6.5.2 for stack bond masonry.

STONE MASONRY. Masonry composed of field, quarried or cast stone units bonded by mortar.

- Ashlar stone masonry. Stone masonry composed of rectangular units having sawed, dressed or squared bed surfaces and bonded by mortar.
- Rubble stone masonry. Stone masonry composed of irregular-shaped units bonded by mortar.

- Stone masonry is comprised of natural marble, limestone, granite, sandstone and slate for building purposes. Ashlar stone is further distinguished as coursed or random. Rubble stone masonry is further distinguished as coursed, random or rough.

- Ashlar stone masonry. Units for ashlar masonry construction are rectangular in shape but variable in size.
- Rubble stone masonry. Unlike ashlar stone masonry, which has rectangular units, rubble stone masonry units are irregular in shape. Rubble stone masonry is further distinguished as coursed, random or rough.

STRENGTH.

Design strength. Nominal strength multiplied by a strength reduction factor.

- Nominal strength. Strength of a member or cross section calculated in accordance with these provisions before application of any strength-reduction factors.

- Required strength. Strength of a member or cross section required to resist factored loads.

- The term “strength” is used in both general and specific senses. In the general sense, the strength of a member is its capacity to resist internal forces and moments. In the specific sense, strength is further categorized by type. The tensile strength of a member, for instance, refers to how much tensile force the member can support.

- In the context of strength design, the force resulting from factored design actions is referred to as the required strength. An approximation to the “minimum expected” strength of the member is referred to as the “nominal strength” (see the commentary on nominal strength). This nominal strength is then multiplied by a strength reduction factor to account for material, design and construction variabilities to determine the design strength. The design strength must equal or exceed the required strength.

- In the context of working stress design, the force resulting from unfactored design loads is referred to as the “applied (actual) force.” The anticipated strength would then be reduced by appropriate safety factors to either an allowable working stress or an allowable working strength (for example, for anchor bolts). This working stress or strength is required to equal or exceed the applied (actual) stress or force.

- “Design strength,” “Nominal strength” and “Required strength” are defined in more detail immediately below. Working stresses and strengths are defined in ACI 530/ACI 5/TMS 402.

- The strength design of masonry (see Section 2108), the required strength is that which corresponds to the factored design loads on the structure. The design strength (nominal strength times the appropriate strength reduction factor) must equal or exceed the required strength.

TIE, LATERAL. Loop of reinforcing bar or wire enclosing longitudinal reinforcement.

- Lateral ties enclose longitudinal reinforcement. They are typically used in columns to support the compression reinforcement and masonry core so that these can support...
extreme loads even with some degradation of the masonry. Reinforcement can be assumed to be effective in carrying compressive forces only when supported by lateral ties.

Lateral ties also resist shear loads. Ties must form a closed rectangle or loop to completely surround the longitudinal reinforcement. Stirrups, in contrast, can be open.

**TIE, WALL.** A connector that connects wythes of masonry walls together.

- Ties are used to connect adjacent wythes and are subject to requirements for strength, durability and installation. Ties are adjustable or nonadjustable. A typical nonadjustable “Z” wire tie is shown in Figure 2109.6.3(1).

**TILE.** A ceramic surface unit, usually relatively thin in relation to facial area, made from clay or a mixture of clay or other ceramic materials, called the body of the tile, having either a “glazed” or “unglazed” face and fired above red heat in the course of manufacture to a temperature sufficiently high enough to produce specific physical properties and characteristics.

- Ceramic tile units are manufactured from nonmetallic materials and fired at high temperatures to obtain specific properties. Tile is considered a thin, nonstructural finish that must be supported by a strong, stiff, dimensionally stable backing.

**TILE, STRUCTURAL CLAY.** A hollow masonry unit composed of burned clay, shale, fire clay or mixture thereof, and having parallel cells.

- These clay masonry units are produced as end tiles and side tiles and differ from clay brick by having required cells with thinner webs between them.

**WALL.** A vertical element with a horizontal length-to-thickness ratio greater than three, used to enclose space.

- **Cavity wall.** A wall built of masonry units or of concrete, or a combination of these materials, arranged to provide an airspace within the wall, and in which the inner and outer parts of the wall are tied together with metal ties.

- **Composite wall.** A wall built of a combination of two or more masonry units bonded together, one forming the backup and the other forming the facing elements.

- **Dry-stacked, surface-bonded walls.** A wall built of concrete masonry units where the units are stacked dry, without mortar on the bed or head joints, and where both sides of the wall are coated with a surface-bonding mortar.

- **Masonry-bonded hollow wall.** A wall built of masonry units so arranged as to provide an airspace within the wall, and in which the facing and backing of the wall are bonded together with masonry units.

- **Parapet wall.** The part of any wall entirely above the roof line.

- **Masonry walls typically enclose space. They are generally required to be designed and installed for weather resistance, durability and adequate structural strength.**

The given dimensional requirements differentiate walls from columns.

**Cavity wall.** Cavity walls are made up of solid or hollow masonry units separated by a continuous airspace or cavity. This continuous airspace adds insulating value and acts as a barrier to moisture when detailed with flashing and weep holes. In many cavity walls, thermal insulation is placed between the wythes to further enhance thermal efficiency.

**Composite wall.** A composite wall is a multiwythe wall with wythes that act together to resist loads. The distinction of having wythes with different mechanical properties is important in engineering design. Walls constructed of different materials must be evaluated for lateral- and vertical-load-bearing performance and for differential movement between the wythes.

**Dry-stacked, surface-bonded walls.** Although this type of wall is dry stacked, a leveling course must be set in a full bed of mortar. Dry-stacked walls are also required to be placed in a running bond pattern (see commentary to the definition of “Mortar, surface-bonding”).

**Masonry-bonded hollow wall.** Hollow walls are similar to cavity walls in that they are made up of solid or hollow units separated by an airspace. Unlike a cavity wall, however, the wythes are bonded together by masonry units, which causes the wythes to act together under load.

**Parapet wall.** These portions of masonry walls project above the roof. A parapet wall is exposed to weather on both sides and is laterally unsupported at the top. Parapets often have copings.

**WEB.** An interior solid portion of a hollow masonry unit as placed in masonry.

- The webs of hollow units are provided to support and strengthen the face shells. Web heights are permitted to be reduced so that horizontal reinforcement can be placed in the element.

**WYTHE.** Each continuous, vertical section of a wall, one masonry unit in thickness.

- Sometimes referred to as a “leaf” or “tier,” each wythe is one thickness of a masonry unit.

**NOTATIONS.**

\[ A_n = \text{Net cross-sectional area of masonry, square inches (mm}^2) \]

\[ b = \text{Effective width of rectangular member or width of flange for T and I sections, inches (mm)} \]

\[ d_r = \text{Diameter of reinforcement, inches (mm)} \]

\[ f_r = \text{Modulus of rupture, psi (MPa)} \]

\[ f_y = \text{Specified yield stress of the reinforcement or the anchor bolt, psi (MPa)} \]

\[ f_m = \text{Specified compressive strength of masonry at age of 28 days, psi (MPa)} \]
2103.1 Concrete masonry units. Concrete masonry units shall conform to the following standards: ASTM C 55 for concrete brick; ASTM C 73 for calcium silicate face brick; ASTM C 90 for load-bearing concrete masonry units or ASTM C 744 for prefaced concrete and calcium silicate masonry units.

Proper selection of materials is essential to produce masonry with adequate strength and durability. This section sets forth prescriptive and performance-based requirements (referenced standards) for masonry materials. Test procedures and criteria for establishing and verifying quality are included. Concrete masonry refers to solid and hollow concrete units, including concrete brick, concrete block, split-face block, slump block and other special units. This section requires conformance to ASTM standards for each specific type of concrete masonry unit. The standards include requirements for materials; manufacture; physical properties; moisture content; strength; absorption; minimum dimensions and permissible variations; inspection; testing and rejection.

Concrete masonry units are selected based on the desired use and appearance. Units are typically specified by weight, type and strength. Hollow load-bearing concrete masonry units are manufactured in accordance with the requirements of ASTM C 90 using portland cement, water and mineral aggregates. Other suitable materials, such as approved admixtures, are permitted in accordance with ASTM C 90.

Hollow load-bearing concrete masonry units have three weight classifications: normal-weight units of 125 pounds per cubic foot (pcf) (2000 kg/m^3) or more; medium-weight units of between 105 pcf (1680 kg/m^3) and 125 pcf (2000 kg/m^3) and lightweight units of less than 105 pcf (1680 kg/m^3). Lightweight aggregates generally are expanded blast-furnace slag or similar suitable materials. Normal-weight units are made from sand, gravel, crushed stone or air-cooled, blast-furnace-slag aggregates.

Hollow load-bearing concrete masonry units are classified into two types. Type I are moisture-controlled units complying with the moisture-content requirements of ASTM C 90; Type II are nonmoisture-controlled units. Concrete brick is required to comply with ASTM C 55. Concrete building brick and other solid concrete veneer and facing units are typically smaller than concrete masonry units conforming to ASTM C 90. They are made from portland cement, water and mineral aggregates, with or without inclusion of other approved materials.

Concrete brick is manufactured as lightweight, medium-weight and normal-weight units as described above for hollow concrete masonry units. Concrete brick is manufactured in two grades: Grade N and Grade S. Grade N units are used as architectural veneer and facing units in exterior walls, where high strength and resistance to moisture penetration and freeze-thaw cycling are required. Grade S units are used when moderate strength and resistance to freeze-thaw action and moisture penetration are required.

These units are classified into two types for each of the grades defined. Type I are moisture-controlled units complying with the moisture-content requirements of ASTM C 55. Type II are nonmoisture-controlled units. Calcium silicate face brick is a solid masonry unit complying with ASTM C 73. These units are manufactured principally from silica sand, hydrated lime and water.

Calcium silicate face brick is manufactured in two grades: Grade SW and Grade MW. Grade SW is required where exposure to moisture in the presence of freezing temperatures is anticipated. Grade MW is permitted where the anticipated exposure has freezing temperatures, but without water saturation.

Grade SW units have a minimum permitted compressive strength on the gross area of 4,500 pounds per square inch (psi) (31.0 MPa) (average of three units), but not less than 3,500 psi (24.1 MPa) for any individual unit. Grade MW units have a minimum permitted compressive strength on the gross area of 2,500 psi (17.2 MPa) (average of three units), but not less than 2,000 psi (13.8 MPa) for any individual unit.

ASTM C 744 is referenced for the manufacture of prefaced concrete and calcium silicate masonry units, commonly referred to as “glazed” concrete masonry units. The specified exposed surfaces of these units are covered during their manufacture with resin, resin and inert filler or cement and inert filler to produce a smooth
resinous tile-like facing.

Facing requirements of that standard address resistance to chemicals; failure of adhesion of the facing material; abrasion surface-burning characteristics, color and color change; soiling and cleansability. The standard also covers dimensional tolerances, including face dimensions and distortions.

2103.2 Clay or shale masonry units. Clay or shale masonry units shall conform to the following standards: ASTM C 34 for structural clay load-bearing wall tile; ASTM C 56 for structural clay nonload-bearing wall tile; ASTM C 62 for building brick (solid masonry units made from clay or shale); ASTM C 1088 for solid units of thin veneer brick; ASTM C 126 for ceramic-glazed structural clay facing tile, facing brick and solid masonry units; ASTM C 212 for structural clay facing tile; ASTM C 216 for facing brick (solid masonry units made from clay or shale) and ASTM C 652 for hollow brick (hollow masonry units made from clay or shale).

Exception: Structural clay tile for nonstructural use in fireproofing of structural members and in wall furring shall not be required to meet the compressive strength specifications. The fire-resistance rating shall be determined in accordance with ASTM E 119 and shall comply with the requirements of Table 602.

Section 2103.2 requires conformance with ASTM standards for masonry units manufactured from clay or shale. The various standards also include requirements for materials; manufacture; physical properties; minimum dimensions and permissible variations; inspections and testing.

Clay or shale masonry units are manufactured from clay and shale, which are compounds of silica or alumina. Shale is simply a hardened clay. The raw materials are formed into the desired shape by extrusion and cutting, molding or pressing while in the plastic state. The units are then fired in a kiln. The raw materials and the manufacturing process influence the physical properties of the manufactured unit.

Clay or shale masonry units are selected for their intended use from a variety of shapes, sizes and strengths. Units are specified based on grades and type.

Solid face brick units are required to conform to ASTM C 216. This standard covers clay brick intended to be used in masonry and supplying structural or facing components, or both, to the structure. These units are available in a variety of sizes, textures, colors and shapes.

ASTM C 216 contains requirements for two grades of durability: Grade SW and Grade MW. Grade SW is used where a high and uniform degree of resistance to freeze-thaw degradation and disintegration by weathering is desired and when the brick may be saturated while frozen. Grade MW is used where moderate resistance to cyclic freeze-thaw damage is permissible or where the brick may be damp but not saturated with water during certain cycles. Grade NW is used where little resistance to cyclic freeze-thaw damage is required and is acceptable for applications protected from water absorption and freezing.

Hollow brick has two grades of durability: Grade SW and Grade MW. Grade SW is used where a high and uniform degree of resistance to freeze-thaw degradation and disintegration by weathering is desired and when the brick may be saturated while frozen. Grade MW is used where moderate resistance to cyclic freeze-thaw damage is permissible or where the brick may be damp but not saturated with water. Grade NW is used where little resistance to cyclic freeze-thaw damage is required and is acceptable for applications protected from water absorption and freezing.

Type FBS (face brick standard) units are permitted for general use in masonry. Type FBX (face brick select) units are also for general use, but have a higher degree of precision and lower permissible variation in size than Type FBS units. Type FBA (face brick architectural) units are also for general use, but are intentionally manufactured to produce characteristic architectural effects resulting from nonuniformity in size and texture of the units.

Solid units of building brick are required to conform to ASTM C 62. This specification covers brick intended for use in both structural and nonstructural masonry where external appearance is not critical. This brick was formerly called "common brick," and the standard does not contain appearance requirements.

ASTM C 62 contains requirements for three grades of durability: Grade SW, Grade MW and Grade NW. Grade SW is intended for use where a high and uniform degree of resistance to freeze-thaw degradation and disintegration by weathering is desired and when the brick may be saturated while frozen. Grade MW is intended for use where moderate resistance to cyclic freeze-thaw damage is permissible or where the brick may be damp but not saturated with water during certain cycles. Grade NW is used where little resistance to cyclic freeze-thaw damage is required and is acceptable for applications protected from water absorption and freezing.

Hollow brick is required to conform to ASTM C 652, which regulates hollow building and hollow facing brick. Hollow brick differs from structural clay tile in that it has more stringent physical property requirements, such as thicker shell and web dimensions and higher minimum compressive strengths.

Hollow brick has two grades of durability: Grade SW and Grade MW. Grade SW is used where a high and uniform degree of resistance to freeze-thaw degradation and disintegration by weathering is desired and when the brick may be saturated while frozen. Grade MW is used where moderate resistance to cyclic freeze-thaw damage is permissible or where the brick may be damp but not saturated with water. Grade NW is used where little resistance to cyclic freeze-thaw damage is required and is acceptable for applications protected from water absorption and freezing.

Type HBS (hollow brick standard) units are for general use, but have a higher degree of precision and lower permissible variation in size than Type HBS units. Type HBA (hollow brick architectural) units are also for general use, but are intentionally manufactured to produce characteristic architectural effects resulting from nonuniformity in size and texture of the units. Type HBB (hollow building brick) units are for general use in masonry where a particular color, texture, finish, uniformity or limits on cracks, warpage or other imperfections detracting from their appearance are not a consideration.

ASTM C 1088 regulates thin brick used in adhered veneer having a maximum actual thickness of 11/4 inches (44 mm). Thin veneer brick units are specified in three types of appearance and two grades of durability.

Exterior-grade units are for exposure to weather;
interior-grade units are not. Type TBS (standard) units are permitted for general use. Type TBX (select) units are also for general use, but have a higher degree of precision and lower permissible variation in size than Type TBS units. Type TBA (architectural) units are also for general use, but are intentionally manufactured to produce characteristic effects in variations of size, color and texture.

ASTM C 34 is referenced for the manufacture of structural clay load-bearing wall tile. This type of tile has two grades. Grade LBX is suitable for general use in masonry construction and can be used in masonry exposed to weathering, provided that the units meet durability requirements for Grade SW of ASTM C 216 for solid units of face brick. This tile grade is also suitable for the direct application of stucco.

Grade LB is suitable for general use in masonry not exposed to freeze-thaw action, or for exposed masonry where protected with a minimum 3-inch (76 mm) facing of stone, brick or other masonry materials.

Fire-resistant tile intended for use in load-bearing masonry is required to conform to ASTM C 34. Tile intended for use in fireproofing structural members is required to be of such sizes and shapes as to cover completely the exposed surfaces of the members.

ASTM C 212, the referenced standard regulating structural clay facing tile, covers two types of structural clay load-bearing facing tile: Types FTX and FTS.

Type FTX clay facing tile is a smooth-face tile suitable for use in exposed exterior and interior masonry walls and partitions where low absorption, easy cleaning and resistance to staining are required. The physical characteristics of this tile require a high degree of mechanical perfection, narrow color range and minimum variation in face dimensions.

Type FTS clay facing tile is a smooth- or rough-textured face tile suitable for general use in exposed exterior and interior masonry walls and partitions where moderate absorption, variation in face dimensions, minor defects in surface finish and moderate color variations are permissible.

There are two classes of tile for the types stated above: standard (for general use) and special duty (having superior resistance to impact and moisture transmission and supporting greater lateral and vertical loads).

ASTM C 56 is the standard regulating the manufacture of nonload-bearing tile, which is made from the same materials as other types of tile previously mentioned and is used for partitions, fireproofing and furring.

ASTM C 126 prescribes requirements for ceramic-glazed structural clay load-bearing facing tile and brick and other solid masonry units made from clay, shale, fire clay or combinations thereof. The standard specifies two grades and two types of ceramic-glazed masonry: Grade S is used with comparatively narrow mortar joints, while Grade SS is used where variations in face dimensions are very small; Type I units are used where only one finished face is to be exposed, while Type II units are used where both finished faces are to be exposed.

The finish of glazed units is important. Requirements and test methods are prescribed for imperviousness, opacity, resistance to fading and crazing, hardness, abrasion resistance and flame spread smoke density. Compressive strength requirements, dimensional tolerances and permissible distortions are also prescribed by the standard.

The exception to this section allows structural clay tile that does not meet the compressive strength specifications to be used as nonstructural fireproofing for structural members. The fire-resistance rating must be determined in accordance with ASTM E 119.

2103.3 Stone masonry units. Stone masonry units shall conform to the following standards: ASTM C 503 for marble building stone (exterior); ASTM C 568 for limestone building stone; ASTM C 615 for granite building stone; ASTM C 616 for sandstone building stone or ASTM C 629 for slate building stone.

Many types of natural stone, including marble, granite, slate, limestone and sandstone, are used in building construction. This section covers natural stones that are sawed, cut, split or otherwise shaped for masonry purposes. Natural stones for building purposes are specified in various grades, textures and finishes and are required to have physical properties appropriate to their intended use.

Where applicable to specific kinds of natural stone, the finished units are required to be sound and free from spalls, cracks, open seams, pits and other defects that would impair structural strength and durability and, when applicable, fire resistance.

This section requires conformance to the following ASTM standards for natural stone masonry: ASTM C 503 for marble building stone (exterior); ASTM C 568 for limestone building stone; ASTM C 615 for granite building stone; ASTM C 616 for sandstone building stone or ASTM C 629 for slate building stone. The standards contain requirements for absorption, density (except for slate), compressive strength (except for slate), modulus of rupture, abrasion resistance (except for granite) and acid resistance (slate only).

2103.4 Ceramic tile. Ceramic tile shall be as defined in, and shall conform to the requirements of, ANSI A137.1.

Ceramic tile is made from clay, possibly mixed with other ceramic materials. Metallic oxides may be included for glaze coloring. Ceramic tile products are available in a broad range of sizes, appearances, characteristics and function.

ANSI A137.1 is the recognized industry standard for the manufacture, testing and labeling of ceramic tile. According to this standard, tile should be shipped in sealed cartons with the grade of contents indicated by grade seals with a distinctive coloring: blue for standard grade (units as perfect and free from defects as is possible in the manufacturing process) and yellow for “seconds” (units having slight defects, but free from structural defects and cracks).

ANSI A137.1 groups ceramic tile into four major
types: glazed wall tile, mosaic tile, quarry tile and paving tile.

2103.5 Glass unit masonry. Hollow glass units shall be partially evacuated and have a minimum average glass face thickness of \( \frac{1}{16} \) inch (4.8 mm). Solid glass block units shall be provided when required. The surfaces of units intended to be in contact with mortar shall be treated with a polyvinyl butyral coating or latex-based paint. Reclaimed units shall not be used.

- Consensus national standards have not been written to establish minimum material properties or test methods for glass blocks. Reliance must be placed on the manufacturer's specifications and glass block is required to meet the minimum specified dimensions of those specifications. Glass block has generally performed well in service.

2103.6 Second-hand units. Second-hand masonry units shall not be reused unless they conform to the requirements of new units. The units shall be of whole, sound materials and free from cracks and other defects that will interfere with proper laying or use. Old mortar shall be cleaned from the unit before reuse.

- This section allows for the use of salvaged brick and other second-hand masonry units, provided that their quality and condition meet the requirements for new masonry units. Second-hand units must be whole, of sound material, clean and free from defects that would interfere with proper laying or use.

Most second-hand masonry units come from the demolition of old buildings. Masonry units manufactured in the past do not generally compare with the quality of masonry made by modern manufacturing methods under controlled conditions. Therefore, designers should expect salvaged masonry units to have lower strength and durability than new units.

Generally, the difference between walls laid up with new masonry units and second-hand units of the same type is the adhesion of the mortar to the masonry surfaces. When new masonry units are laid in fresh mortar, water and fine cementitious particles are absorbed into the masonry, thereby improving bond strength. In contrast, pores in the bed faces of second-hand masonry units, regardless of cleaning, are filled with particles of cement, lime and deleterious substances that impede adequate absorption, thereby adversely affecting bond between the mortar and the masonry.

2103.7 Mortar. Mortar for use in masonry construction shall conform to ASTM C 270 and shall conform to the proportion specifications of Table 2103.7(1) or the property specifications of Table 2103.7(2). Type S or N mortar shall be used for glass unit masonry. The amount of water used in mortar for glass unit masonry shall be adjusted to account for the lack of absorption. Retempering of mortar for glass unit masonry shall not be permitted after initial set. Unused mortar shall be discarded within 2\( \frac{1}{2} \) hours after initial mixing except that unused mortar for glass unit masonry shall be discarded within 1\( \frac{1}{2} \) hours after initial mixing.

- Masonry mortar bonds masonry units to form an integral structure. Mortar provides a tight and weather-resistant seal between units; bonds with steel joint reinforcement, ties and other metal accessories and compensates for dimensional variations in masonry units. It can also serve aesthetic purposes through contrasts of color, texture and shadow lines created by different types of tooled joints.

This section of the code establishes ASTM C 270 as the standard regulating mortar to be used in masonry construction. The standard covers mortars for use in the construction of nonreinforced and reinforced unit masonry structures. It specifies types of mortar and two alternative specifications—the proportion specification and the property specification.

Type M mortar has the highest compressive and tensile bond strength. It is suitable for general use, particularly where maximum masonry compressive strength is required and in construction that is in contact with earth.

Type S mortar is a general-purpose mortar with high compressive and tensile bond strengths. It is often used in reinforced masonry and in unreinforced masonry that requires high strength to resist out-of-plane lateral loads.

Type N mortar is a general-purpose mortar with medium compressive and tensile bond strengths. It is used where high vertical and lateral loads are not expected.

Type O is a low-strength mortar suitable for use in nonload-bearing construction and where the masonry will not be subject to severe weathering or freeze-thaw cycling.

The materials used in mortar are required to conform to the following standard specifications referenced in ASTM C 270, ASTM C 5, ASTM C 91, ASTM C 144, ASTM C 150, ASTM C 207, ASTM C 595 and ASTM C 1329.

In addition to type, mortar for masonry is further classified according to its primary cementitious materials. In portland cement-lime mortar, the cementitious materials are portland cement and hydrated mason's lime. In masonry-cement mortar and mortar-cement mortar, the principal cementitious material is portland cement, which is contained in the masonry cement and the mortar cement.

Regardless of a masonry mortar’s principal cementitious constituents, each ingredient—cement, lime (when used), sand and water—contributes to the mortar’s overall performance. Portland cement, masonry cement, cementitious material or blended hydraulic cement make the hardened mortar strong and durable. Lime contributes to the workability and water retention of fresh mortar and to the flexibility, compressive strength and tensile bond strength of hardened mortar. Sand serves as a filler material, increases strength and reduces shrinkage. Water determines the consistency of fresh mortar and also hydrates the cementitious materials, resulting in hardening of the mortar.

Tables 2103.7(1) and 2103.7(2) are based on Tables 1 and 2 of ASTM C 270. These tables provide requirements for the production of mortar by the proportion
method (by volume) and by the property method (by compressive strength and other properties), respectively. Whether the proportion or property specification governs depends on the contract documents. When neither proportion nor property specification is prescribed, the proportion specification governs, unless data are presented to and accepted by the specifier to show that mortar meets the requirements of the property specification.

ASTM C 270 also covers materials and testing requirements for water retention, compressive strength and air content.

The types of mortar recommended for use in various types of masonry construction are shown in the appendix to ASTM C 270. The performance of masonry is influenced by mortar workability, water retentivity, bond strength, compressive strength and long-term deformability (creep). Each mortar type has corresponding use limitations. For example, allowable compressive stresses permitted in Section 2109.3.2 for empirical design are greater for Types M and S mortar than for Type N mortar.

Glass-block units are required to be laid in Type S or N mortar. Admixtures set accelerators or antifreeze compounds are not permitted in mortars for glass-block masonry.

### TABLE 2103.7(1). See page 21-20.

- This table prescribes proportions for each mortar type when mortar is specified by proportion. The table covers portland cement-lime mortars, masonry-cement mortars and mortar-cement mortars. Materials are measured by volume. The required volume of mason's sand used is based on the combined volume of all cementitious materials (including lime, if applicable).

### TABLE 2103.7(2). See page 21-20.

- This table prescribes minimum required physical properties of plastic and hardened mortar for each type when mortar is specified by property. The table covers portland cement-lime mortars, masonry-cement mortars and mortar-cement mortars. The specified properties are compressive strength, water retention and air content. Values are for mortars prepared in a laboratory in accordance with ASTM C 270. These values do not directly relate to specimens of field mortar tested in accordance with ASTM C 780.

#### 2103.8 Surface-bonding mortar. Surface-bonding mortar shall comply with ASTM C 887. Surface bonding of concrete masonry units shall comply with ASTM C 946.

- Specifications for materials to be used in premixed surface-bonding mortar and for the properties of the mortar are contained in ASTM C 887. Requirements for masonry units and other materials used in constructing dry-stacked, surface-bonded masonry for walls and for the construction itself are contained in ASTM C 946.

In addition to its primary function of bonding masonry units, surface-bonding mortar can provide resistance to penetration by wind-driven rain.

#### 2103.9 Mortars for ceramic wall and floor tile. Portland cement mortars for installing ceramic wall and floor tile shall comply with ANSI A108.1A and ANSI A108.1B and be of the compositions indicated in Table 2103.9.

- This section pertains to cement mortars and organic adhesives used for setting ceramic wall and floor tiles. Each mortar type has certain qualities that make it suitable for installing tile over different kinds of backing materials or under a certain set of conditions.

Cement mortars are “thick-bed” mortars applied in thicknesses of $\frac{3}{4}$ to 1 $\frac{1}{4}$ inches (19.1 to 32 mm) on floors and $\frac{1}{4}$ to 1 inch (19.1 to 25 mm) on walls to achieve the specified slopes and flatness in the finished tile work. Portland cement mortars are suitable for setting ceramic tile in most installations. They can be applied over properly prepared backings of clay or concrete masonry; concrete; wood frame; rough wood floors and plywood floors; foam insulation board; gypsum wallboard and portland cement or gypsum plaster. Cement mortars can be reinforced with metal lath or wire mesh; in such cases, however, additional mortar thickness may be required. Cement mortars have good structural strength and are not affected by prolonged contact with water.

Complete material and installation specifications are contained in ANSI A108.1A and A108.1B, which include required specifications for: installation of wire lath and scratch coats; mortar mixes, bond coat mixes and mortar application; installation methods on floors, walls and countertops; grouting of tile and general requirements for tile installations.

### TABLE 2103.9 CERAMIC TILE MORTAR COMPOSITIONS

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MORTAR</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>Scratchcoat</td>
<td>1 cement; $\frac{1}{2}$ hydrated lime; 4 dry or 5 damp sand</td>
</tr>
<tr>
<td></td>
<td>Setting bed and leveling coat</td>
<td>1 cement; $\frac{1}{2}$ hydrated lime; 5 damp sand to 1 cement 1 hydrated lime, 7 damp sand</td>
</tr>
<tr>
<td>Floors</td>
<td>Setting bed</td>
<td>1 cement; $\frac{3}{4}$ hydrated lime; 5 dry or 6 damp sand; or 1 cement; 5 dry or 6 damp sand</td>
</tr>
<tr>
<td>Ceilings</td>
<td>Scratchcoat and sand bed</td>
<td>1 cement; $\frac{1}{2}$ hydrated lime; 2/3 dry sand or 3 damp sand</td>
</tr>
</tbody>
</table>

- Portland cement-lime mortars are a mixture of portland cement (ASTM C 150), hydrated lime (ASTM C 207) and damp mason's sand (ASTM C 144). Proportions of these ingredients are given in Table 2103.9, dealing with the portland cement-lime mortars most commonly used for setting ceramic tile on wall, floor and ceiling construction and measured in parts by volume. Complete material and installation specifications are contained in ANSI A108.1.
### TABLE 2103.7(1) — MASONRY

**PROPORTIONS BY VOLUME (cementitious materials)**

<table>
<thead>
<tr>
<th>MORTAR TYPE</th>
<th>MORTAR</th>
<th>PROPORTIONS BY VOLUME (cementitious materials)</th>
<th>AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portland cement or blended cement</td>
<td>Masonry cement</td>
<td>Mortar cement</td>
</tr>
<tr>
<td>Cement-lime</td>
<td>M</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Mortar cement</td>
<td>M</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1/2</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Masonry cement</td>
<td>M</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1/2</td>
<td>—</td>
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<tr>
<td></td>
<td>S</td>
<td>—</td>
<td>—</td>
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<tr>
<td></td>
<td>N</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>MIXING AND STORAGE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Portland cement conforming to the requirements of ASTM C 150.</td>
</tr>
<tr>
<td>b. Blended cement conforming to the requirements of ASTM C 595.</td>
</tr>
<tr>
<td>c. Masonry cement conforming to the requirements of ASTM C 91.</td>
</tr>
<tr>
<td>d. Mortar cement conforming to the requirements of ASTM C 1329.</td>
</tr>
<tr>
<td>e. Hydrated lime conforming to the requirements of ASTM C 207.</td>
</tr>
</tbody>
</table>

### TABLE 2103.7(2) — MORTAR PROPERTIES

<table>
<thead>
<tr>
<th>MORTAR TYPE</th>
<th>MORTAR</th>
<th>AVERAGE COMPRRESSIVE STRENGTH AT 28 DAYS minimum (psi)</th>
<th>WATER RETENTION minimum (%)</th>
<th>AIR CONTENT maximum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portland cement</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td>Cement-lime</td>
<td>M</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td>Mortar cement</td>
<td>M</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td>Masonry cement</td>
<td>M</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>2,500</td>
<td>1,800</td>
<td>750</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 6.895 kPa.

a. This aggregate ratio (measured in damp, loose condition) shall not be less than 2 1/4 and not more than 3 times the sum of the separate volumes of cementitious materials.
b. Average of three 2-inch cubes of laboratory prepared mortar, in accordance with ASTM C 270.
c. When structural reinforcement is incorporated in cement-lime or mortar cement mortars, the maximum air content shall not exceed 12 percent.
d. When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall not exceed 18 percent.
2103.9.1 **Dry-set portland cement mortars.** Premixed prepared portland cement mortars, which require only the addition of water and are used in the installation of ceramic tile, shall comply with ANSI A118.1. The shear bond strength for tile set in such mortar shall be as required in accordance with ANSI A118.1. Tile set in dry-set portland cement mortar shall be installed in accordance with ANSI A108.5.

- **Dry-set portland cement mortar for ceramic tile** is required to comply with ANSI A118.1, which describes test methods and minimum requirements for dry-set mortar, including sampling, free water content, setting characteristics, shrinkage, shear strength and staining.

  Dry-set mortar is a mixture of portland cement, sand and perhaps water-retention admixtures. Dry-set mortars are suitable for use over properly prepared backings of clay or concrete masonry; concrete; cut-cell expanded polystyrene or rigid closed-cell urethane insulation board; gypsum wallboard; lean portland cement mortar and hardened wall and floor setting beds.

  Installation must comply with ANSI A108.5. The “thin-bed” mortars are applied in a single layer as thin as 3/16 inch (2.4 mm), but usually in thicknesses of 1/8 to 1/4 inch (3.2 to 6.4 mm). The use of dry-set mortar for leveling work is limited to a maximum thickness of 1/4 inch (6.4 mm).

  This material has excellent water and impact resistance. It is also water-cleanable, nonflammable, good for exterior use and requires no presoaking of the tile. Dry-set mortar is intended for use with glazed wall tile, ceramic mosaics, pavers and quarry tile.

  Shear bond strength (of tile set in mortar) is required to be tested in accordance with standards applicable to the mortar used. Tile set with dry-set mortar must be installed in accordance with ANSI A108.5.

2103.9.2 **Electrically conductive dry-set mortars.** Premixed prepared portland cement mortars, which require only the addition of water and comply with ANSI A118.2, shall be used in the installation of electrically conductive ceramic tile. Tile set in electrically conductive dry-set mortar shall be installed in accordance with ANSI A108.7.

- Mortars used in the installation of electrically conductive ceramic tile are required to conform to ANSI A108.7 for premixed prepared mortars and to ANSI A108.7 for conductive dry-set mortars. ANSI A108.7 is the correct reference for tile set in conductive dry-set mortar.

2103.9.3 **Latex-modified portland cement mortar.** Latex-modified portland cement thin-set mortars in which latex is added to dry-set mortar as a replacement for all or part of the gauging water that are used for the installation of ceramic tile shall comply with ANSI A118.4. Tile set in latex-modified portland cement shall be installed in accordance with ANSI A108.5.

- **Latex-modified portland cement mortar** is a mixture of portland cement, sand and special latex admixtures. It is applied as a thin-bed material, like dry-set portland cement mortar (see commentary, Section 2103.9.1).

  Since the latex used in these mortars varies among manufacturers, instructions for mixing and use must be followed carefully. Applicable material and installation standards are ANSI A108.5 and A118.4.

2103.9.4 **Epoxy mortar.** Ceramic tile set and grouted with chemical-resistant epoxy shall comply with ANSI A118.3. Tile set and grouted with epoxy shall be installed in accordance with ANSI A108.6.

- **Epoxy mortar** is a two-part system consisting of epoxy resin and hardener. It is applied as a layer of 1/16 to 1/8 inch (1.6 to 3.2 mm) in thickness and is suitable for use on properly prepared floors of concrete, wood, plywood, steel plate or ceramic tile. It is particularly suitable where chemical resistance or high bond strength is required. Deflection control is critical for the successful use of this material, and floor systems should not deflect more than 1/360 of their span. Epoxy mortar is recommended for setting ceramic mosaics, quarry tile and paver tile. Applicable material and installation standards are ANSI A108.6 and A118.3.

2103.9.5 **Furan mortar and grout.** Chemical-resistant furan mortar and grout that are used to install ceramic tile shall comply with ANSI A118.5. Tile set and grouted with furan shall be installed in accordance with ANSI A108.8.

- **Furan mortar** is a two-part system consisting of a furan resin and a hardener. It is suitable where chemical resistance is critical. It is used primarily on floors in laboratories and industrial plants. Acceptable subfloors include concrete, steel plate and ceramic tile. Furan grout is intended for quarry tile and pavers, mainly in industrial areas requiring maximum chemical resistance.

  ANSI A118.5 is the standard regulating both furan mortar and grout. Installation must comply with ANSI A108.8.

2103.9.6 **Modified epoxy-emulsion mortar and grout.** Modified epoxy-emulsion mortar and grout that are used to install ceramic tile shall comply with ANSI A118.8. Tile set and grouted with modified epoxy-emulsion mortar and grout shall be installed in accordance with ANSI A108.9.

- **Modified epoxy-emulsion mortar and grout** used to install ceramic tile are required to comply with ANSI A118.8 and to be installed in accordance with ANSI A108.9.

  ANSI A118.8 describes the test methods and the minimum requirements for modified epoxy-emulsion mortar and grout. The chemical and solvent resistance of these mortars and grouts tends to exceed those of organic adhesives and equal those of latex-modified portland-cement mortars. They are not, however, designed to meet the requirements of ANSI A108.6 or A118.3.

  These types of mortars and grouts are three-part systems that include emulsified epoxy resins and hardeners, preblended portland cement and silica sand. They are used as a bond-coat setting mortar or grout. They can be cleaned from wall and floor surfaces using a wet sponge prior to initial set.

  ANSI A118.8 regulates water absorption, flexural...
strength, thermal expansion, linear shrinkage, tensile strength and compressive strength.

2103.9.7 Organic adhesives. Water-resistant organic adhesives used for the installation of ceramic tile shall comply with ANSI A136.1. The shear bond strength after water immersion shall not be less than 40 psi (275 kPa) for Type I adhesive, and not less than 20 psi (138 kPa) for Type II adhesive, when tested in accordance with ANSI A136.1. Tile set in organic adhesives shall be installed in accordance with ANSI A108.4.

- Organic adhesives are prepared materials that cure or set by evaporation and that are ready to use without adding liquid or powder. Adhesives are suitable for installing tiles on prepared wall and floor surfaces, including: brick and concrete masonry; concrete; gypsum wallboard; portland cement or gypsum plaster and wood-flooring systems. Organic adhesives (mastics) are applied as a thin layer approximately \( \frac{1}{16} \) inch (1.6 mm) thick. An underlayment is used to level and true surfaces. Organic adhesive does not permit the soaking of tiles and is not suitable for exterior use. Bond strength varies greatly among the numerous brands of organic adhesives available for use in construction. Adhesives must meet minimum bond-strength requirements of this section of ANSI A136.1 for Type I and II adhesive. The installation of tile with organic adhesives is required to conform to ANSI A108.4.

2103.9.8 Portland cement grouts. Portland cement grouts used for the installation of ceramic tile shall comply with ANSI A118.6. Portland cement grouts for tile work shall be installed in accordance with ANSI A108.10.

- Portland cement grouts are the most commonly used grouts for tile walls. The mixture of portland cement and other ingredients is water resistant and uniform in color. The water in the grout is essential to promote a good bond and to develop full grout strength. This type of grout is required to comply with ANSI A118.6 and to be installed in accordance with ANSI A108.10.

2103.10 Grout. Grout shall conform to Table 2103.10 or to ASTM C 476. When grout conforms to ASTM C 476, the grout shall be specified by proportion requirements or property requirements.

- Grout intended for use in the construction of engineered and empirically designed masonry structures is required to comply with ASTM C 476, which regulates materials, measurement, mixing and storage of materials.

Two types of grout are used in masonry: fine and coarse. Fine grout is made of cement, sand and water, with optional small quantities of lime. Coarse grout includes the same ingredients, plus pea gravel or a larger \( \frac{3}{4} \)-inch (19.1 mm) coarse aggregate.

Whether fine or coarse grout is used depends on the size of the grout space to be filled. Coarse grout is permitted to be used in cavities that are 2 inches (51 mm) or more in width and in the cells of hollow units that are 4 inches (102 mm) or more in both directions. Smaller spaces require the use of fine grout.

The materials used in masonry grout are required to be listed in ASTM C 476 and must conform to the following standard specifications: ASTM C 5; ASTM C 150; ASTM C 207; ASTM C 404 and ASTM C 595.

Grout may be specified either by proportion or property. When the proportion method is specified, Table 2103.10 provides required proportions of grout materials by volume. Information on property requirements is given in ASTM C 476.

<table>
<thead>
<tr>
<th>TABLE 2103.10</th>
<th>GROUT PROPORTIONS BY VOLUME FOR MASONRY CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE</strong></td>
<td><strong>PARTS BY VOLUME OF PORTLAND CEMENT OR BLENDED CEMENT</strong></td>
</tr>
<tr>
<td>Fine grout</td>
<td>1</td>
</tr>
<tr>
<td>Coarse grout</td>
<td>1</td>
</tr>
</tbody>
</table>

- This table, which is based on ASTM C 476, prescribes volume proportions of grout for masonry. Information on fine and coarse grout is given in the commentary to ACI 530.1/ASCE 6/TMS 602. Additionally, ACI 530.1/ASCE 6/TMS 602 provides specific requirements as to where fine and coarse grout are permitted to be used.

2103.11 Metal reinforcement and accessories. Metal reinforcement and accessories shall conform to Sections 2103.11.1 through 2103.11.7.

- This section contains standards and material requirements for anchors, joint reinforcement, wire accessories, ties, wire fabric and for required corrosion protection of these items.

Several referenced standards originally applied to steel reinforcement for concrete, but are suitable and required for masonry construction as well.

2103.11.1 Deformed reinforcing bars. Deformed reinforcing bars shall conform to one of the following standards: ASTM A 615 for deformed and plain billet-steel bars for concrete reinforcement; ASTM A 706 for low-alloy steel deformed bars for concrete reinforcement; ASTM A 767 for zinc-coated reinforcing steel bars; ASTM A 775 for epoxy-coated reinforcing steel bars and ASTM A 996 for rail steel and axle steel deformed bars for concrete reinforcement.

- ASTM A 615 regulates the manufacture of plain and deformed reinforcement, Grades 40 and 60, for new or recycled steel.

ASTM A 706 regulates the manufacture of plain and
2103.11.2 Joint reinforcement. Joint reinforcement shall comply with ASTM A 951. The maximum spacing of crosswires in ladder-type joint reinforcement and of point of connection of cross wires to longitudinal wires of truss-type reinforcement shall be 16 inches (400 mm).

- ASTM A 951 contains material requirements, mechanical properties and tolerances for joint reinforcement. Longitudinal wires are required to be deformed in accordance with this standard to provide a mechanical bond with the surrounding mortar. Cross wires are plain.

- ASTM A 82 regulates the manufacture of cold-drawn, plain steel wire for joint reinforcement, wire anchors and ties. Joint reinforcement can be epoxy coated to provide added corrosion protection (see commentary, Section 2103.11.6).

2103.11.3 Deformed reinforcing wire. Deformed reinforcing wire shall conform to ASTM A 496.

- ASTM A 496 regulates the manufacture of cold-worked, deformed wire having yield stresses of 70 ksi (483 MPa) (welded wire fabric) and 75 ksi (517 MPa). This wire is used as reinforcement and in the manufacture of welded, deformed-wire fabric. It is not commonly used in masonry.


- ASTM A 185 regulates the manufacture of plain welded-wire fabric, using ASTM A 82 steel. ASTM A 497 regulates the manufacture of welded deformed wire fabric using steels conforming to ASTM A 82 and A 496, alone or in combination. Wire fabric is seldom used in masonry.

2103.11.5 Anchors, ties and accessories. Anchors, ties and accessories shall conform to the following standards: ASTM A 36 for structural steel; ASTM A 82 for plain steel wire for concrete reinforcement; ASTM A 185 for plain steel-welded wire fabric for concrete reinforcement; ASTM A 167, Type 304, for stainless and heat-resisting chromium-nickel steel plate, sheet and strip and ASTM A 366 for cold-rolled carbon steel sheet, commercial quality.

- Anchors, ties and accessories are manufactured in a variety of ways with a number of materials. Applicable ASTM specifications prescribe minimum requirements for these materials.

- ASTM A 36 regulates the manufacture of hot-rolled steel with a minimum specified yield stress of 36 ksi (248 MPa), for general structural purposes. This material is suitable for welding.

- ASTM A 82 regulates the manufacture of cold-drawn, plain-steel wire for joint reinforcement, wire anchors and ties.

- ASTM A 185 regulates the manufacture of plain-steel welded-wire fabric, using ASTM A 82 steel, or ASTM A 167 Type 304, corrosion-resistant steel.

- ASTM A 366 regulates the manufacture of sheet steel used for metal anchors and ties. The specification covers cold-rolled carbon steel sheet of commercial quality, in coils or cut lengths. This material is intended for exposed or unexposed parts made by bending, moderate drawing, forming or welding. This standard also specifies mechanical properties and tests relative to bending, hardness and moderate deformability and sets requirements for chemical composition. See Figure 2109.6.3(1) for typical masonry accessories.

2103.11.6 Prestressing tendons. Prestressing tendons shall conform to one of the following standards:

- Wire . . . . . . . . . . . . . . . . ASTM A 421
- Low-relaxation wire . . ASTM A 421
- Strand . . . . . . . . . . . . . . . . ASTM A 416
- Low-relaxation strand . . ASTM A 416
- Bar . . . . . . . . . . . . . . . . . . ASTM A 722

Exceptions:

1. Wire, strands and bars not specifically listed in ASTM A 421, ASTM A 416 or ASTM A 722 are permitted, provided they conform to the minimum requirements in ASTM A 421, ASTM A 416, or ASTM A 722 and are approved by the architect/engineer.

2. Bars and wires of less than 150 kips per square inch (ksi) (1034 MPa) tensile strength and conforming to ASTM A 82, ASTM A 510, ASTM A 615, ASTM A 616, ASTM A 996 or ASTM A 706/A 706 M are permitted to be used as prestressed tendons provided that:

   2.1. The stress relaxation properties have been assessed by tests according to ASTM E 328 for the maximum permissible stress in the tendon.

   2.2. Other nonstress-related requirements of ACI 530/ASCE 5/TMS 402, Chapter 4, addressing prestressing tendons are met.

- This section specifies the materials for components of the prestressing system. They are similar to those used in prestressed concrete.
2103.11.7 Corrosion protection. Corrosion protection for prestressing tendons, prestressing anchorages, couplers and end block shall comply with the requirements of ACI 530.1/ASCE 6/TMS 602, Article 2.4G. Corrosion protection for carbon steel accessories used in exterior wall construction or interior walls exposed to a mean relative humidity exceeding 75 percent shall comply with either Section 2103.11.7.1 or 2103.11.7.2. Corrosion protection for carbon steel accessories used in interior walls exposed to a mean relative humidity equal to or less than 75 percent shall comply with either Section 2103.11.7.1, 2103.11.7.2 or 2103.11.7.3.

Joint reinforcement, anchors, wall ties and accessories are required to be galvanized to protect the steel from deterioration and corrosion, unless the steel is inherently corrosion resistant, such as ASTM A 167 Type 304 stainless steel. The application and thickness of the galvanizing depends on the intended location or severity of exposure. Carbon steel accessories in exterior masonry wall construction are required to be either hot-dipped galvanized in accordance with Section 2103.11.7.1 or epoxy coated in accordance with Section 2103.11.7.2. Carbon steel accessories for use in interior wall construction are permitted to comply with less-restrictive mill galvanized requirements as noted in Section 2103.11.7.3.

2103.11.7.1 Hot-dipped galvanized. Apply a hot-dipped galvanized coating after fabrication as follows:

1. For joint reinforcement, wall ties, anchors and inserts, apply a minimum coating of 1.5 ounces per square foot (psf) (458 g/m²) complying with the requirements of ASTM A 153, Class B.
2. For sheet metal ties and sheet metal anchors, comply with the requirements of ASTM A 153, Class B.
3. For steel plates and bars, comply with the requirements of either ASTM A 123 or ASTM A 153, Class B.

Carbon steel accessories located in exterior masonry wall construction are required to meet the protection requirements of ASTM A 153, which regulates zinc-coated iron and steel hardware. The minimum required coating of 1.5 ounces per square foot of surface (458 g/m²) is derived from Table 1 of ASTM A 153 for rolled, pressed and forged articles under 3/16 inch (4.8 mm) in thickness and over 15 inches (381 mm) in length.

The finish and appearance of zinc-coated articles are specified in ASTM A 153. Zinc-coated articles are required to be free from uncoated areas, blisters, flux deposits, black spots and other inclusions that would interfere with the intended use. The coating is required to be smooth and uniform in thickness.

2103.11.7.2 Epoxy coatings. Carbon steel accessories shall be epoxy coated as follows:

1. For joint reinforcement, comply with the requirements of ASTM A 884 Class B, Type 2 – 18 mils (457µm).
2. For wire ties and anchors, comply with the requirements of ASTM A 899 Class C –20 mils (508µm).

3. For sheet metal ties and anchors, provide a minimum thickness of 20 mils (508µm) or in accordance with the manufacturer’s specification.

As an alternative to hot-dipped galvanizing, carbon steel accessories in exterior walls can be epoxy coated. This section specifies the appropriate coating type and minimum coating thickness applicable to each type of accessory.

2103.11.7.3 Mill galvanized. Apply a mill galvanized coating as follows:

1. For joint reinforcement, wall ties, anchors and inserts, apply a minimum coating of 0.1 ounce psf (31g/m²) complying with the requirements of ASTM A 641.
2. For sheet metal ties and sheet metal anchors, apply a minimum coating complying with Coating Designation G-60 according to the requirements of ASTM A 653.
3. For anchor bolts, steel plates or bars not exposed to the earth, weather or a mean relative humidity exceeding 75 percent, a coating is not required.

Carbon steel accessories for use in interior-wall construction are permitted to comply with less-restrictive material specifications (ASTM A 641), as noted.

2103.11.8 Tests. Where unidentified reinforcement is approved for use, not less than three tension and three bending tests shall be made on representative specimens of the reinforcement from each shipment and grade of reinforcing steel proposed for use in the work.

Reinforcing bars are to be rolled with raised symbols or letters impressed on the metal identifying the manufacturing mill. When required by the building official, the grade of material is to be identified by a satisfactory mill test. When the manufacturing mill is not identified but the reinforcement is approved for use under ordinary material procedures, at least three tension and three bending tests are required on representative specimens of the reinforcement from each shipment and grade of reinforcing steel proposed for use. The tension and bending tests are required to be performed by an approved testing agency.

SECTION 2104
CONSTRUCTION

2104.1 Masonry construction. Masonry construction shall comply with the requirements of Sections 2104.1.1 through 2104.5 and with ACI 530.1/ASCE 6/TMS 602.

This section establishes the requirements, based on accepted practice and referenced standards, regulating materials and construction methods used in engineered and empirically designed masonry construction. Engineered masonry construction is further regulated by Sections 2101.2.1 and 2101.2.2.
**2104.1.1 Tolerances.** Masonry, except masonry veneer, shall be constructed within the tolerances specified in ACI 530.1/ASCE 6/TMS 602.

The MSJC Specification, ACI 530.1/ASCE 6/TMS 602, prescribes tolerances for placement of reinforcement and masonry units. Specific tolerances listed include cross sections of elements; thicknesses of mortar joints; widths of grout spaces; variation from level; variation from plumb; trueness to a line; alignment of columns and walls; location of elements and placement of reinforcement and accessories. These required tolerances are intended to inhibit corrosion; provide placement locations reflecting those assumed in design; provide clearance for mortar and grout and maintain compatible lateral deflections of parallel wythes. Tolerances are relatively strict since masonry is a structural material and is also exposed to weather. Aesthetics are not a factor in these requirements.

**2104.1.2 Placing mortar and units.** Placement of mortar and units shall comply with Sections 2104.1.2.1 through 2104.1.2.5.

Workmanship is of primary importance in providing strong and durable masonry construction. This is especially true for the placement of mortar and masonry unit. Water penetration can often be traced to bond breaks at the mortar-unit interface. Additionally, masonry strength relies on the mortar bedded areas required in this section and ACI 530.1/ASCE 6/TMS 602.

**2104.1.2.1 Bed and head joints.** Unless otherwise required or indicated on the construction documents, head and bed joints shall be \( \frac{3}{8} \) inch (9.5 mm) thick, except that the thickness of the bed joint of the starting course placed over foundations shall not be less than \( \frac{1}{4} \) inch (6.4 mm) and not more than \( \frac{3}{4} \) inch (19.1 mm).

The required thickness for bed joints has a permitted tolerance of plus or minus \( \frac{1}{8} \) inch (3 mm). This thickness is intended to provide bonding of reinforcement and ties and to allow for the dimensional tolerances of the masonry units. The greater permitted thickness of the starting mortar course is intended to accommodate variations in the elevation of the top surface of the foundation.

**2104.1.2.1.1 Open-end units.** Open-end units with beveled ends shall be fully grouted. Head joints of open-end units with beveled ends need not be mortared. The beveled ends shall form a grout key that permits grouts within \( \frac{5}{8} \) inch (15.9 mm) of the face of the unit. The units shall be tightly butted to prevent leakage of the grout.

Open-end units can be placed around vertical reinforcing steel, rather than having to be lifted up and over it, as closed-end units must be. Such units are manufactured with one or no end shells. The special type of open-end unit described in this section is manufactured with beveled ends of the faceshells, so that when the unit is grouted, grout fills the head joint seam (see Figure 2104.1.2.1.1). Because of this, head joints of such construction need not be filled with mortar. Open-end units without this bevel must be laid with mortared head joints.
**2104.1.2.2 Hollow units.** Hollow units shall be placed such that face shells of bed joints are fully mortared. Webs shall be fully mortared in all courses of piers, columns, pilasters, in the starting course on foundations where adjacent cells or cavities are to be grouted, and where otherwise required. Head joints shall be mortared a minimum distance from each face equal to the face shell thickness of the unit.

- Figure 2104.1.2.2 shows the typical placement of mortar for hollow-unit masonry walls. Except for the initial bed joint at the starter course, the cross webs of hollow units in walls are not usually mortared except at the cross webs of cells that are to be grouted in partially grouted walls. Cross webs of hollow units in piers, columns and pilasters, however, are required to be mortared.

**2104.1.2.3 Solid units.** Unless otherwise required or indicated on the construction documents, solid units shall be placed in fully mortared bed and head joints. The ends of the units shall be completely buttered. Head joints shall not be filled by slushing with mortar. Head joints shall be constructed by shoving mortar tight against the adjoining unit. Bed joints shall not be furrowed deep enough to produce voids.

- Solid units result in fully mortared bed joints since the 25-percent core area is effectively crossed with mortar. Height-to-thickness ratios and calculated stresses are based on the fully mortared bed joint.

  Filling head joints by slushing from above is not permitted, since this could result in voids and lead to water penetration. The head-joint mortar may be placed on the end of the masonry unit prior to placing the unit in the wall. The furrow typically formed during bed joint placement should not be too deep since mortar voids would result (see Figure 2104.1.2.3).

**2104.1.2.4 Glass unit masonry.** Glass units shall be placed so head and bed joints are filled solidly. Mortar shall not be furrowed.

  Unless otherwise required, head and bed joints of glass unit masonry shall be \( \frac{1}{4} \) inch (6.4 mm) thick, except that vertical joint thickness of radial panels shall not be less than \( \frac{1}{8} \) inch (3.2 mm). The bed joint thickness tolerance shall be minus \( \frac{1}{16} \) inch (1.6 mm) and plus \( \frac{1}{8} \) inch (3.2 mm). The head joint thickness tolerance shall be plus or minus \( \frac{1}{16} \) inch (3.2 mm).

- Glass unit masonry is required to be placed with full head and bed joints. Glass units are manufactured to be modular with a joint thickness of \( \frac{1}{4} \) inch (6.4 mm), smaller than the typical \( \frac{3}{8} \) inch (9.6 mm) for concrete masonry and the \( \frac{3}{8} \) inch (9.6 mm) or \( \frac{1}{2} \) inch (12.8 mm) joint thickness for clay brick masonry. Designers should recognize this difference and use correct nominal dimensions when laying out glass unit masonry.

  Tolerances for glass unit masonry are much tighter than for other types of masonry because glass unit masonry units are manufactured to very tight tolerances and are more dimensionally stable than other types of masonry.

  Head joints on radial panels of glass unit masonry are permitted to be as thin as \( \frac{1}{8} \) inch (3.2 mm), because placing rectangular units in a curved wall requires wider joints on one face of the wall and narrower joints on the other face.

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**Figure 2104.1.2.2 MORTAR PLACEMENT ON HOLLOW UNITS IN WALLS**
2104.1.2.5 All units. Units shall be placed while the mortar is soft and plastic. Any unit disturbed to the extent that the initial bond is broken after initial positioning shall be removed and relaid in fresh mortar.

- Mortar should not be spread too far ahead of units, as it will stiffen and lose plasticity, especially in hot weather. Mortar that has stiffened should not be used. ASTM C 270 requires that mortar be used within 2½ hours of initial mixing.

A test for mortar workmanship includes removal of a unit. Bonded mortar will stick to the removed unit as well as the remaining masonry; stiff, unbonded mortar will not. Broken joints should be remortared.

2104.1.3 Installation of wall ties. The ends of wall ties shall be embedded in mortar joints. Wall tie ends shall engage outer face shells of hollow units by at least \( \frac{1}{2} \) inch (12.7 mm). Wire wall ties shall be embedded at least 1\( \frac{1}{2} \) inches (38 mm) into the mortar bed of solid masonry units or solid-grouted hollow units. Wall ties shall not be bent after being embedded in grout or mortar.

- Installation of wall ties requires adequate embedment in mortar, adequate strength and durability of ties. Wall ties are not permitted to be bent after being embedded in grout or mortar, since movement of the ties will reduce the effectiveness of the embedment and subsequent bonding.
2104.1.4 Chases and recesses. Chases and recesses shall be constructed as masonry units are laid. Masonry directly above chases or recesses wider than 12 inches (305 mm) shall be supported on lintels.

- Chases and recesses are designed so that they do not reduce the required strength of the walls or affect the required fire-resistance rating of the wall. Any required chases must be formed during construction of the masonry wall and not by cutting out a section of the finished wall, which could create a weak point and jeopardize the wall strength.

  This empirical limitation requires lintels for chases and recesses wider than 12 inches (305 mm). Although arching action reduces lintel moments, the potential of weaknesses created by chases and recesses makes them subject to engineered design. The supporting lintel is permitted to be of masonry, concrete or steel and must be engineered as required in Section 2104.1.5.

2104.1.5 Lintels. The design for lintels shall be in accordance with the masonry design provisions of either Section 2107 or 2108. Minimum length of end support shall be 4 inches (102 mm).

- Masonry lintels are required to be engineered as load-bearing beam elements by either the working stress design method of Section 2107 or the strength design method of Section 2108. This requirement is consistent with the empirical provisions, which do not include horizontally spanning elements such as beams. Bearing on masonry is required to be a minimum of 4 inches (102 mm) to adequately distribute stresses.

2104.1.6 Support on wood. Masonry shall not be supported on wood girders or other forms of wood construction except as permitted in Section 2304.12.

- Masonry is not permitted to be supported on wood construction, except as permitted in Section 2304.12, because of both the danger of collapse in case of fire and the serviceability considerations noted below.

  Masonry is brittle and relatively weak in tension. It can crack when subjected to deformations. Wood is flexible and usually exhibits elastic deformation and creep (additional deflection from long-term loads). Because of this, masonry supported on wood tends to crack. Therefore, masonry is not permitted to be supported by wood members, unless such masonry meets the exceptions in Section 2304.12.

  Glass-block panels are typically limited in size and are often used in windows as decoration. For this limited use, support on wood is permitted. The deflection limitation in Section 2110.4.2 is consistent with the requirements for masonry. In calculating the probable deflection of the supporting wood member, consideration of creep is recommended.

2104.1.7 Masonry protection. The top of unfinished masonry work shall be covered to protect the masonry from the weather.

- Water can accumulate within masonry walls and it evaporates relatively slowly. Moisture migrates to the surface, dissolves salts in the masonry and deposits them on the surface as a white powder called "efflorescence." To prevent this, the tops of walls exposed to weather are required to be covered.

2104.1.8 Weep holes. Weep holes provided in the outside wythe of masonry walls shall be at a maximum spacing of 33 inches (838 mm) on center (o.c.). Weep holes shall not be less than \( \frac{11}{16} \) inch (4.8 mm) in diameter.

- Masonry is not water tight. Water can penetrate into and through it. Weep holes are to be provided in all masonry wall construction to help water leave the wall. Without weep holes, moisture would remain within the masonry construction and evaporation would be its only means of exit.

  Many methods for providing weep holes are available, including open head joints; \( \frac{3}{8} \)-inch-diameter (9.6 mm) holes in joints and wicking cord laid in the joint and behind the brick.

  The 33-inch (838 mm) maximum spacing of weep holes, while apparently odd since it is not modular for typical masonry, was selected because weep holes are often spaced at 32 inches (813 mm) on center, plus or minus typical construction tolerances.

2104.2 Corbeled masonry. The maximum corbeled projection beyond the face of the wall shall not be more than one-half of the wall thickness nor one-half the wythe thickness for hollow walls. The maximum projection of one unit shall not exceed one-half the height of the unit nor one-third the thickness at right angles to the wall.

- This section covers the limitations and the construction features of corbeled masonry.

  A corbel is formed by projecting courses of masonry with the first or lowest course projecting out from the face of the wall and each successive course projecting out from the supporting course below. While corbels may be constructed using various load-bearing masonry units, they are most commonly applied to clay masonry and are used for aesthetic purposes and to support offset or thickened walls above them.

  The permitted extent of corbeling is illustrated in Figure 2104.2. The total horizontal projection of a corbel from the face of the wall is limited to no more than one-half the thickness of a solid wall or more than one-half the thickness of the wythe in a cavity wall. Furthermore, the projection of a single course is not to exceed one-half of the unit height, nor one-third of the unit bed depth, whichever is less.

  These limitations establish a maximum angle of corbelled brick masonry, measured from the plane of the wall, of about \( 26\frac{1}{2} \) degrees (0.46 rad). A smaller angle can be achieved by decreasing the brick projections to less than the maximum allowed by this section.

  Corbels produce and often transfer eccentric loads, which must be considered in the design of masonry walls.
Corbels constructed in walls of hollow units or in hollow masonry walls are required to be of solid masonry. This requirement can be satisfied by using solid units, grouting the cores of hollow units or grouting open spaces in hollow walls.

2104.2.1 Molded cornices. Unless structural support and anchorage are provided to resist the overturning moment, the center of gravity of projecting masonry or molded cornices shall lie within the middle one-third of the supporting wall. Terra cotta and metal cornices shall be provided with a structural frame of approved noncombustible material anchored in an approved manner.

Figure 2104.2.1 illustrates this requirement. Unless cornices or other projections are specifically designed to be supported and anchored to the wall or other adequate structural supports, such as columns, beams, spandrels or floor slabs, the center of gravity of the projecting element is required to fall within the middle third (kern) of the supporting wall.

Cornices are usually ornamental and may or may not support other loads. They can be made of cast-in-place or precast concrete; cast or natural stone; terra cotta; brick or even metal.

Metal and terra-cotta cornices are commonly furnished with a structural frame of noncombustible material that can be anchored to the masonry wall or to other building supports as approved by the building official.

2104.3 Cold weather construction. The cold weather construction provisions of ACI 530.1/ASCE 6/TMS 602, Article 1.8 C, or the following procedures shall be implemented when either the ambient temperature falls below 40°F (4°C) or the temperature of masonry units is below 40°F (4°C).

△ When masonry construction is conducted in temperatures below 40°F (4°C), both the masonry components and the structure are required to be protected in accordance with this section. One of the main goals of these provisions is to prevent fresh mortar from freezing.

During cold-weather construction, especially in temperatures below freezing, the curing and subsequent performance of masonry are influenced by the temperature and properties of the mortar and the masonry units, as well as the severity of the exposure (temperature and wind).

2104.3.1 Preparation.

1. Temperatures of masonry units shall not be less than 20°F (-7°C) when laid in the masonry. Masonry units containing frozen moisture, visible ice or snow on their surface shall not be laid.
2. Visible ice and snow shall be removed from the top surface of existing foundations and masonry to receive new construction. These surfaces shall be heated to above freezing, using methods that do not result in damage.

- Under cold-weather conditions masonry construction should not proceed if these requirements are not met. Masonry units to be used during cold-weather construction should be dry. Masonry must not be laid on snow or ice-covered surfaces, because bond cannot be developed between the units and the mortar bed under those conditions. Additionally, the units can move when the mortar thaws.

2104.3.2 Construction. The following requirements shall apply to work in progress and shall be based on ambient temperature.

- This section sets minimum requirements to be met as masonry work proceeds based on the ambient temperature. Mortars (or grout) mixed at low temperatures using cold (not frozen) materials have plastic properties that are significantly different from those mixed at temperatures above 40°F (4°C). If the water content of the mortar is more than 6 to 8 percent when it freezes, expansion and possible damage could occur. If the water content of the mortar is less than 6 to 8 percent, the expected mortar expansion is less severe.

Antifreeze admixtures should not be permitted as a means of lowering the freezing point of mortar. Simply keeping the mortar from freezing does not result in proper hydration. Some commercially available mortar admixtures that claim to have antifreeze qualities may be improperly described or labeled because they do not significantly lower the freezing point of the mortar, but rather serve as accelerators of cement hydration. Calcium chloride is the most commonly used accelerator and is the main ingredient in many commercially available mortar admixtures. Because chlorides enhance the corrosion of embedded steel, however, admixtures containing chlorides should not be used in masonry containing metal ties, joint reinforcement or other metal accessories in contact with mortar.

Mortar mixed at a low temperature requires longer curing times and gains strength more slowly than mortar mixed at higher temperatures. To counteract the slow strength development of mortar at low temperatures, mixing water is required to be heated. In some instances, the sand used in the mortar is also heated. To accelerate early strength development, Type III (high-early-strength portland cement) can be substituted for Type I cement.

Cold-weather conditions do not require any changes to the mortar or grout mix proportions of cement, lime and sand (and coarse aggregate for grout).

2104.3.2.1 Construction requirements for temperatures between 40°F (4°C) and 32°F (0°F). The following construction requirements shall be met when the ambient temperature is between 40°F (4°C) and 32°F (0°C):

1. Glass unit masonry shall not be laid.
2. Water and aggregates used in mortar and grout shall not be heated above 140°F (60°C).
3. Mortar sand or mixing water shall be heated to produce mortar temperatures between 40°F (4°C) and 120°F.
(49°C) at the time of mixing. When water and aggregates for grout are below 32°F (0°C), they shall be heated.

- See the commentary to Section 2104.3.2.

2104.3.2.2 Construction requirements for temperatures between 32°F (0°C) and 25°F (-4°C). The requirements of Section 2104.3.2.1 and the following construction requirements shall be met when the ambient temperature is between 32°F (0°C) and 25°F (-4°C):

1. The mortar temperature shall be maintained above freezing until used in masonry.
2. Aggregates and mixing water for grout shall be heated to produce grout temperature between 70°F (21°C) and 120°F (49°C) at the time of mixing. Grout temperature shall maintained above 70°F (21°C) at the time of grout placement.

- See the commentary to Section 2104.3.2.

2104.3.2.3 Construction requirements for temperatures between 25°F (-4°C) and 20°F (-7°C). The requirements of Sections 2104.3.2.1 and 2104.3.2.2 and the following construction requirements shall be met when the ambient temperature is between 25°F (-4°C) and 20°F (-7°C):

1. Masonry surfaces under construction shall be heated to 40°F (4°C).
2. Wind breaks or enclosures shall be provided when the wind velocity exceeds 15 miles per hour (mph) (24 km/h).
3. Prior to grouting, masonry shall be heated to a minimum of 40°F (4°C).

- See the commentary to Sections 2104.3 and 2104.3.3.

Low temperatures do not significantly affect the performance characteristics of masonry units. The absorption (suction) characteristics of cold, wet and frozen masonry units are decreased, however, which may affect mortar bond. Preheating masonry units prevents the sudden cooling of warm mortar in contact with cold units. A heated unit will absorb more water from the mortar because of the absorptive characteristics of a cooling body.

In selecting masonry units for cold-weather construction, consideration should be given to the absorption rates (see ASTM C 67). Units with initial rates of absorption of 30 grams per 30 square inches (19 355 mm²) per minute are preferable for cold-weather construction because they greatly reduce the possibility of disruptive expansion of the mortar due to freezing. Units with an initial rate of absorption of 5 to 6 grams per 30 square inches (19 355 mm²) per minute or less may not absorb sufficient water to prevent disruptive expansion if the mortar freezes (also see commentary, Section 2104.3.2).

2104.3.2.4. Construction requirements for temperatures below 20°F (-7°C). The requirements of Sections 2104.3.2.1, 2104.3.2.2 and 2104.3.2.3 and the following construction requirement shall be met when the ambient temperature is below 20°F (-7°C): Enclosures and auxiliary heat shall be provided to maintain air temperature within the enclosure to above 32°F (0°C).

- In addition to all of the above requirements, ambient temperatures below 20°F (-7°C) require the masonry construction to be enclosed and the use of auxiliary heat (also see commentary, Section 2104.3.2).

2104.3.3 Protection. The requirements of this section and Sections 2104.3.3.1 through 2104.3.3.4 apply after the masonry is placed and shall be based on anticipated minimum daily temperature for grouted masonry and anticipated mean daily temperature for ungrouted masonry.

- This section sets minimum requirements to be met after masonry work is completed based on the anticipated temperature. Lower expected temperatures require more extensive means of protection.

2104.3.3.1 Glass unit masonry. The temperature of glass unit masonry shall be maintained above 40°F (4°C) for 48 hours after construction.

- See the commentary to Sections 2104.3 and 2104.3.3.

2104.3.3.2 Protection requirements for temperatures between 40°F (4°C) and 25°F (-4°C). When the temperature is between 40°F (4°C) and 25°F (-4°C), newly constructed masonry shall be covered with a weather-resistant membrane for 24 hours after being completed.

- See the commentary to Sections 2104.3 and 2104.3.3.

2104.3.3.3 Protection requirements for temperatures between 25°F (-4°C) and 20°F (-7°C). When the temperature is between 25°F (-4°C) and 20°F (-7°C), newly constructed masonry shall be completely covered with weather-resistant insulating blankets, or equal protection, for 24 hours after being completed. The time period shall be extended to 48 hours for grouted masonry, unless the only cement in the grout is Type III portland cement.

- See the commentary to Sections 2104.3 and 2104.3.3.

2104.3.3.4 Protection requirements for temperatures below 20°F (-7°C). When the temperature is below 20°F (-7°C), newly constructed masonry shall be maintained at a temperature above 32°F (0°C) for at least 24 hours after being completed by using heated enclosures, electric heating blankets, infrared lamps or other acceptable methods. The time period shall be extended to 48 hours for grouted masonry, unless the only cement in the grout is Type III portland cement.

- When temperatures are less than 20°F (-7°C), temporary heating is required to protect the masonry (also see commentary, Sections 2104.3 and 2104.3.3).
2104.4 Hot weather construction. The hot weather construction provisions of ACI 530.1/ASCE 6/TMS 602, Article 1.8 D, or the following procedures shall be implemented when the temperature or the temperature and wind-velocity limits of this section are exceeded.

- Temperature, solar radiation, humidity and wind influence the rate of absorption of masonry units and the rate of mortar set. During hot-weather conditions, special precautions must be taken for adequate strength gain of the masonry.

2104.4.1 Preparation. The following requirements shall be met prior to conducting masonry work.

- This section imposes minimum required precautions before masonry work proceeds under hot-weather conditions. The purpose is to maintain mortar temperatures less than that which causes a flash set.

2104.4.1.1 Temperature. When the ambient temperature exceeds 100°F (38°C), or exceeds 90°F (32°C) with a wind velocity greater than 8 mph (13 km/h):

1. Necessary conditions and equipment shall be provided to produce mortar having a temperature below 120°F (49°C).
2. Sand piles shall be maintained in a damp, loose condition.

- When hot-weather conditions exceed those specified, procedures are required to keep mortar and sand in an acceptable condition.

2104.4.1.2 Special conditions. When the ambient temperature exceeds 115°F (46°C), or 105°F (40°C) with a wind velocity greater than 8 mph (13 km/h), the requirements of Section 2104.4.1.1 shall be implemented, and materials and mixing equipment shall be shaded from direct sunlight.

- When hot-weather conditions are extreme, materials and mixing equipment are required to be shaded, in addition to the requirements in Section 2104.4.1.1. Unshaded equipment becomes so hot that mortar can experience flash set.

2104.4.2 Construction. The following requirements shall be met while masonry work is in progress.

- This section imposes minimum precautions to be taken as masonry work proceeds under hot-weather conditions. Their purpose is to keep mortar temperatures lower than that which causes flash set. Ice is prohibited because of the potential for weak mortar and grout.

2104.4.2.1 Temperature. When the ambient temperature exceeds 100°F (38°C), or exceeds 90°F (32°C) with a wind velocity greater than 8 mph (13 km/h):

1. The temperature of mortar and grout shall be maintained below 120°F (49°C).
2. Mixers, mortar transport containers and mortar boards shall be flushed with cool water before they come into contact with mortar ingredients or mortar.
3. Mortar consistency shall be maintained by retempering with cool water.
4. Mortar shall be used within 2 hours of initial mixing.

- When hot-weather conditions exceed the limitations of this section, procedures are required to keep mortar and grout cool. These procedures include flushing mortar board, containers and other surfaces in contact with mortar and grout with water and retempering.

2104.4.2.2 Special conditions. When the ambient temperature exceeds 115°F (46°C), or exceeds 105°F (40°C) with a wind velocity greater than 8 mph (13 km/h), the requirements of Section 2104.4.2.1 shall be implemented and cool mixing water shall be used for mortar and grout. The use of ice shall be permitted in the mixing water prior to use. Ice shall not be permitted in the mixing water when added to the other mortar or grout materials.

- In extreme hot-weather conditions, ice can be added to the mixing water for mortar and grout to maintain their temperatures at acceptable levels. Ice cannot, however, be present in the mixing water when it is added to the dry materials in the mortar or grout.

2104.4.3 Protection. When the mean daily temperature exceeds 100°F (38°C), or exceeds 90°F (32°C) with a wind velocity greater than 8 mph (13 km/h), newly constructed masonry shall be fog sprayed until damp at least three times a day until the masonry is three days old.

- When hot-weather conditions are extended (as defined by the mean daily temperature), masonry is required to be fogsprayed to help hydrate it. Excessive wetting of the wall, however, can cause adverse effects such as efflorescence and moisture expansion in concrete masonry.

2104.5 Wetting of brick. Brick (clay or shale) at the time of laying shall require wetting if the unit’s initial rate of water absorption exceeds 30 grams per 30 square inches (19 355 mm²) per minute or 0.035 ounce per square inch (1 g/645 mm²) per minute, as determined by ASTM C 67.

- Clay brick laid on fresh mortar generally absorbs water from the mortar along with fine particles of cementitious materials, which help to bond the mortar with the brick. If the brick absorbs too much water, the mortar may have insufficient water for hydration. It is therefore necessary to determine the initial rate of absorption (IRA) of the brick.

- Mortar bonds best with brick whose IRA is between 5 and 30 grams per 30 square inches (19 355 mm²) of surface per minute. Where the water absorption rate exceeds 30 grams per 30 square inches (19 355 mm²) per minute (as determined by ASTM C 67), brick is required to be wetted before placement, but should be surface dry when laid.


SECTION 2105
QUALITY ASSURANCE

2105.1 General. A quality assurance program shall be used to ensure that the constructed masonry is in compliance with the construction documents.

- There are two means of determining the compressive strength of masonry: the unit strength method and the prism test method. The first eliminates the expense of prism tests, but is more conservative.

2105.2 Acceptance relative to strength requirements.

- The quality assurance provisions in this section emphasize verification of masonry compressive strengths. This is accomplished by comparing conservatively estimated strengths (based on unit strength and mortar type) or prism test strengths to the specified compressive strength of the masonry, $f'_m$, and, when required, by mortar, grout or both to see that they are in compliance.

- These quality assurance methods are for general consistency of the constructed masonry. Masonry is relatively strong in compression and thus rarely fails in that manner, but rather in flexural tension. Compression tests are required, however, because they are simple ways of assessing quality.

- As implied in the above paragraph, two methods are prescribed in Section 2105.2 to judge acceptance relative to the compressive strength of the masonry assemblage—the unit strength method and the prism test method. These are described in Section 2105.2 and in this commentary. When the strength of constructed masonry is questioned, testing of prisms that have been saw cut from the masonry is permitted in accordance with Section 2105.3.

2105.2.1 Compliance with $f'_m$. Compressive strength of masonry shall be considered satisfactory if the compressive strength of each masonry wythe and grouted collar joint equals or exceeds the value of $f'_m$.

- Design of structural masonry is based on the specified compressive strength of the masonry, $f'_m$. This strength is required to be shown on the contract documents, since structural design is based on it. Strength of the constructed masonry determined by the unit strength method or the prism strength method is required to equal or exceed the specified compressive strength of the masonry, $f'_m$.

- In a multiwythe wall designed as a composite wall, the compressive strength of masonry for each wythe or grouted collar joint must equal or exceed $f'_m$.

2105.2.2 Determination of compressive strength. The compressive strength for each wythe shall be determined by the unit strength method or by the prism test method as specified herein.

- Table 2105.2.2.1.1 lists the compressive strength of masonry in terms of the strength of the clay masonry unit and the mortar type. This table is based on the research results cited in the commentary to ACI 530.1/ASCE 6/TMS 602. A similar table has been used successfully in both ACI 530.1/ASCE 6/TMS 602 and the Uniform Building Code™ (UBC) since 1988.
The designer can use this table to estimate a specified compressive strength of masonry to use in design, based on the expected strength of the clay masonry units and the specified mortar type. The contractor can use the table to find what concrete masonry strength and mortar type are needed to comply with the specified strength of the masonry, \( f'_m \), given in the contract documents. The column entitled “Net Area Compressive Strength of Masonry” must equal or exceed the specified strength of the masonry, \( f'_m \).

### 2105.2.2.2 Prism test method.

- **The prism test method is used when required in the project specifications or when the restrictions of Section 2105.2.2.1 do not apply. Prisms are required to be constructed in accordance with ASTM C 1314 using the same materials and workmanship as in the structure.**
- **ASTM C 1314 replaced ASTM E 447 for field-constructed prism specimens, which was referenced in editions of the specification prior to 1999. The use of ASTM C 1314 is intended to address many of the concerns over the difficulty and imprecision of ASTM E 447 for large prisms.**

### 2105.2.2.1 General.

The compressive strength of masonry shall be determined by the prism test method:

1. Where specified in the construction documents.
2. Where masonry does not meet the requirements for application of the unit strength method in Section 2105.2.2.1.
3. Prism tests are required whenever specified and whenever the masonry does not meet the restrictions for the unit strength method.

### 2105.2.2.2 Number of prisms per test.

A prism test shall consist of three prisms constructed and tested in accordance with ASTM C 1314.

- **Whenever prism testing is specified or used, three prism specimens must be constructed and tested in accordance with ASTM C 1314.**

### 2105.3 Testing prisms from constructed masonry.

When approved by the building official, acceptance of masonry that does not meet the requirements of Section 2105.2.2.1 or 2105.2.2.2 shall be permitted to be based on tests of prisms cut from the masonry construction in accordance with Sections 2105.3.1, 2105.3.2 and 2105.3.3.

- **While uncommon, there are times when the strength of masonry determined by the unit strength method or prism test method may be questioned or may be lower than the specified strength. Because low strengths could result from inappropriate testing procedures or unintentional damage to the test specimens, prisms may be saw cut from the completed masonry wall and tested. This section prescribes procedures for such tests.**

Such testing is difficult, requires at least 28 days and requires replacement of the affected wall area. Therefore, every effort should be taken so that strengths de-
2105.3.1 Prism sampling and removal. A set of three masonry prisms that are at least 28 days old shall be saw cut from the masonry for each 5,000 square feet (465 m²) of the wall area that is in question but not less than one set of three masonry prisms for the project. The length, width and height dimensions of the prisms shall comply with the requirements of ASTM C 1314. Transporting, preparation and testing of prisms shall be in accordance with ASTM C 1314.

- Removal of prisms from a constructed wall requires care so that the prism is not damaged and that damage to the wall is minimal. Prisms must be representative of the wall, yet not contain reinforcing steel, which would bias the results. As with a prism test of newly constructed masonry, a prism test from existing masonry requires three prism specimens.

2105.3.2 Compressive strength calculations. The compressive strength of prisms shall be the value calculated in accordance with ASTM C 1314, except that the net cross-sectional area of the masonry shall be based on the net mortar bedded area.

- Compressive strength calculations from saw-cut specimens must be based on the net mortar bedded area, which must be determined before the prism is tested. The testing agency must determine this area accurately.

2105.3.3 Compliance. Compliance with the requirement for the specified compressive strength of masonry, f′ ′ , must be considered satisfied provided the modified compressive strength equals or exceeds the specified f′ ′. Additional testing of specimens cut from locations in question shall be permitted.

- Strengths determined from saw-cut prisms must equal or exceed the specified strength of masonry, f′ ′.

SECTION 2106 SEISMIC DESIGN

2106.1 Seismic design requirements for masonry. Masonry structures and components shall comply with the requirements in Section 1.13.2.2 of ACI 530/ASCE 5/TMS 402 and Section 1.13.3, 1.13.4, 1.13.5, 1.13.6 or 1.13.7 of ACI 530/ASCE 5/TMS 402 depending on the structure’s seismic design category as determined in Section 1616.3. All masonry walls, unless isolated on three edges from in-plane motion of the basic structural systems, shall be considered to be part of the seismic-force-resisting system. In addition, the following requirements shall be met.

- Section 2106 contains minimum requirements for masonry structures based upon their seismic design category. This section requires the use of MSJC Code seismic design criteria. Requirements established for various seismic risk categories are cumulative from lower to higher categories. These prescriptive and design-oriented provisions have been established to improve the performance of masonry during seismic events by providing additional structural strength, ductility and stability against the dynamic effects of earthquakes. As seismic demand increases, the provisions require more positive connection between structural elements, increased ductility and greater material reliability.

Chapter 16 contains state-of-the-art criteria for seismic design, including provisions applicable to masonry. The requirements of Chapter 16 for seismic resistance (for example, design forces and masonry detailing) remain applicable and are discussed in the commentary to that chapter. Compliance with Chapter 21 is not a substitute for compliance with the seismic provisions of Chapter 16. More information on seismic design is contained in the commentaries to Chapter 16 and the NEHRP Provisions.

To comply with the provisions in Section 2106, the seismic design category must be determined for the building or structure under consideration. Refer to the commentary to Chapter 16 for information on determining the seismic design category and other seismic parameters. Based on the seismic design category, the designer needs to meet the minimum requirements of Section 2106.2, 2106.3, 2106.4, 2106.5 or 2106.6 as well as the referenced MSJC Code sections.

2106.1.1 Basic seismic-force-resisting system. Buildings relying on masonry shear walls as part of the basic seismic-force-resisting system shall comply with Section 1.13.2.2 of ACI 530/ASCE 5/TMS 402 or with Section 2106.1.1.1, 2106.1.1.2 or 2106.1.1.3.

- A basic seismic-force-resisting system must be defined for all buildings. Most masonry buildings use shear walls to serve as the basic seismic-force-resisting system, although other systems are sometimes used (such as concrete or steel frames with masonry infill). Such shear walls must be designed by the engineered methods in Section 2107 or 2108, unless the structure is assigned to Seismic Design Category A, in which case the empirical provisions of Section 2109 may be used.

There are three types of masonry shear wall systems that are recognized by the IBC, but are not specifically listed in the MSJC Code. They are ordinary plain prestressed shear walls (Section 2106.1.1.1), intermediate prestressed masonry shear walls (Section 2106.1.1.2) and special prestressed masonry shear walls (Section 2106.1.1.3). The shear wall systems recognized by the MSJC Code are discussed below.

Ordinary plain masonry shear walls (see Section 1.13.2.2.1 of ACI 530/ASCE 5/TMS 402) meet minimum requirements only and thus may be used only in areas of low seismic risk. Plain masonry walls are designed as unreinforced masonry (by the noted section), although they may in fact contain reinforcement.

Ordinary reinforced masonry shear walls (see Section 1.13.2.2.3 of ACI 530/ASCE 5/TMS 402) are required to meet minimum requirements for reinforced masonry as noted in the referenced section. Because they contain reinforcement, their performance is expected to be better than that of plain masonry shear walls and they are accordingly permitted in areas of both low and moderate seismic risk. Additionally, these
walls have more favorable seismic design parameters, including higher response modification factors, $R$, than plain masonry shear walls. When assigned to moderate seismic risk areas (Seismic Design Category C), however, minimum reinforcement is required as noted in Section 2106.4.

Detailed plain masonry shear walls (see Section 1.13.2.2.2 of ACI 530/ASCE 5/TMS 402) are designed as unreinforced masonry in accordance with the section noted, but contain minimum reinforcement in the horizontal and vertical directions. Because of this reinforcement, these walls have more favorable seismic design parameters, including higher response modification factors, $R$, than ordinary plain masonry shear walls.

Intermediate reinforced masonry shear walls (see Section 1.13.2.2.4 of ACI 530/ASCE 5/TMS 402) are designed as reinforced masonry as noted in the referenced section and are also required to contain a minimum amount of prescriptive reinforcement. Because they contain reinforcement, their seismic performance is better than that of plain masonry shear walls and they are accordingly permitted in both areas of low and moderate seismic risk. Additionally, these walls have more favorable seismic design parameters, including higher response modification factors, $R$, than plain masonry shear walls and ordinary reinforced masonry shear walls.

Special reinforced masonry shear walls (see Section 1.13.2.2.5 of ACI 530/ASCE 5/TMS 402) are designed as reinforced masonry as noted in the referenced section and are also required to meet restrictive reinforcement and material requirements. Because of these reinforcement and material requirements, they are permitted to be used in all seismic risk areas. Additionally, these walls have the most favorable seismic design parameters, including the highest response modification factors, $R$, of any of the masonry shear wall types.

2106.1.1.1 Ordinary plain prestressed masonry shear walls. Ordinary plain prestressed masonry shear walls shall comply with the requirements of Chapter 4 of ACI 530/ASCE 5/TMS 402.

This type of shear wall is recognized as a basic seismic-force-resisting system under the code and it must comply with the limitations for these systems in Section 1617.6. The only other stipulation is that it comply with the prestressed masonry requirements of the MSJC Code.

2106.1.1.2 Intermediate prestressed masonry shear walls. Intermediate prestressed masonry shear walls shall comply with the requirements of Section 1.13.2.2.4 of ACI 530/ASCE 5/TMS 402 and shall be designed by Chapter 4, Section 4.5.3.3, of ACI 530/ASCE 5/TMS 402 for flexural strength and by Section 3.2.4.1.2 of ACI 530/ASCE 5/TMS 402 for shear strength. Sections 1.13.2.2.5(a), 3.2.3.5 and 3.2.4.3.2(c) of ACI 530/ASCE 5/TMS 402 shall be applicable for reinforcement. Flexural elements subjected to load reversals shall be symmetrically reinforced. The nominal moment strength at any section along a member shall not be less than one-fourth the maximum moment strength. The cross-sectional area of bonded tendons shall be considered to contribute to the minimum reinforcement in Section 1.13.2.2.4 of ACI 530/ASCE 5/TMS 402. Tendons shall be located in cells that are grouted the full height of the wall.

This type of shear wall is recognized as a basic seismic-force-resisting system under the code and it must comply with the limitations for these systems in Section 1617.6. Besides requiring that it comply with the prestressed masonry provisions of the MSJC Code, additional requirements must be met that are consistent with the results of research and testing carried out in New Zealand. These additional requirements intend that the walls develop their flexural capacity prior to shear failure. Tendons are limited to cells that are fully grouted, since testing has not substantiated that laterally unrestrained tendons are satisfactory for moderate seismic hazards.

2106.1.1.3 Special prestressed masonry shear walls. Special prestressed masonry shear walls shall comply with the requirements of Section 1.13.2.2.5 of ACI 530/ASCE 5/TMS 402 and shall be designed by Chapter 4, Section 4.5.3.3, of ACI 530/ASCE 5/TMS 402 for flexural strength and by Section 3.2.4.1.2 of ACI 530/ASCE 5/TMS 402 for shear strength. Sections 1.13.2.2.5(a), 3.2.3.5 and 3.2.4.3.2(c) of ACI 530/ASCE 5/TMS 402 shall be applicable for reinforcement. Flexural elements subjected to load reversals shall be symmetrically reinforced. The nominal moment strength at any section along a member shall not be less than one-fourth the maximum moment strength. The cross-sectional area of bonded tendons shall be considered to contribute to the minimum reinforcement in Section 1.13.2.2.5 of ACI 530/ASCE 5/TMS 402. Special prestressed masonry shear walls shall also comply with the requirements of Section 3.2.3.5 of ACI 530/ASCE 5/TMS 402.

This type of shear wall is recognized as a basic seismic-force-resisting system under the code and it must comply with the limitations for these systems in Section 1617.6. Besides requiring that it comply with the prestressed masonry provisions of the MSJC Code, additional limitations apply that are based on the testing used to substantiate these systems. These additional requirements intend that the walls develop their flexural capacity prior to shear failure.

2106.1.1.3.1 Prestressing tendons. Prestressing tendons shall consist of bars conforming to ASTM A 722.

Test specimens for prestressed masonry shear wall systems used only high-strength bar tendons, indicating that is an appropriate restriction for these systems that are intended for exposure to high seismic hazards.

2106.1.1.3.2 Grouting. All cells of the masonry wall shall be grouted.

Testing of prestressed masonry shear wall systems indicates that exposure to high seismic hazard is only per-
2106.2 Anchorage of masonry walls. Masonry walls shall be anchored to the roof and floors that provide lateral support for the wall in accordance with Section 1604.8.2.

- This provision applies to all masonry structures, regardless of seismic design category. Because masonry walls typically depend on lateral support from floors and roofs, they are required to be anchored directly to those elements. Section 1604.8.2 prohibits reliance on friction (from dead load) alone to hold walls, floors and roofs together and prescribes minimum forces for design of anchorage.

2106.3 Seismic Design Category B. Structures assigned to Seismic Design Category B shall conform to the requirements of Section 1.13.4 of ACI 530/ASCE 5/TMS 402 and to the additional requirements of this section.

- Requirements in Seismic Design Category (SDC) B are slightly more restrictive than in SDC A. Since the requirements are cumulative with each successive SDC, masonry assigned to SDC B must meet the requirements for SDC A (Section 1.13.3 of the MSJC Code) as well as Section 1.13.4 of the MSJC Code and the requirements in Section 2106.3. Therefore, besides those requirements in Section 2106.2, masonry shear walls must also be one of the types discussed in the commentary to Section 2106.1.1 and be rationally designed in this SDC and above.

2106.3.1 Masonry walls not part of the lateral-force-resisting system. Masonry partition walls, masonry screen walls and other masonry elements that are not designed to resist vertical or lateral loads, other than those induced by their own mass, shall be isolated from the structure so that the vertical and lateral forces are not imparted to these elements. Isolation joints and connectors between these elements and the structure shall be designed to accommodate the design story drift.

- So that seismic loads are not inadvertently transferred into elements such as masonry partition and screen walls, they are required to be isolated from the seismic-force-resisting system. However, these elements need out-of-plane support. Appropriate connectors are available and should be used. This is, in effect, a modification to the seismic requirements of the MSJC Code, since in that standard this is a requirement for SDC C structures and higher.

2106.4 Additional requirements for structures in Seismic Design Category C. Structures assigned to Seismic Design Category C shall conform to the requirements of Section 1.13.5 of ACI 530/ASCE 5/TMS 402 and the additional requirements of this section.

- In addition to the requirements of SDC, minimum levels of reinforcement and detailing are required to enhance ductility and load-transfer capability in masonry structures assigned to SDC C. The minimum provisions for improved performance of masonry construction in SDC C must be met, regardless of the method of design.

2106.4.1 Design of discontinuous members that are part of the lateral-force-resisting system. Columns and pilasters that are part of the lateral-force-resisting system and that support reactions from discontinuous stiff members such as walls shall be provided with transverse reinforcement spaced at no more than one-fourth of the least nominal dimension of the column or pilaster. The minimum transverse reinforcement ratio shall be 0.0015. Beams supporting reactions from discontinuous walls or frames shall be provided with transverse reinforcement spaced at no more than one-half of the nominal depth of the beam. The minimum transverse reinforcement ratio shall be 0.0015.

- The requirements in this section are intended to reduce the chance of local failure or collapse in elements supporting discontinuous portions of the lateral-force-resisting system by increasing the strength and toughness of those elements. Elements used to redistribute or transfer the effects of seismic overturning are susceptible to local inelastic response that can significantly impair the ability of the lateral-force-resisting system to achieve the required overall ductility. The provisions in this section are intended to increase the ability of elements to resist inelastic deformations. This allows inelastic deformations to be distributed throughout the buildings, as is implied by the large response modification factors used in design.

2106.5 Additional requirements for structures in Seismic Design Category D. Structures assigned to Seismic Design Category D shall conform to the requirements of Section 2106.4, Section 1.13.6 of ACI 530/ASCE 5/TMS 402 and the additional requirements of this section.

- Requirements in this section parallel most of the requirements in the MSJC Code.

2106.5.1 Loads for shear walls designed by the working stress design method. When calculating in-plane shear or diagonal tension stresses by the working stress design method, shear walls that resist seismic forces shall be designed to resist 1.5 times the seismic forces required by Chapter 16. The 1.5 multiplier need not be applied to the overturning moment.

- This provision is based on a similar provision from the UBC. It requires that the in-plane shear stresses due to seismic loading be increased by 50 percent for design purposes and is intended to provide adequate strength and ductility in shear walls of structures in seismically active areas.

2106.5.2 Shear wall shear strength. For a shear wall whose nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength, two shear regions exist.

- For all cross sections within a region defined by the base of
the shear wall and a plane at a distance $L_w$ above the base of the shear wall, the nominal shear strength shall be determined by Equation 21-1.

$$V_s = A_n \rho_n f_y \quad \text{(Equation 21-1)}$$

The required shear strength for this region shall be calculated at a distance $L_w/2$ above the base of the shear wall, but not to exceed one-half story height.

For the other region, the nominal shear strength of the shear wall shall be determined from Section 2108.

- The intent of this provision is to provide a ductile flexural limit state. The plastic hinge region is considered to extend vertically from the base of the wall to a distance equal to the plan length of the wall. In this region, the shear strength of the wall is based on the transverse reinforcement only. Above the plastic hinge, the shear strength of the wall is based on both the masonry and the transverse reinforcement.

### 2106.6 Additional requirements for structures in Seismic Design Category E or F

Structures assigned to Seismic Design Category E or F shall conform to the requirements of Section 2106.5 and Section 1.13.7 of ACI 530/ASCE 5/TMS 402.

- Additional restrictions are imposed on buildings assigned to the highest seismic risk categories.

### SECTION 2107

#### WORKING STRESS DESIGN

**2107.1 General.** The design of masonry structures using working stress design shall comply with Section 2106 and the requirements of Chapters 1 and 2, except Section 2.1.2.1 and 2.1.3.3 of ACI 530/ASCE 5/TMS 402. The text of ACI 530/ASCE 5/TMS 402 shall be modified as follows.

- Section 2107 adopts the working stress design method of Chapters 1 and 2 of the MSJC Code (ACI 530/ASCE 5/TMS 402) with modifications that the IBC Structural Committee felt were needed. This method of engineered masonry design has been used successfully for years and remains the dominant method of designing masonry structures.

Refer to the commentary to Chapters 1 and 2 of the MSJC Code for additional information on the working stress design method for masonry. This section also requires conformance to the seismic design provisions of Section 2106. The sections of the MSJC Code specifically not adopted exclude redundant or conflicting provisions such as the MSJC load combinations, which are only intended to apply where no such load combinations are included in the building code.

The pseudo-strength design provision of ACI 530/ASCE 5/TMS 402, Section 2.1.3.3, is also excluded. This method allows masonry to be designed using strength-based seismic loads and working stress provisions. Since Chapter 16 contains service-level load combinations, however, pseudo-strength design is not needed and is therefore not permitted.

**2107.2 Modifications to ACI 530/ASCE 5/TMS 402.**

- The IBC Structural Subcommittee considered and adopted several modifications to the MSJC Code regarding special inspection, column requirements, splice requirements for reinforcement (both lap splices and mechanical or welded splices) and maximum bar size. These modifications supersede the MSJC Code provisions when working stress design is used.

**2107.2.1 ACI 530/ASCE 5/TMS 402, Chapter 2.** Special inspection during construction shall be provided as set forth in Section 1704.5.

- The inspection provisions for masonry in Chapter 17 were based on the inspection requirements in the MSJC Code and Specification, with several key modifications. Masonry designed by working stress procedures must be inspected in accordance with the IBC inspection requirements.

**2107.2.2 ACI 530/ASCE 5/TMS 402, Section 2.1.6.** Masonry columns used only to support light-frame roofs of carports, porches, sheds or similar structures with a maximum area of 450 square feet (41.8 m²) assigned to Seismic Design Category A, B or C are permitted to be designed and constructed as follows:

1. Concrete masonry materials shall be in accordance with Section 2103.1. Clay or shale masonry units shall be in accordance with Section 2103.2.
2. The nominal cross-sectional dimension of columns shall not be less than 8 inches (203 mm).
3. Columns shall be reinforced with not less than one No. 4 bar centered in each cell of the column.
4. Columns shall be grouted solid.
5. Columns shall not exceed 12 feet (3658 mm) in height.
6. Roofs shall be anchored to the columns. Such anchorage shall be capable of resisting the design loads specified in Chapter 16.
7. Where such columns are required to resist uplift loads, the columns shall be anchored to their footings with two No. 4 bars extending a minimum of 24 inches (610 mm) into the columns and bent horizontally a minimum of 15 inches (381 mm) in opposite directions into the footings. One of these bars is permitted to be the reinforcing bar specified in Item 3 above. The total weight of a column and its footing shall not be less than 1.5 times the design uplift load.

- Section 2107.2.2 exempts lightly loaded columns (such as those that support carport roofs, which experience primarily axial tension and flexure in high-wind events) from the prescriptive requirements of Section 2.1.6 of the MSJC Code. All other columns need to comply with Section 2.1.6 of the MSJC Code. This provision is similar to one in the Standard Building Code® (SBC®) and is intended to relax an aspect of the MSJC Code, which defines columns by geometry rather than function. According to that document, masonry members of a cer-
tain geometry, even though they act primarily in flexure, are classified as columns and thus must meet minimum reinforcement requirements for columns.

2107.2.3 ACI 530/ASCE 5/TMS 402, Section 2.1.10.6.1.1, lap splices. The minimum length of lap splices for reinforcing bars in tension or compression, \( l_{sd} \), shall be calculated by Equation 21-2, but shall not be less than 15 inches (380 mm).

\[
l_{sd} = \frac{0.16d^2f_y\gamma}{K\sqrt{f'_m}} \quad (\text{Equation 21-2})
\]

For SI:

\[
l_{sd} = \frac{1.95d^2f_y\gamma}{K\sqrt{f'_m}}
\]

where:

- \( d \) = Diameter of reinforcement, inches (mm).
- \( f_y \) = Specified yield stress of the reinforcement or the anchor bolt, psi (MPa).
- \( f'_m \) = Specified compressive strength of masonry at age of 28 days, psi (MPa).
- \( l_{sd} \) = Minimum lap splice length, inches (mm).
- \( K \) = The lesser of the masonry cover, clear spacing between adjacent reinforcement or five times \( d_f \), inches (mm).
- \( \gamma \) = 1.0 for No. 3 through No. 5 reinforcing bars. 1.4 for No. 6 and No. 7 reinforcing bars. 1.5 for No. 8 through No. 9 reinforcing bars.

This modification brings consistency to the requirements for splice lengths for reinforcement according to working stress and strength design. The IBC Structural Committee accepted this modification based on broad support from the masonry industry and engineers, since it was noted that existing splice-length requirements are overly conservative for small bar sizes and unconservative for large ones. Note that Section 2107.2.5 prohibits lap splicing of bars that are larger than No. 9.

Traditional requirements for development lengths and splices of reinforcing bars in masonry have long been questioned because of the disparity between required development lengths (and lap lengths) typically used for masonry and those used in reinforced concrete. This provision is based on requirements that have been in the UBC for several years, but also incorporates updates based on extensive research that supports the conclusion of reinforcement. The requirements are based on tests of splices and successful performance in construction.

2107.2.5 ACI 530/ASCE 5/TMS 402, splices for large bars. Reinforcing bars larger than No. 9 in size shall be spliced using mechanical connectors in accordance with ACI 530/ASCE 5/TMS 402, Section 2.1.10.6.3.

Research has shown that effectively lap splicing large reinforcing bars in masonry is difficult and impractical because of the excessive lap lengths required. This section adds a provision not in the MSJC Code requiring mechanical splices for all bars larger than No. 9 (32 mm) in diameter. Such large bars are rarely required in masonry and do not perform as well as a larger number of smaller bars.

2107.2.6 ACI 530/ASCE 5/TMS 402, Maximum reinforcement percentage. Special reinforced masonry shear walls having a shear span ratio, \( M/Vd \), equal to or greater than 1.0 and having an axial load, \( P \) greater than 0.05 \( f'_m A_n \) which are subjected to in-plane forces, shall have a maximum reinforcement ratio, \( \rho_{max} \), not greater than that computed as follows:

\[
\rho_{max} = \frac{nf'_m}{2f_y \left( n + \frac{f_y}{f'_m} \right)} \quad (\text{Equation 21-3})
\]

The allowable stress design (ASD) provisions of the MSJC Code have no limit on the maximum reinforcement ratio. This section places such a limit on the maximum reinforcement ratio in special reinforced masonry shear walls. It is necessary to account for the relatively high potential for inelastic response in such systems. This requirement is based on the recommendations of a blue-ribbon panel appointed by the Masonry Alliance for Codes and Standards (MACS). It was the panel’s conclusion that these requirements should only apply to the design of shear walls for in-plane forces that have significant axial load (\( P > 0.05 f'_m A_n \)) and that are controlled by flexure (i.e., \( M/Vd \geq 1.0 \)).

SECTION 2108
STRENGTH DESIGN OF MASONRY

2108.1 General. The design of masonry structures using strength design shall comply with Section 2106 and the requirements of Chapters 1 and 3 of ACI 530/ASCE 5/TMS 402.

The minimum nominal thickness for hollow clay masonry
in accordance with Section 3.2.5.5 of ACI 530/ASCE 5/TMS 402 shall be 4 inches (102 mm).

The first edition of the IBC contained extensive strength design requirements, since a consensus standard for the strength design of masonry did not yet exist. Since strength design procedures were incorporated in the 2002 edition of the MSJC Code (ACI 530/ASCE 5/TMS 402), this section now requires that strength design be in accordance with Chapters 1 and 3 of the MSJC Code with some modifications to specific sections. For instance, the minimum nominal thickness of 6 inches (152 mm) for hollow day units is reduced to 4 inches (102 mm). This section also invokes the minimum seismic requirements of Section 2106 for all masonry designed by this method. Additionally, masonry designed by this method must be inspected during construction in accordance with the special inspection provisions of Section 1704.5.

2108.2 ACI 530/ASCE 5/TMS 402, Section 3.2.2(g). Modify Section 3.2.2(g) as follows:

3.2.2(g). The relationship between masonry compressive stress and masonry strain shall be assumed to be defined by the following:

Masonry stress of \( 0.80 f'_{m} \) shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance, \( a = 0.80 c \), from the fiber of maximum compressive stress. The distance, \( c \), from the fiber of maximum strain to the neutral axis shall be measured perpendicular to that axis. For out-of-plane bending, the width of the equivalent stress block shall not be taken greater than six times the nominal thickness of the masonry wall or the spacing between reinforcement, whichever is less. For in-plane bending of flanged walls, the effective flange width shall not exceed six times the thickness of the flange.

This section modifies the design assumptions of the MSJC Code. These principles have traditionally been used for reinforced masonry members designed by the strength method. The values for the maximum usable strain are based on extensive research of masonry materials and are different from the values used in the 1997 UBC. Concerns have been raised regarding the implied precision of the values. However, the reported values for the maximum usable strain accurately represent those observed during testing.

While tension may still develop in the masonry of a reinforced element, it is not considered effective in resisting design loads. However, the tensile resistance of masonry is considered implicitly in computing the stiffness of reinforced masonry. If it were not, the effective moment of inertia would always be just the cracked transformed moment of inertia.

The modification made by the IBC provides direction on the stress block width for out-of-plane bending as well as for flanged walls. These limitations are consistent with the NEHRP Provisions and are based on usual practice under previous codes.

2108.3 ACI 530/ASCE 5/TMS 402, Section 3.2.3.4. Modify Section 3.2.3.4 (b) and (c) as follows:

3.2.3.4 (b). A welded splice shall have the bars butted and welded to develop at least 125 percent of the yield strength, \( f_y \), of the bar in tension or compression, as required. Welded splices shall be of ASTM A 706 steel reinforcement. Welded splices shall not be permitted in plastic hinge zones of intermediate or special reinforced walls or special moment frames of masonry.

3.2.3.4 (c). Mechanical splices shall be classified as Type 1 or 2 according to Section 21.2.6.1 of ACI 318. Type 1 mechanical splices shall not be used within a plastic hinge zone or within a beam-column joint of intermediate or special reinforced masonry shear walls or special moment frames. Type 2 mechanical splices are permitted in any location within a member.

This section modifies the strength design splice requirements for consistency with the 2000 edition of the NEHRP Provisions. Splices for reinforcement can be achieved by lapping the reinforcement, welding the reinforcement or mechanical splicing.

Two modifications are made to welded splice requirements [Item (b)]. Splices in reinforcing steel used in the lateral-force-resisting system subjected to high seismic strains must be able to develop the strength of the steel in order to achieve the required performance. To be successfully welded, the chemistry of the steel must be controlled to limit carbon content as well as other elements, such as sulfur and phosphorus. Since the chemistry of reinforcing steel conforming to ASTM A 615, for example, is not controlled and is likely to be unknown, a weld that develops the strength of the steel is not guaranteed. ASTM A 706 steel, on the other hand, has controlled chemistry and can be reliably welded; therefore, if splices are to be accomplished by welding, the use of ASTM A 706 reinforcing steel is mandatory.

Welded splices are required to be able to develop at least 125 percent of the yield strength of the spliced rebars; however, reinforcing steel conforming to ASTM A 706 or for that matter ASTM A 615 or A 996 can have an actual yield strength greater than 125 percent of the minimum required yield strength. This means a code-conforming welded splice may conceivably fail before the spliced bars have yielded, thereby limiting the inelastic deformability of that structural member. The use of welded splices is, therefore, prohibited at locations of potential plastic hinging of members in structural systems that are expected to undergo significant inelastic response in resisting forces due to earthquakes.

The modification to mechanical splices in Item (c) requires that the splice be classified in accordance with ACI 318 as Class 1 or Class 2. This is due to the fact that reinforcing steel is predominantly produced from remelted steel scrap, making it difficult to control the strength. The resulting products tend to have a strength considerably higher than the specified yield strength. This is similar to the situation that has occurred in structural steel where the actual yield strength can be much greater than the specified yield strength. Since there is no upper limit on the yield strength (except for ASTM A 706) and only a minimum required yield strength, most reinforcing steel will have a
higher yield point than that specified.

Testing by the California Department of Transportation (CALTRANS) indicates the overstrength can be as much as 60 percent over the specified strength. Cyclic tests of splices meeting only the 125-percent criterion (i.e. Class 1) show that, in many cases, they cannot survive several excursions in the post yield range as imposed by cyclic testing. Splices in reinforcing steel used in the lateral-force-resisting system in plastic hinge zones and beam-column joints are subjected to high seismic strains, and they must be able to develop the strength of the steel in order to achieve the required performance. Hence, the requirement for a Type 2 splice that develops the specified tensile strength of the bar.

2108.4 ACI 530/ASCE 5/TMS 402, Section 3.2.3.5.1. Add the following text to Section 3.2.3.5.1:

For special prestressed masonry shear walls, strain in all prestressing steel shall be computed to be compatible with a strain in the extreme tension reinforcement equal to five times the strain associated with the reinforcement yield stress, \( f_y \). The calculation of the maximum reinforcement shall consider forces in the prestressing steel that correspond to these calculated strains.

- This MSJC Code section limits the percentages of flexural reinforcement in order to provide ductile behavior. Overreinforced flexural members can fail in a brittle mode by the crushing of the masonry. Such failures are sudden and catastrophic and, therefore, must be avoided.

- Section 2106.1.1.3, covering special prestressed masonry shear walls, requires compliance with this code section, which includes a modification of the MSJC Code section specifically for those shear wall types. This modification clarifies how the reinforcing limitation is to be met for this structural system.

SECTION 2109
EMPIRICAL DESIGN OF MASONRY

2109.1 General. Empirically designed masonry shall conform to Section 2109 of ACI 530/ASCE 5/TMS 402. This section permits empirical design of masonry by either the provisions of Section 2109 or Chapter 5 of ACI 530/ASCE 5/TMS 402. This is because nearly all of the requirements in Section 2109 are based on the requirements in Chapter 5 of ACI 530/ASCE 5/TMS 402 with minor modifications. Additional information on these provisions can be found in the commentary to ACI 530/ASCE 5/TMS 402.

Empirical provisions are design rules developed by experience rather than engineering analysis. The empirical rules in these provisions are based on records dating back as far as 1889 in A Treatise on Masonry Construction, by Ira Baker. The most recent publication providing the basis for these empirical provisions is ANSI A41.1.

This empirical design method is based on several premises: gravity loads are reasonably centered on bearing walls; effects of reinforcement are neglected; walls are laid in running bond and buildings have limited height, seismic risk and wind loading. The requirements of and limitations regarding the use of empirical design reflect these assumptions.

2109.1.1 Limitations. Empirical masonry design shall not be utilized for any of the following conditions:

1. The design or construction of masonry in buildings assigned to Seismic Design Category D, E or F as specified in Section 1616, and the design of the seismic-force-resisting system for buildings assigned to Seismic Design Category B or C.

2. The design or construction of masonry structures located in areas where the basic wind speed exceeds 110 mph (177 km/hr).

3. Buildings more than 35 feet (10 668 mm) in height which have masonry wall lateral-force-resisting systems.

In buildings that exceed one or more of the above limitations, masonry shall be designed in accordance with the engineered design provisions of Section 2107 or 2108, or the foundation wall provisions of Section 1805.5.

- Empirical design is permitted for structures having limited seismic risk, wind loading and height. These limitations are justified, since buildings that were representative of the historically based empirical provisions are uncommon today. For example, buildings of the past were smaller and had more interior masonry walls and typically had different floor construction than modern buildings.

Where any one of the three stated limitations exists, the masonry structure is not permitted to be empirically designed. Engineered design in accordance with Section 2107 or 2108 is required in such instances. Foundation walls complying with Section 1805.5 are also acceptable.

1. The empirical provisions of Section 2109 and the required referenced standards, plus the seismic loading and detailing requirements of Chapter 16, are adequate for the level of risk associated with the seismic-force-resisting systems of buildings located in Seismic Design Category A. Where masonry is used for purposes other than the seismic-force-resisting system, the empirical design method may be used for buildings assigned to Seismic Design Category A, B or C. Engineered design is required for buildings in higher seismic design categories.

2. This requirement applies individually to the lateral-load-resisting system and to building elements not effectively participating in the lateral-load-resisting system. For example, empirical design of the lateral-load-resisting system is permitted only where the basic wind speed does not exceed 110 mph (145 km/hr). Otherwise, engineered design is required. These are similar to, but not the same as, the wind load restrictions.
2109.2 – TABLE 2109.2.1.3

MASONRY

2109.2 Lateral stability.

The lateral stability requirements of Section 2109.2 are required for buildings using empirical design for lateral load resistance. The requirements of this section do not apply when the engineered masonry design method of Section 2101.1.1 is used. This section contains requirements for empirical design of lateral-load-resisting systems composed of diaphragms and shear walls.

Requirements include minimum lengths of masonry shear walls in both principal plan directions of the building and maximum span-to-width (depth) ratios of floor and roof diaphragms. Requirements for roofs and dry-stacked, surface-bonded walls are also part of this section.

Lateral load resistance is a basic requirement for structural design. The distribution of loads within the lateral-load-resisting system is a function of the relative rigidities of diaphragms and shear walls. The lateral-load-resisting system transfers lateral wind and seismic forces to the foundation in the form of base shear and overturning moment and maintains stability of the structure under gravity loads.

2109.2.1 Shear walls. Where the structure depends upon masonry walls for lateral stability, shear walls shall be provided parallel to the direction of the lateral forces resisted.

- The shear wall requirements in this section apply where empirically designed masonry is used for lateral load resistance. Shear walls are required in both principal plan directions of the structure, parallel to the lateral loads required in Chapter 16. Load-bearing walls serve as shear walls.
- For empirical design, this section limits length- or span-to-width ratios of floor and roof diaphragms between shear walls, based on the inherent rigidity of the diaphragm construction. This effectively distributes shear walls throughout the structure at adequate intervals for the diaphragm span.

The assumed deflected shape of a diaphragm is illustrated in Figure 2109.2.1.3(1). Flexible diaphragms deflect more than rigid ones, possibly resulting in detachment of components. A rigid diaphragm deflects little and transfers loads to shear walls in proportion to their relative rigidities (an important engineered masonry consideration). Symmetrical distribution of shear walls in the building plan is desirable, reducing torsional rotation of the building under lateral loads.

2109.2.1.1 Shear wall thickness. Minimum nominal thickness of masonry shear walls shall be 8 inches (203 mm).

Exception: Shear walls of one-story buildings are permitted to be a minimum nominal thickness of 6 inches (152 mm).

An empirical minimum nominal shear wall thickness of 8 inches (203 mm) is required to transfer lateral loads to the foundation. This minimum is based on experience. Shear walls that are also load-bearing walls are required to comply with the compressive stress requirements of Section 2106 and the lateral support requirements of Section 2107. Those requirements may govern.

The exception addresses single-story buildings that have limited lateral loads and, therefore, limited base shears and overturning moments. This justifies the permitted minimum nominal thickness of 6 inches (152 mm), as listed in the exception to this section.

2109.2.1.2 Cumulative length of shear walls. In each direction in which shear walls are required for lateral stability, shear walls shall be positioned in two separate planes. The minimum cumulative length of shear walls provided shall be 0.4 times the long dimension of the building. Cumulative length of shear walls shall not include openings or any element whose length is less than one-half its height.

- Figure 2109.2.1.2 diagrams the lengths in each direction of the building, parallel to the lateral loads. The term “cumulative” refers to the sum of the lengths of shear wall segments in a single direction. The required length of shear wall in each direction is 0.4 times the long dimension of the building.

Walls above and below openings such as windows and doors are not considered to be shear wall segments. Neither are portions of a wall that have a height of two or more times its length.

2109.2.1.3 Maximum diaphragm ratio. Masonry shear walls shall be spaced so that the length-to-width ratio of each diaphragm transferring lateral forces to the shear walls does not exceed the values given in Table 2109.2.1.3.

- For empirical design, this section limits length- or span-to-width ratios of floor and roof diaphragms between shear walls, based on the inherent rigidity of the diaphragm construction. This effectively distributes shear walls throughout the structure at adequate intervals for the diaphragm span.

The assumed deflected shape of a diaphragm is illustrated in Figure 2109.2.1.3(1). Flexible diaphragms deflect more than rigid ones, possibly resulting in detachment of components. A rigid diaphragm deflects little and transfers loads to shear walls in proportion to their relative rigidities (an important engineered masonry consideration). Symmetrical distribution of shear walls in the building plan is desirable, reducing torsional rotation of the building under lateral loads.

<table>
<thead>
<tr>
<th>FLOOR OR ROOF DIAPHRAGM CONSTRUCTION</th>
<th>MAXIMUM LENGTH-TO-WIDTH RATIO OF DIAPHRAGM PANEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place concrete</td>
<td>5:1</td>
</tr>
<tr>
<td>Precast concrete</td>
<td>4:1</td>
</tr>
<tr>
<td>Metal deck with concrete fill</td>
<td>3:1</td>
</tr>
<tr>
<td>Metal deck with no fill</td>
<td>2:1</td>
</tr>
<tr>
<td>Wood</td>
<td>2:1</td>
</tr>
</tbody>
</table>

- Table 2109.2.1.3 sets the maximum span-to-width ratio of diaphragms constructed of the listed materials. See Figure 2109.2.1.3(2) for an illustration of the terms “diaphragm span” (length) and “width” (depth). Concrete diaphragms are permitted to have high span-to-span ratios because of their rigidity, whereas wood diaphragms are permitted to have low span-to-span ratios because of their flexibility.
MINIMUM CUMULATIVE SHEAR WALL LENGTH = 0.4 x LONG DIMENSION
MINIMUM L = 0.4(60.7') = 24.3'
X - DIRECTION: L = 2(5.7 + 6.0 + 4.0 + 4.0 + 4.0 + 4.0 + 6.0 + 5.7) = 78.8 ft. > 24.3 ft. OK
Y - DIRECTION: L = 2(24.0 + 10.0 + 10.0 + 12.7 + 6.0) = 125.4 ft. > 24.3 ft. OK

For SI: 1 foot = 304.8 mm.

Figure 2109.2.1.2
CUMULATIVE LENGTH OF SHEAR WALL REQUIREMENTS FOR EMPIRICALLY DESIGNED MASONRY

Figure 2109.2.1.3(1)
DIAPHRAGM ACTION (PLAN VIEW)
2109.2.2 Roofs. The roof construction shall be designed so as not to impart out-of-plane lateral thrust to the walls under roof gravity load.

Roofs are not permitted to rely on masonry walls to resist thrust perpendicular to the wall. The low tensile capacity of masonry and the lack of engineered design for these loads in the empirical provisions result in this requirement. Connections that apply thrust perpendicular to the wall are not permitted.

As another example, a wood frame cathedral ceiling does not, by design, have ceiling joists to resist outward thrust. If the ridge beam is not designed for vertical support and limited deflection, opposing sloped rafters usually transfer thrust to the outside walls.

Consideration of horizontal thrust is also necessary for truss connections, especially scissor trusses. In a truss, the bottom chord is usually in tension. Chord elongation can impart significant lateral thrust perpendicular to masonry bearing walls. In general, the lower the roof slope, the greater the lateral thrust.

2109.2.3 Surface-bonded walls. Dry-stacked, surface-bonded concrete masonry walls shall comply with the requirements of this code for masonry wall construction, except where otherwise noted in this section.

Dry-stacked, surface-bonded masonry walls consist of courses of concrete masonry units without mortar joints assembled to form unreinforced walls. Both sides of the walls are coated with a 1/16 to 1/8 inch-thick layer (1.6 to 3.2 mm) of cementitious mortar reinforced with glass fibers capable of increasing the tensile strength of the masonry and unifying the construction.

2109.2.3.1 Strength. Dry-stacked, surface-bonded concrete masonry walls shall be of adequate strength and proportions to support all superimposed loads without exceeding the allowable stresses listed in Table 2109.2.3.1. Allowable stresses not specified in Table 2109.2.3.1 shall comply with the requirements of ACI 530/ASCE 5/TMS 402.

- The flexural strength of surface-bonded walls is about the same as conventional masonry with mortar joints. In the vertical direction, where walls are supported top and bottom, Table 2109.2.3.1 allows a maximum flexural tensile stress of 18 psi (0.12 MPa) based on the gross area. In the horizontal direction, where walls span laterally between supports, a maximum flexural stress of 30 psi (0.21 MPa) is permitted based on the gross area when units are dry stacked in running bond.

The shear strength of surface-bonded walls is less than that of conventional, mortar-jointed walls. This table allows a shear strength of 10 psi (0.069 MPa) based on the gross area.

2109.2.3.2 Construction. Construction of dry-stacked, surface-bonded masonry walls, including stacking and leveling of units, mixing and application of mortar and curing and protection shall comply with ASTM C 946.

- The construction of dry-stacked, surface-bonded walls must conform to the requirements of ASTM C 946.

It is not practical to construct the horizontal surface of a wall footing or foundation level enough to receive the base (first) course of masonry without additional leveling. Therefore, it is customary to lay the base course of masonry on a mortar bed so that the remainder of the dry-stacked units will be erected level. As the units are erected, their ends should be butted together as tightly as possible.
If the bearing surfaces of the concrete units are not ground smooth and flat, shims may be required between the units to erect the wall plumb and level. Such shims should be of metal, mortar, wood or plastic.

Because dry-stacked walls have no mortar joints, it is not possible to use horizontal steel joint reinforcement to reduce the size of cracks associated with temperature and moisture movements. Reinforced bond beams and sufficient control joints in surface-bonded masonry can be used to reduce the widths of such cracks.

The joints of dry-stacked units are tight, with no space for connectors to be embedded in the wall. The face shells or cross webs of such concrete masonry units therefore, should be notched or depressed to accommodate ties and anchors that must be embedded in grout.

Packaged dry-bonding mortar should be mixed with water at the job site in accordance with ASTM C 946 or the manufacturer’s recommendations, including curing and protection procedures after application of the material. Surface-bonding mortars are usually applied by hand troweling to thicknesses between 1/16 and 1/8 inch (1.6 to 3.2 mm). While they may also be sprayed on, this is usually followed by hand or mechanical troweling to obtain the desired finish.

2109.3 Compressive stress requirements.

- This section applies to empirically designed masonry and, as with the other empirical design requirements of Section 2109, not to masonry designed by the engineered approaches of Sections 2107 and 2108.

Vertical dead and live loads, as required in Chapter 16, encompass a wide range of possibilities, as does the conceivable configuration of supported floor spans. Consequently, specifying empirical minimum sizes that would account for all vertical loading and span conditions would be impractical. Section 2109.3 contains an empirical compressive stress design procedure for single- and multiwythe composite masonry walls that result in areas of masonry to resist vertical loads. The design is based on an average compressive stress on the gross cross-sectional area, using specified instead of nominal dimensions.

The result is a way of sizing and proportioning masonry without complete engineering analysis and design. The required areas are intended to be conservative with respect to engineered design and, along with the other empirical design provisions, to adequately address buildings and elements permitted to be empirically designed by the provisions of Section 2109.

2109.3.1 Calculations. Compressive stresses in masonry due to vertical dead plus live loads, excluding wind or seismic loads, shall be determined in accordance with Section 2109.3.2.1. Dead and live loads shall be in accordance with Chapter 16, with live load reductions as permitted in Section 1607.9.

- This section identifies the vertical design loads that must be used in calculating average compressive stresses. The required dead plus live loads are intended to include all loads except wind and seismic loads. Design roof loads given in Chapter 16 are required, including applicable design snow loads.

Effects of wind and seismic forces on empirically designed masonry structures are addressed by the lateral stability requirements of Section 2109.2 and by the seismic, wind and building height limitations of Section 2109.1.1.

2109.3.2 Allowable compressive stresses. The compressive stresses in masonry shall not exceed the values given in Table 2109.3.2. Stress shall be calculated based on specified rather than nominal dimensions.

- The maximum permitted compressive stresses on the gross cross-sectional area are given in Table 2109.3.2. Calculation of gross-area compressive stresses is discussed in the commentary to Section 2109.3.2.1. Section 2109.3.2 requires the use of specified dimensions (see also the commentary for the definition of "Dimensions" in Section 2102.1).

**TABLE 2109.3.2.** See page 21-46.

- The compressive strength of the unit, as well as the mortar type used, limit the allowable compressive stress on the gross area.

2109.3.2.1 Calculated compressive stresses. Calculated compressive stresses for single wythe walls and for multiwythe composite masonry walls shall be determined by dividing the design load by the gross cross-sectional area of the member. The area of openings, chases or recesses in walls shall not be included in the gross cross-sectional area of the wall.

- Using the vertical design load required by Section 2109.3.1, the compressive stress on the gross cross-sectional area of the masonry must be calculated.

Gross cross-sectional area is illustrated in Figure 2102.1(3) for two single-wythe wall examples. Specified (not nominal) dimensions are used and mortared head joints are included. Cores are not required to be subtracted. Other openings in the wall, including chases and recesses, are required to be subtracted.

The calculated compressive stress is the total required design load divided by the gross cross-sectional area, as illustrated in Figure 2109.3.2.1(1) for a single-wythe wall. The dead weight of the masonry units is part of the total required design load. The calculated compressive stresses are not to exceed the allowable values listed in Table 2109.3.2.

The allowable compressive stresses for masonry directly under concentrated loads (bearing stresses) are recommended in the commentary to ACI 530/ASCE 5/TMS 402: 125 percent of the Table 2109.3.2 value if the load acts on the full wall thickness; or 150 percent of the Table 2109.3.2 value if the load acts on concentrically placed bearing plates greater than one-half, but less than the full supporting area. Concentrated loads on load-bearing walls transmitted from beams, girders
or other structural elements normally bear on units of solid masonry or on hollow masonry units with grout-filled cores at least 4 inches (102 mm) high.

Bearing plates are often used to distribute concentrated loads and to prevent damage to the bearing areas of the supporting masonry. Masonry bond beams can also be used for this purpose.

Concentrated loads must be distributed over an area whose length cannot exceed the center-to-center distance between loads, nor one-half of the wall height [see Figure 2109.3.2.1(2)]. Loads are not to be distributed across continuous vertical joints, such as expansion or control joints in masonry walls, or across head joints in stack bond construction. For large concentrated loads, masonry pilasters may be required.

2109.3.2.2 Multiwythe walls. The allowable stress shall be as given in Table 2109.3.2 for the weakest combination of the units used in each wythe.

Multiwythe masonry walls are often constructed with units having different mechanical properties. An example of a multiwythe wall is a composite 8-inch (204 mm) nominal thickness wall using Type S mortar, consisting of one wythe of 4-inch-wide (102 mm) common brick and one wythe of 4-inch-wide (102 mm) lightweight concrete block, bonded together with required joint reinforcement and having completely filled collar joints.

In this example, if the compressive strength of the concrete masonry unit is less than that of the common brick, the allowable compressive stress for both wythes is to be based on the strength of the concrete masonry unit.

### TABLE 2109.3.2

<table>
<thead>
<tr>
<th>CONSTRUCTION; COMPRESSIVE STRENGTH OF UNIT GROSS AREA (psi)</th>
<th>ALLOWABLE COMPRESSIVE STRESSES FOR EMPIRICAL DESIGN OF MASONRY</th>
<th>ALLOWABLE COMPRESSIVE STRESSES(^a)/GROSS CROSS-SECTIONAL AREA (psi)</th>
<th>Type M or S mortar</th>
<th>Type N mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8,000 or greater</td>
<td>350</td>
<td>300</td>
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<tr>
<td>4,500</td>
<td>225</td>
<td>200</td>
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<td>2,500</td>
<td>160</td>
<td>140</td>
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<tr>
<td>1,500</td>
<td>115</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grouted masonry, of clay or shale; sand-lime or concrete:</td>
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<td></td>
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<tr>
<td>4,500 or greater</td>
<td>225</td>
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<tr>
<td>1,500</td>
<td>115</td>
<td>100</td>
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<tr>
<td>Solid masonry of solid concrete masonry units:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000 or greater</td>
<td>225</td>
<td>200</td>
<td></td>
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</tr>
<tr>
<td>2,000</td>
<td>160</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,200</td>
<td>115</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masonry of hollow load-bearing units:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,000 or greater</td>
<td>140</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,500</td>
<td>115</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>75</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>60</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hollow walls (noncomposite masonry bonded)(^b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid units:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,500 or greater</td>
<td>160</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,500</td>
<td>115</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hollow units</td>
<td>75</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone ashlar masonry:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite</td>
<td>720</td>
<td>640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone or marble</td>
<td>450</td>
<td>400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone or cast stone</td>
<td>360</td>
<td>320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubble stone masonry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coursed, rough or random</td>
<td>120</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For SI: 1 pound per square inch = 0.006895 MPa.

\(^a\) Linear interpolation for determining allowable stresses for masonry units having compressive strengths which are intermediate between those given in the table is permitted.

\(^b\) Where floor and roof loads are carried upon one wythe, the gross cross-sectional area is that of the wythe under load; if both wythes are loaded, the gross cross-sectional area is that of the wall minus the area of the cavity between the wythes. Walls bonded with metal ties shall be considered as noncomposite walls unless collar joints are filled with mortar or grout.
For loading on only one wythe of a composite (grouted collar joint), multiwythe masonry wall, the wythes and the collar joint are to be considered part of the gross cross-sectional area. For loading on only one wythe of a noncomposite (ungrouted collar joint) multiwythe masonry wall, the gross cross-sectional area is limited to the area of the wythe under load and the allowable compressive stresses in Table 2109.3.2 are based on the units and mortar comprising the wythe under load.

The use of the term “composite” refers to multicomponent masonry members that act as a unit. Note b of Table 2109.3.2 considers a multiwythe masonry wall to act compositely (monolithically) if it is bonded with metal ties (or joint reinforcement) and has completely filled collar joints.

Openings in the wall, including chases and recesses, are required to be subtracted from the gross wall area, as stated in Section 2106.2.1.

2109.4 Lateral support.

- Section 2109.4 contains empirical design provisions for the spacing of lateral support locations of masonry walls. Requirements include maximum ratios of wall length or wall height to wall thickness. The requirements of this section do not apply when the engineered masonry design method of Section 2101.1.1 is selected.

Compression elements such as columns and walls may have axial capacities limited by buckling, based on slenderness effects (which depends on their stiffness and unsupported length). Limits are also included for nonbearing walls to account for resistance to out-of-plane loads.

The design professional is responsible for indicating in the construction documents the method of lateral support of masonry walls.

2109.4.1 Intervals. Masonry walls shall be laterally supported in either the horizontal or vertical direction at intervals not exceeding those given in Table 2109.4.1.

- The requirements of this section prescribe maximum length or height-to-thickness ratios for locations of lateral support (see Figure 2109.4.1). Providing lateral support at the resulting maximum heights increases the buckling capacity to an acceptable level. Spacing of lateral support must be designed either vertically or horizontally, but not in both directions.

<table>
<thead>
<tr>
<th>CONSTRUCTION</th>
<th>MAXIMUM WALL LENGTH TO THICKNESS OR WALL HEIGHT TO THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing walls</td>
<td>20</td>
</tr>
<tr>
<td>Solid units or fully grouted</td>
<td>20</td>
</tr>
<tr>
<td>All others</td>
<td>18</td>
</tr>
<tr>
<td>Nonbearing walls</td>
<td>18</td>
</tr>
<tr>
<td>Exterior</td>
<td>36</td>
</tr>
<tr>
<td>Interior</td>
<td>36</td>
</tr>
</tbody>
</table>

- This table shows maximum length- or height-to-thickness ratios between locations of lateral support. Lateral support is required to be provided either vertically or horizontally, but not in both directions.

Figure 2109.4.1 illustrates use of the table for an em-
empirically designed masonry building. As shown, the height is measured between points of lateral support.

2109.4.2 Thickness. Except for cavity walls and cantilever walls, the thickness of a wall shall be its nominal thickness measured perpendicular to the face of the wall. For cavity walls, the thickness shall be determined as the sum of the nominal thicknesses of the individual wythes. For cantilever walls, except for parapets, the ratio of height-to-nominal thickness shall not exceed six for solid masonry or four for hollow masonry. For parapets, see Section 2109.5.5.

The nominal thickness or the sum of the nominal thicknesses is used in determining the wall thickness for use in Table 2109.4.1. Figure 2102.1(5) illustrates nominal versus specified thickness of a particular concrete masonry unit. Nominal dimensions are discussed in the commentary to Section 2102.1 (see the definition of "Dimensions").

The use of the nominal thickness is permitted for calculating thickness ratios for empirical design. In contrast, the engineered design method uses the rational Euler buckling equation and the accuracy of specified dimensions is appropriately required. Table 2109.4.1 is intended, however, to produce conservative results with respect to the engineered method in most cases.

For cavity walls, the adjacent wythes do not act together because of the absence of a shear connection. Thus, the wall thickness consists of only the sum of the wythes.

This section does not include retaining walls, which...
must comply with the requirements of Chapter 18. For definitions of “Solid” and “Hollow” masonry, refer to Section 2102.1.

Free-standing cantilever walls have a lower allowable height-to-thickness ratio because of the lack of lateral support at the free (unsupported) end. Parapets are subject to the more restrictive requirements of Section 2109.5.5 because of their location and exterior exposure.

**2109.4.3 Support elements.** Lateral support shall be provided by cross walls, pilasters, buttresses or structural frame members when the limiting distance is taken horizontally, or by floors, roofs acting as diaphragms or structural frame members when the limiting distance is taken vertically.

- Lateral support points complying with the requirements of this section are achieved by required anchorage complying with Section 2109.7.

  The code requires only one direction of span for lateral support, either vertical or horizontal. The lateral support of masonry walls can be achieved by floors or roofs when the limiting distance is measured vertically, or by columns, buttresses (pilasters) or cross walls when the limiting distance is measured horizontally.

- A masonry pier is an isolated column designed to support vertical loads. A pilaster is a masonry column integrally bonded to a wall.

- A buttress is a pilaster whose outside edge (face running in the same direction as the wall) slants toward the wall and whose horizontal cross section increases from top to bottom. Buttresses are used mainly for out-of-plane lateral support of high walls. Both pilasters and buttresses may project out from one or both faces of the wall.

  For empirical design, solid bearing walls are permitted to span 20 times their thickness between supports, while hollow walls or walls of hollow masonry units can span 18 times their thickness. For example, a 16-inch (406 mm) hollow block wall or wall constructed with hollow units or masonry bonded hollow walls is decreased in thickness, a course or courses of solid masonry are to be placed between the wall below and the thinner wall above, or special units or construction shall be used to transmit the loads from face shells or wythes above to those below.

**2109.5 Thickness of masonry.** Minimum thickness requirements shall be based on nominal dimensions of masonry.

- Section 2109.5 provides requirements for minimum nominal thicknesses of empirically designed walls of masonry, including rubble stone (see the definition of “Dimensions”). Changes in thickness and parapet walls are also included in this section.

**2109.5.1 Thickness of walls.** The thickness of masonry walls shall conform to the requirements of Section 2109.5.

- Section 2109.5.1 contains provisions for minimum nominal thicknesses of empirically designed masonry walls. The requirements of this section do not apply when engineered masonry design is used.

  The MSJC has concluded that the minimum thickness ratios listed in Section 2109.4.1 (which are derived from ANSI A41.1) are not always conservative when compared to the results achieved from a working stress analysis.

**2109.5.2 Minimum thickness.** The minimum thickness of masonry bearing walls more than one story high shall be 8 inches (203 mm). Bearing walls of one-story buildings shall not be less than 6 inches (152 mm) thick.

- The minimum thicknesses required in this section are nominal thicknesses (in accordance with the definition in Section 2102.1) and apply to bearing walls. Like the measurement of thickness in Section 2109.4, the space between cavity walls and multiwythe, noncomposite walls is to be excluded when determining wall thickness.

**2109.5.3 Rubble stone walls.** The minimum thickness of rough or random or coursed rubble stone walls shall be 16 inches (406 mm).

- Rubble stone walls are composed of stone masonry having irregularly shaped units bonded by mortar. The greater thickness required for these walls is justified by this irregularity. Accordingly, Table 2109.3.2 permits relatively low compressive stresses for this material. Nominal thickness in this case is the average thickness. This section is not applicable to ashlar masonry (rectangular units).

**2109.5.4 Change in thickness.** Where walls of masonry of hollow units or masonry bonded hollow walls are decreased in thickness, a course or courses of solid masonry shall be interposed between the wall below and the thinner wall above, or special units or construction shall be used to transmit the loads from face shells or wythes above to those below.

- Where hollow walls are decreased in thickness, one or more courses of solid masonry are to be placed between the thicker wall below and the thinner wall above. Alternatively, special construction can be introduced to transmit the load from the wall above to the supporting wall below. For walls constructed with concrete masonry units, a bond beam as thick as the lower wall may be placed between the two wall sections.

**2109.5.5 Parapet walls.**

- Parapet walls are cantilever walls located above the roof line that are typically exposed to weather on both faces; therefore, they may require special consideration.

**2109.5.5.1 Minimum thickness.** Unreinforced parapet walls shall be at least 8 inches (203 mm) thick, and their height shall not exceed three times their thickness.

- Because of their exposure conditions and the hazard associated with unreinforced parapets, a minimum thickness of 8 inches (203 mm) and a maximum height-to-thickness ratio of 3:1 is required. These requirements are minimums and thicker parapets or smaller height-to-thickness ratios may be necessary.
2109.5.5.2 Additional provisions. Additional provisions for parapet walls are contained in Sections 1503.2 and 1503.3.

See the commentary to Sections 1504.2, 1504.3 and 1504.4 regarding the application of these provisions to parapets.

2109.5.6 Foundation walls. Foundation walls shall comply with the requirements of Sections 2109.5.6.1 and 2109.5.6.2.

Masonry foundation walls must comply with Section 1805.5 if the requirements of this section cannot be met.

2109.5.6.1 Minimum thickness. Minimum thickness for foundation walls shall comply with the requirements of Table 2109.5.6.1. The provisions of Table 2109.5.6.1 are only applicable where the following conditions are met:

1. The foundation wall does not exceed 8 feet (2438 mm) in height between lateral supports,
2. The terrain surrounding foundation walls is graded to drain surface water away from foundation walls,
3. Backfill is drained to remove ground water away from foundation walls,
4. Lateral support is provided at the top of foundation walls prior to backfilling,
5. The length of foundation walls between perpendicular masonry walls or pilasters is a maximum of three times the basement wall height,
6. The backfill is granular and soil conditions in the area are nonexpansive, and
7. Masonry is laid in running bond using Type M or S mortar.

This section provides empirical criteria for foundation walls that are based on similar requirements in the MSJC Code. It is necessary to satisfy the seven listed conditions in order to use this approach.

<table>
<thead>
<tr>
<th>WALL CONSTRUCTION</th>
<th>NOMINAL WALL THICKNESS (inches)</th>
<th>MAXIMUM DEPTH OF UNBALANCED BACKFILL (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow unit masonry</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Solid unit masonry</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Fully grouted masonry</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

The minimum foundation wall thickness can be established from this table based on the depth of fill that is supported, as well as the proposed wall construction.

2109.5.6.2 Design requirements. Where the requirements of Section 2109.5.6.1 are not met, foundation walls shall be designed in accordance with Section 1805.5.

If the conditions of Section 2109.5.6.1 cannot be met, the more general requirements for foundation walls in Chapter 18 must be complied with.

2109.6 Bond.

Section 2109.6 contains provisions for bonding adjacent wythes of empirically designed multiwythe masonry walls. The requirements of this section do not apply to engineered masonry design methods of Section 2107 or 2108.

2109.6.1 General. The facing and backing of multiwythe masonry walls shall be bonded in accordance with Section 2109.6.2, 2109.6.3 or 2109.6.4.

This section establishes the requirements and methods of bonding together the facing and backing of adjacent wythes of multiwythe masonry walls. The use of masonry units, nonadjustable metal ties, adjustable metal ties and metal joint reinforcement as bonding elements is provided for in this section.

Bonding increases structural integrity, including load transfer between adjacent wythes and across head and collar joints. The requirements include both transverse (through-wall) and longitudinal (in-wall) bonding. Longitudinal bonding is provided for in Section 2109.5, with requirements for running bond and stack bond.

Adjacent wythes of multiwythe masonry walls are usually brick-to-brick, brick-to-block or block-to-block. Collar joints are usually 1/8 to 4 inches (9.5 to 102 mm) thick.

Adjacent wythes of multi-wythe masonry walls are considered composite (monolithic) when connected by metal ties or joint reinforcement and by a collar joint solidly filled with mortar or grout. Accordingly, Note b of Table 2109.3.2 requires completely filled collar joints if adjacent wythes bonded with metal ties are to be considered composite (monolithic) for empirical compressive stress design.

2109.6.2 Bonding with masonry headers.

Masonry headers (bonders) are permitted to be used to connect adjacent wythes, in accordance with this section. Differential thermal movement, especially at exterior walls, can crack masonry bonders. Metal ties or joint reinforcement are more ductile and are recommended at these locations. Walls having the specified masonry bonders are considered composite (monolithic). Header requirements are based on successful past performance.

2109.6.2.1 Solid units. Where the facing and backing (adjacent wythes) of solid masonry construction are bonded by means of masonry headers, no less than 4 percent of the wall surface of each face shall be composed of headers extending not less than 3 inches (76 mm) into the backing. The distance between adjacent full-length headers shall not exceed 24 inches (610 mm) either
vertically or horizontally. In walls in which a single header does not extend through the wall, headers from the opposite sides shall overlap at least 3 inches (76 mm), or headers from opposite sides shall be covered with another header course overlapping the header below at least 3 inches (76 mm).

- Solid masonry units are defined in Section 2102.1. The 4-percent requirement applies to each surface of the wall and 24-inch (610 mm) spacing is required in both horizontal and vertical directions. Spacing is measured between the nearest surfaces of masonry units. The 3-inch (76 mm) overlap is a projected measurement, since headers are spaced a maximum of 24 inches (610 mm) vertically.

- Bonding requirements for solid units are less restrictive than for hollow units because of the greater cross-sectional area crossing the collar joint.

2109.6.2.2 Hollow units. Where two or more hollow units are used to make up the thickness of a wall, the stretcher courses shall be bonded at vertical intervals not exceeding 34 inches (864 mm) by lapping at least 3 inches (76 mm) over the unit below, or by lapping at vertical intervals not exceeding 17 inches (432 mm) with units that are at least 50 percent greater in thickness than the units below.

- Hollow masonry units are defined in Section 2102.1. An entire course of headers is required at the stated vertical spacing. Spacing is measured between the nearest surfaces of masonry units. The halved spacing of 17 inches (432 mm) is permitted for units having twice the thickness, because of the greater cross-sectional area crossing the collar joint. Bonding requirements for hollow units are more restrictive than for solid units because of the smaller cross-sectional area crossing the collar joint.

2109.6.2.3 Masonry bonded hollow walls. In masonry bonded hollow walls, the facing and backing shall be bonded so that not less than 4 percent of the wall surface of each face is composed of masonry bonded units extending not less than 3 inches (76 mm) into the backing. The distance between adjacent bonders shall not exceed 24 inches (610 mm) either vertically or horizontally.

- This section prescribes procedures for bonding hollow walls using masonry units.

2109.6.3 Bonding with wall ties or joint reinforcement.

- Figure 2109.6.3(1) illustrates typical masonry accessories. Shown are ladder-type and truss-type joint reinforcement and a "Z" wire wall tie. The spacing requirements given in this section are illustrated in Figure 2109.6.3(2). Strength and durability requirements for metal ties and joint reinforcement are given in Section 2103.11. Wall ties are required to be placed in accordance with Section 2104.1.3.

- Metal wall ties or joint reinforcement provide a more ductile connection between adjacent wythes than do masonry headers. The size, spacing and number of ties required in this section are based on experience.
2109.6.3.1 Bonding with wall ties. Except as required by Section 2109.6.3.1.1, where the facing and backing (adjacent wythes) of masonry walls are bonded with wire size W2.8 (MW18) wall ties or metal wire of equivalent stiffness embedded in the horizontal mortar joints, there shall be at least one metal tie for each 4\(\sqrt{1/2}\) square feet (0.42 m\(^2\)) of wall area. The maximum vertical distance between ties shall not exceed 24 inches (610 mm), and the maximum horizontal distance shall not exceed 36 inches (914 mm). Rods or ties bent to rectangular shape shall be used with hollow masonry units laid with the cells vertical. In other walls, the ends of ties shall be bent to 90-degree (1.57 rad) angles to provide hooks no less than 2 inches (51 mm) long. Wall ties shall be without drips. Additional bonding ties shall be provided at all openings, spaced not more than 36 inches (914 mm) apart around the perimeter and within 12 inches (305 mm) of the opening.

Requirements for spacing of nonadjustable wall ties are shown in Figure 2109.6.3(2). The minimum wire size is W2.8. Where wythes of hollow units are bonded and cores are required to be vertical, rectangular-shaped ties are required. "Z" ties, illustrated in Figure 2109.6.3(1), are used in other applications. Drips on wall ties can adversely affect the tie strength and are, therefore, prohibited.

2109.6.3.1.1 Bonding with adjustable wall ties. Where the facing and backing (adjacent wythes) of masonry are bonded with adjustable wall ties, there shall be at least one tie for each 1.77 square feet (0.164 m\(^2\)) of wall area. Neither the vertical nor horizontal spacing of the adjustable wall ties shall exceed 16 inches (406 mm). The maximum vertical offset of bed joints from one wythe to the other shall be 1\(\sqrt{1/3}\) inches (32 mm). The maximum clearance between connecting parts of the ties shall be 1\(\sqrt{1/4}\) inch (1.6 mm). When pintle legs are used, ties shall have at least two wire size W2.8 (MW18) legs.

Spacing requirements for bonding with adjustable ties are shown in Figure 2109.6.3(2) and are more restrictive because of the lower stiffness of those ties. A single tie of the pintle- and eye-type is required to have two legs. The maximum clearance between the eye and pintle is 1\(\sqrt{1/16}\) inch (1.6 mm). Figures 2109.6.3.1.1 (1), (2) and (3) show requirements for adjustable anchors.

2109.6.3.2 Bonding with prefabricated joint reinforcement. Where the facing and backing (adjacent wythes) of masonry are bonded with prefabricated joint reinforcement, there shall at least one cross wire serving as a tie for each 2\(\sqrt{1/3}\) square feet (0.25 m\(^2\)) of wall area. The vertical spacing of the joint reinforcing shall not exceed 24 inches (610 mm). Cross wires on prefabricated joint reinforcement shall not be less than W1.7 (MW11) and shall be without drips. The longitudinal wires shall be embedded in the mortar.

Truss and ladder-type joint reinforcement is illustrated in Figures 2102.1(4), 2109.6.3(1), 2109.6.3.1.1(1) and 2109.6.3.1.1(2). Ladder-type joint reinforcement better accommodates differential movement between wythes. Cross wires are required to have a minimum wire size of W1.7 for the transfer of stresses between adjacent wythes across the collar joint. Cross wires are permitted to be plain, while longitudinal wires are required to be deformed for increased bond strength.

2109.6.4 Bonding with natural or cast stone.

- Because of the irregularity of mortar joints permitted with coursed, random or rough stone masonry, as well as the need for peripheral mortar area in through-wall bonding units, metal ties do not adequately bond and are not required in this type of construction.

2109.6.4.1 Ashlar masonry. In ashlar masonry, bonder units, uniformly distributed, shall be provided to the extent of not less than 10 percent of the wall area. Such bonder units shall extend not less than 4 inches (102 mm) into the backing wall.

- Ashlar is often classified as either coursed or random. Bonding requirements apply equally to both types. The 10-percent requirement applies to one wall surface only. The "uniform distribution" requirement is intended to allow for slight deviations necessary for the nonmodular units typically encountered.

2109.6.4.2 Rubble stone masonry. Rubble stone masonry 24 inches (610 mm) or less in thickness shall have bonder units with a maximum spacing of 36 inches (914 mm) vertically and 36 inches (914 mm) horizontally, and if the masonry is of greater thickness than 24 inches (610 mm), shall have one bonder unit for each 6 square feet (0.56 m\(^2\)) of wall surface on both sides.

- Rubble stone masonry is required to be through bonded using stones placed at a maximum spacing of 3 feet (914 mm) vertically and horizontally. Where the wall is more than 24 inches (610 mm) thick, at least one bond unit is required for each 6 square feet (0.56 m\(^2\)) of wall surface on both sides.

2109.6.5 Masonry bonding pattern.

- Masonry may be constructed with a variety of bond patterns to provide a variety of decorative appearances. Because some of these bond patterns are stronger than others, two broad categories have been established to describe them. Section 2109.5.1 applies to masonry laid in running bond. Section 2109.6.5.2 applies to masonry laid in "other than running bond," which in that section is referred to as "stack bond," although that term can also be used to describe a very specific bond pattern in which the head joints are aligned continuously from course to course, rather than being offset. See the definitions of "Running bond" and "Stack bond" in Section 2102.1 and related commentary.

2109.6.5.1 Masonry laid in running bond. Each wythe of masonry shall be laid in running bond, head joints in successive courses shall be offset by not less than one-fourth the unit length or the masonry walls shall be reinforced longitudinally as required in Section 2109.6.5.2.
The requirement for running bond is illustrated in Figure 2102.1(6). The minimum overlap is intended to provide structural continuity across head joints.

2109.6.5.2 Masonry laid in stack bond. Where unit masonry is laid with less head joint offset than in Section 2109.6.5.1, the minimum area of horizontal reinforcement placed in mortar bed joints or in bond beams spaced not more than 48 inches (1219 mm) apart, shall be 0.0003 times the vertical cross-sectional area of the wall.

Where the overlap required for running bond, as illustrated in Figure 2102.1(6), is not provided, additional structural continuity must be provided across head joints in accordance with this section. Each mortar joint or bond beam is required to have the minimum stated reinforcement to provide distributed reinforcement in the wall.

2109.7 Anchorage.

This section contains provisions for anchorage of empirically designed masonry elements at locations of lateral support, including intersecting walls, floors, roofs and adjoining structural framing. The requirements of this section do not apply to the engineered masonry design methods of Sections 2107 and 2108.

2109.7.1 General. Masonry elements shall be anchored in accordance with Sections 2109.7.2 through 2109.7.4.
This section establishes the requirements and methods of anchoring masonry walls to intersecting walls, floors and roofs. This section covers anchoring requirements for masonry bonders and for metal ties and anchors.

Anchorage in accordance with this section is required for empirically designed masonry. Anchorage provisions address empirical lateral load resistance, but not the vertical load resistance of the connection, floor or roof system. The vertical load resistance of the connection, floor or roof system, including permitted spans, bearing requirements and bracing, must comply with applicable code requirements. The empirical provisions in this chapter do not address elements with horizontal spans, such as wood, floor decks, roof systems or concrete or steel beams.

2109.7.2 Intersecting walls. Masonry walls depending upon one another for lateral support shall be anchored or bonded at locations where they meet or intersect by one of the methods indicated in Sections 2109.7.2.1 through 2109.7.2.5.

Where required by the lateral bracing requirements in Section 2109.4, intersecting walls and partitions must be anchored together by any of the methods described in the sections that follow (see Figure 2109.7.2). These requirements, however, do not prohibit other methods for connecting intersecting walls.

For example, long walls, by design, often require control joints or expansion joints at cross walls. The construction details for these walls differ considerably from walls that are required to be anchored or bonded monolithically.

Intersecting walls, such as tees and corners, may be tied together using interlocking masonry units or heavy metal ties placed in the bed joints.

2109.7.2.1 Bonding pattern. Fifty percent of the units at the intersection shall be laid in an overlapping masonry bonding pattern, with alternate units having a bearing of not less than 3 inches (76 mm) on the unit below.

Masonry bonding requires that at least 50 percent of the masonry units cross at the juncture of the walls as bonding units. The units must be laid with a 3-inch (76 mm) minimum bearing. Figure 2109.7.2 shows typical brick walls bonded at a tee intersection and a corner. While these coursings are common, others are possible.

2109.7.2.2 Steel connectors. Walls shall be anchored by steel connectors having a minimum section of \( \frac{1}{4} \) inch (6.4 mm) by \( \frac{1}{2} \) inches (38 mm), with ends bent up at least 2 inches (51 mm) or with cross pins to form anchorage. Such anchors shall be at least 24 inches (610 mm) long and the maximum spacing shall be 48 inches (1219 mm).

Rigid steel connectors must be used at vertical intervals of 4 feet (1219 mm) or less. For this type of anchorage, the most commonly used fastener is a steel strip with cross-sectional dimensions not less than \( \frac{1}{4} \) by \( \frac{1}{2} \) inches (6.4 by 38 mm) in lengths of 2 feet (610 mm) or more and with 2-inch (51 mm) hooked ends [see Figure 2109.6.3(1)]. Figure 2109.7.2 shows a tee and corner connection made with steel connectors.

Figure 2109.7.2
ANCHORAGE OF INTERSECTING WALLS
2109.7.2.3 Joint reinforcement. Walls shall be anchored by joint reinforcement spaced at a maximum distance of 8 inches (203 mm). Longitudinal wires of such reinforcement shall be at least wire size W1.7 (MW 11) and shall extend at least 30 inches (762 mm) in each direction at the intersection.

- Figure 2109.7.2 shows a tee and corner connection made with joint reinforcement. Prefabricated joint reinforcement made for that purpose is commonly used. Joint reinforcement is spaced not more than 8 inches (204 mm) vertically.
  - The ladder-type joint reinforcement shown is made with 3/16-inch-diameter (4.8 mm) deformed side bars cross connected with a minimum wire size of W1.7.
  - Where interior nonload-bearing masonry walls or partitions intersect, they may be connected by bonders described in Section 2109.7.2.1 or, if constructed separately, by joint reinforcement or 1/4-inch (6.4 mm) mesh galvanized hardware cloth.
  - Where interior nonload-bearing masonry walls or partitions intersect, they may be connected by bonders described in Section 2109.7.2.1 or, if constructed separately, by joint reinforcement or 1/4-inch (6.4 mm) mesh galvanized hardware cloth.

2109.7.2.4 Interior nonload-bearing walls. Interior nonload-bearing walls shall be anchored at their intersection, at vertical intervals of not more than 16 inches (406 mm) with joint reinforcement or 1/4-inch (6.4 mm) mesh galvanized steel mesh spaced vertically at a maximum interval of 16 inches (406 mm).

2109.7.2.5 Ties, joint reinforcement or anchors. Other metal ties, joint reinforcement or anchors, if used, shall be spaced to provide equivalent area of anchorage to that required by this section.

- Truss-type, prefabricated metal ties and steel strip anchors bent at the ends can be hooked into vertical mortar joints or embedded in grout-filled cores of concrete block units. Other methods of reinforcement can be used if their cross-sectional area and distribution are equivalent.

2109.7.3 Floor and roof anchorage. Floor and roof diaphragms providing lateral support to masonry shall comply with the live loads in Section 1607.3 and shall be connected to the masonry in accordance with Sections 2109.7.3.1 through 2109.7.3.3.

- Where the lateral support locations required in Section 2109.4 are provided by intersecting floors or roofs, the minimum anchorage requirements of this section apply. The specified anchorage is intended to transfer the shears at diaphragms between a floor or roof diaphragm and the wall, as well as provide locations of lateral support.
- This section does not address vertical load resistance of floors or roofs. The connections required by the loads transferred from floors and roofs must be in accordance with applicable requirements for those elements, including required design loads in Chapter 16. The minimum requirements stated here do not address floor and roof loads to be resisted by the connection.

2109.7.3.1 Wood floor joists. Wood floor joists bearing on masonry walls shall be anchored to the wall at intervals not to exceed 72 inches (1829 mm) by metal strap anchors. Joists parallel to the wall shall be anchored with metal straps spaced not more than 72 inches (1829 mm) o.c. extending over and under and secured to at least three joists. Blocking shall be provided between joists at each strap anchor.

- Anchorage with metal straps is specified by this section. Blocking is required for stability against rotation of joists parallel to the wall. Strength and material requirements for metal straps are specified in Section 2103.11.

2109.7.3.2 Steel floor joists. Steel floor joists bearing on masonry walls shall be anchored to the wall with 3/8-inch (9.5 mm) round bars, or their equivalent, spaced not more than 72 inches (1829 mm) o.c. Where joists are parallel to the wall, anchors shall be located at joist bridging.

- The strength and material requirements for 3/8-inch (9.5 mm) round bars are specified in Section 2103.11. The requirements for steel joist construction, including materials, design, load-bearing capacity and cross bridging, are in Chapter 22.

2109.7.3.3 Roof diaphragms. Roof diaphragms shall be anchored to masonry walls with 3/8-inch-diameter (12.7 mm) bolts, 72 inches (1829 mm) o.c. or their equivalent. Bolts shall extend and be embedded at least 15 inches (381 mm) into the masonry, or be hooked or welded to not less than 0.20 square inch (129 mm²) of bond beam reinforcement placed not less than 6 inches (152 mm) from the top of the wall.

- Roofs must be anchored to bond beams and to the tops of other walls. The material requirements for the bolts are given in Section 2103.11.5.

2109.7.4 Walls adjoining structural framing. Where walls are dependent upon the structural frame for lateral support, they shall be anchored to the structural members with metal anchors or otherwise keyed to the structural members. Metal anchors shall consist of 3/4-inch (12.7 mm) bolts spaced at 48 inches (1219 mm) o.c. embedded 4 inches (102 mm) into the masonry, or their equivalent area.

- Selection of connectors for anchoring masonry to steel beams and columns is based on the loads that must be resisted. Lateral restraint perpendicular to the wall is required as a location of lateral support. Diaphragm transfer of shear forces is also required parallel to the wall, if such forces occur. Alternative methods of reinforcement can be used if the cross-sectional area and spacing are equivalent.

2109.8 Adobe construction. Adobe construction shall comply with this section and shall be subject to the requirements of this code for Type V construction.

- Adobe masonry was popular in the southwest United States due to the availability of soil for units, the limited rainfall and low humidity to dry the units, the thermal...
mass provided by the completed adobe structure and the low cost of this form of construction. Requirements for adobe construction are based on previous requirements in the SBC and the UBC. They are a combination of empirical provisions and rudimentary engineering. Since there are no ASTM standards for adobe materials, test methods have been included in the code. Design is based on gross cross-sectional dimensions.

Requirements for unstabilized adobe are contained in Section 2109.8.1. Requirements for stabilized adobe are contained in Section 2109.8.2. Requirements in Sections 2109.8.3 and 2109.8.4 apply to both unstabilized and stabilized adobe. This is one of the few sources for such design information.

2109.8.1 Unstabilized adobe.

Unstabilized adobe does not contain stabilizers and is generally not as durable or dimensionally stable as stabilized adobe.

2109.8.1.1 Compressive strength. Adobe units shall have an average compressive strength of 300 psi (2068 kPa) when tested in accordance with ASTM C 67. Five samples shall be tested and no individual unit is permitted to have a compressive strength of less than 250 psi (1724 kPa).

Average compressive strength, based on five specimens tested in accordance with ASTM C 67, must be at least 300 psi (2068 kPa).

2109.8.1.2 Modulus of rupture. Adobe units shall have an average modulus of rupture of 50 psi (345 kPa) when tested in accordance with the following procedure. Five samples shall be tested and no individual unit is permitted to have a modulus of rupture of less than 35 psi (241 kPa).

Average modulus of rupture, based on five specimens tested in accordance with Sections 2109.8.1.2.1 through 2109.8.1.2.4, must be at least 50 psi (345 kPa).

2109.8.1.2.1 Support conditions. A cured unit shall be simply supported by 2-inch-diameter (51 mm) cylindrical supports located 2 inches (51 mm) in from each end and extending the full width of the unit.

These required support conditions are typical for modulus of rupture tests.

2109.8.1.2.2 Loading conditions. A 2-inch-diameter (51 mm) cylinder shall be placed at midspan parallel to the supports.

Loading through a hydraulic cylinder at midspan is common for these tests.

2109.8.1.2.3 Testing procedure. A vertical load shall be applied to the cylinder at the rate of 500 pounds per minute (37 N/s) until failure occurs.

The required application of vertical load is easily controlled in testing laboratories.

2109.8.1.2.4 Modulus of rupture determination. The modulus of rupture shall be determined by the equation:

\[ f_r = \frac{3WL}{2bt^2} \]  

(Equation 21-4)

where, for the purposes of this section only:

- \( b \) = Width of the test specimen measured parallel to the loading cylinder, inches (mm).
- \( f_r \) = Modulus of rupture, psi (MPa).
- \( L \) = Distance between supports, inches (mm).
- \( t \) = Thickness of the test specimen measured parallel to the direction of load, inches (mm).
- \( W \) = The applied load at failure, pounds (N).

Equation 21-4 is based on simple engineering mechanics and is valid for all rectangular specimens tested in this fashion.

2109.8.1.3 Moisture content requirements. Adobe units shall have a moisture content not exceeding 4 percent by weight.

This section limits the moisture content of unstabilized adobe units to acceptable levels.

2109.8.1.4 Shrinkage cracks. Adobe units shall not contain more than three shrinkage cracks and any single shrinkage crack shall not exceed 3 inches (76 mm) in length or \( \frac{1}{6} \) inch (3.2 mm) in width.

As adobe units dry, they shrink and can crack. This section places limits on those potential cracks to keep the masonry structurally sound and reasonably water resistant.

2109.8.2 Stabilized adobe.

This type of adobe is manufactured with stabilizers to increase its durability and decrease its water absorption.

2109.8.2.1 Material requirements. Stabilized adobe shall comply with the material requirements of unstabilized adobe in addition to Sections 2109.8.2.1.1 and 2109.8.2.1.2.

Stabilized adobe must comply with the few material requirements for unstabilized adobe in Section 2109.8.1. Stabilized units must also comply with soil compatibility and absorption requirements in Sections 2109.2.1.1 and 2109.2.1.2.

2109.8.2.1.1 Soil requirements. Soil used for stabilized adobe units shall be chemically compatible with the stabilizing material.

The soil and stabilizing materials must be chemically compatible, so that the stabilized units will be durable.

2109.8.2.1.2 Absorption requirements. A 4-inch (102 mm) cube, cut from a stabilized adobe unit dried to a constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C), shall not absorb more than 21 1/2 percent moisture by weight when placed upon a constantly water-saturated, porous surface for
seven days. A minimum of five specimens shall be tested and each specimen shall be cut from a separate unit.

- This section prescribes a test method to verify that stabilized adobe units meet absorption limits.

**2109.8.3 Working stress.** The allowable compressive stress based on gross cross-sectional area of adobe shall not exceed 30 psi (207 kPa).

- This section prescribes the allowable compressive stress of adobe based on its gross cross-sectional area.

**2109.8.3.1 Bolts.** Bolt values shall not exceed those set forth in Table 2109.8.3.1.

- This section requires the capacity of bolts to be based on Table 2109.8.3.1. Specific types of bolts are not identified, but headed, bent-bar and plate anchors should all be acceptable.

<table>
<thead>
<tr>
<th>DIAMETER OF BOLTS (inches)</th>
<th>MINIMUM EMBEDMENT (inches)</th>
<th>SHEAR (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3/8</td>
<td>12</td>
<td>200</td>
</tr>
<tr>
<td>3/4</td>
<td>15</td>
<td>300</td>
</tr>
<tr>
<td>7/8</td>
<td>18</td>
<td>400</td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>500</td>
</tr>
<tr>
<td>1 1/8</td>
<td>24</td>
<td>600</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm, 1 pound = 4.448 N.

- The allowable shear values in this table are based on the capacity of the adobe masonry. The capacity of the anchor-bolt steel is much higher, so the lower strength of the adobe controls.

**2109.8.4 Construction.**

- This section contains general construction requirements for height restrictions, mortar restrictions, mortar joint construction and water-resistance requirements for parapet walls and also specific requirements for wall thickness; foundations; isolated piers and columns; tie beams; exterior finish and lintels.

**2109.8.4.1 General.**

- This section contains general construction requirements for height restrictions, mortar restrictions, mortar joint construction and water-resistance requirements for parapet walls.

**2109.8.4.1.1 Height restrictions.** Adobe construction shall be limited to buildings not exceeding one story, except that two-story construction is allowed when designed by a registered design professional.

- Because of the low strength of adobe masonry, it is limited to use in single-story buildings, unless a registered design professional is hired, in which case two-story buildings are permitted.

**2109.8.4.1.2 Mortar restrictions.** Mortar for stabilized adobe units shall comply with Chapter 21 or adobe soil. Adobe soil used as mortar shall comply with material requirements for stabilized adobe. Mortar for unstabilized adobe shall be portland cement mortar.

- A variety of mortars are acceptable for stabilized adobe as noted; however, portland cement-lime mortars are required for unstabilized adobe. Selection of a relatively weak mortar that is compatible with the units is appropriate.

**2109.8.4.1.3 Mortar joints.** Adobe units shall be laid with full head and bed joints and in full running bond.

- Full mortar joints, the same as for other solid units, are required for adobe construction. Units are required to be laid in running bond.

**2109.8.4.1.4 Parapet walls.** Parapet walls constructed of adobe units shall be waterproofed.

- Waterproofing parapets reduce moisture infiltration into the adobe.

**2109.8.4.2 Wall thickness.** The minimum thickness of exterior walls in one-story buildings shall be 10 inches (254 mm). The walls shall be laterally supported at intervals not exceeding 24 feet (7315 mm). The minimum thickness of interior load-bearing walls shall be 8 inches (203 mm). In no case shall the unsupported height of any wall constructed of adobe units exceed 10 times the thickness of such wall.

- Because of the low strength of adobe masonry walls, thicker walls with more closely spaced supports are required.

**2109.8.4.3 Foundations.**

- This section prescribes foundation requirements for adobe masonry.

**2109.8.4.3.1 Foundation support.** Walls and partitions constructed of adobe units shall be supported by foundations or footings that extend not less than 6 inches (152 mm) above adjacent ground surfaces and are constructed of solid masonry (excluding adobe) or concrete. Footings and foundations shall comply with Chapter 18.

- So that adobe masonry is properly supported, solid masonry or concrete foundations are required.

**2109.8.4.3.2 Lower course requirements.** Stabilized adobe units shall be used in adobe walls for the first 4 inches (102 mm) above the finished first-floor elevation.

- Because of their greater durability, stabilized adobe units are required at the base of adobe walls. Conven-
tional masonry units can also be used to satisfy this
requirement.

2109.8.4.4 Isolated piers or columns. Adobe units shall not be
used for isolated piers or columns in a load-bearing capacity.
Walls less than 24 inches (610 mm) in length shall be considered
isolated piers or columns.

Adobe units are not strong enough to carry significant
loads and are, therefore, not permitted to be used as
isolated piers or columns.

2109.8.4.5 Tie beams. Exterior walls and interior load-bearing
walls constructed of adobe units shall have a continuous tie
beam at the level of the floor or roof bearing and meeting the fol-
lowing requirements.

To distribute loads more evenly into the adobe, tie
beams are required at the floor or roof levels. Tie beams
can be constructed of concrete or wood as described in
Sections 2109.8.4.5.1 and 2108.8.4.5.2, respectively.

2109.8.4.5.1 Concrete tie beams. Concrete tie beams shall be a
minimum depth of 6 inches (152 mm) and a minimum width of
10 inches (254 mm). Concrete tie beams shall be continuously
reinforced with a minimum of two No. 4 reinforcing bars. The
ultimate compressive strength of concrete shall be at least 2,500
psi (17.2 MPa) at 28 days.

This section provides requirements for concrete tie beams
to be cast above adobe masonry walls to distribute loads
from floors and roofs.

2109.8.4.5.2 Wood tie beams. Wood tie beams shall be solid or
built up of lumber having a minimum nominal thickness of 1
inch (25 mm), and shall have a minimum depth of 6 inches (152
mm) and a minimum width of 10 inches (254 mm). Joints in
wood tie beams shall be spliced a minimum of 6 inches (152
mm). No splices shall be allowed within 12 inches (305 mm) of
an opening. Wood used in tie beams shall be approved naturally
decay-resistant or pressure-treated wood.

This section provides requirements for wood tie beams
to be constructed above adobe masonry walls to distrib-
ute loads from floors and roofs.

2109.8.4.6 Exterior finish. Exterior walls constructed of
unstabilized adobe units shall have their exterior surface cov-
ered with a minimum of two coats of portland cement plaster
having a minimum thickness of \( \frac{3}{4} \) inch (19.1 mm) and conform-
ing to ANSI A42.2. Lathing shall comply with ANSI A42.3.
Fasteners shall be spaced at 16 inches (406 mm) o.c. maximum.
Exposed wood surfaces shall be treated with an approved wood
preservative or other protective coating prior to lath application.

Unstabilized adobe must be coated with plaster to in-
crease its durability.

2109.8.4.7Lintels. Lintels shall be considered structural mem-
bers and shall be designed in accordance with the applicable
provisions of Chapter 16.

Lintels over door and window openings are required to be
structurally designed to carry imposed loads and to
distribute those loads into the supporting adobe.

SECTION 2110
GLASS UNIT MASONRY

2110.1 Scope. This section covers the empirical requirements
for nonload-bearing glass unit masonry elements in exterior or
interior walls.

Section 2110 contains provisions for glass unit masonry
walls, which are nearly identical to the glass unit ma-
sory provisions in Chapter 7 of ACI 530/ASCE 5/TMS
402. Because those provisions are essentially the
same, IBC Section 2101.2.4 permits glass unit masonry
to comply with the provisions of Chapter 7 of ACI
530/ASCE 5/TMS 402 or of Section 2110.

Glass unit masonry panels are permitted to be used
in interior or exterior walls, provided that they are
nonload bearing and comply with the requirements of
Section 2110, which are partly empirical and partly
based on tests.

2110.1.1 Limitations. Solid or hollow approved glass block
shall not be used in fire walls, party walls, fire barriers or fire
partitions, or for load-bearing construction. Such blocks shall be
erected with mortar and reinforcement in metal channel-type
frames, structural frames, masonry or concrete recesses, embed-
ded panel anchors as provided for both exterior and interior
walls or other approved joint materials. Wood strip framing shall
not be used in walls required to have a fire-resistance rating by
other provisions of this code.

Exceptions:

1. Glass-block assemblies having a fire protection rating
   of not less than \( \frac{1}{2} \) hour shall be permitted as opening
   protectives in accordance with Section 715 in fire bar-
   riers and fire partitions that have a required fire-resis-
   tance rating of 1 hour or less and do not enclose exit
   stairways or exit passageways.

2. Glass-block assemblies as permitted in Section 404.5,
   Exception 2.

Structural glass blocks are not permitted in fire walls,
party walls, fire barrier walls or fire partitions, with two
exceptions. Exception 1 permits glass blocks that have
been tested and classified for a \( \frac{4}{3} \)-hour fire protection
rating in openings to be used in fire barrier walls or fire
partitions with a required fire-resistance rating of 1 hour
or less. Since 1-hour fire barrier walls can be utilized to
enclose interior exit stairways and exit ramps (see Sec-
tion 1019.1), as well as exit passageways (see Section
1020.3), the exception does not apply to those loca-
tions. This is consistent with Sections 1019.1.1 and
1020.4, which limit openings in these exit components
to those that are necessary for egress purposes. Excep-
tion 2 permits glass blocks to be installed in accordance
with the requirements in Section 404.5, Exception 2 for
the enclosure of atriums. Because Section 404.5 re-
quires a 1-hour fire barrier wall to enclose an atrium, this exception is redundant since Exception 1 already permits this.

2110.2 Units. Hollow or solid glass-block units shall be standard or thin units.

- This section contains minimum requirements for glass masonry units, since a corresponding ASTM standard does not exist. Units are permitted to be either hollow or solid and are required to meet requirements for either standard or thin units.

- Glass units are usually factory coated at their edges. Uncoated glass-block units can be field coated by following the manufacturer's instructions.

2110.2.1 Standard units. The specified thickness of standard units shall be 3 7/8 inches (98 mm).

- This section requires a specified thickness for standard glass masonry units of 3 7/8 inches (98 mm).

2110.2.2 Thin units. The specified thickness of thin units shall be 3 1/8 inches (79 mm) for hollow units or 3 inches (76 mm) for solid units.

- Thicknesses for thin glass unit masonry are given in this section.

2110.3 Panel size.

- This section provides limits on the size of exterior standard-unit and thin-unit panels, interior panels, solid glass-block panels and curved glass-block panels.

- The glass-block panels must be restrained laterally and be capable of resisting horizontal forces. Panels exceeding these size limits require intermediate structural supports so that loads can be adequately resisted.

2110.3.1 Exterior standard-unit panels. The maximum area of each individual exterior standard-unit panel shall be 144 square feet (13.4 m²) when the design wind pressure is 20 psf (958 N/m²). The maximum panel dimension between structural supports shall be 25 feet (7620 mm) in width or 20 feet (6096 mm) in height. The panel areas are permitted to be adjusted in accordance with Figure 2110.3.1 for other wind pressures.

- Single panels of glass block are limited to a maximum length of 25 feet (7620 mm) and a maximum height of 20 feet (6096 mm) between structural supports. When subjected to a wind pressure of 20 psf (958 N/m²), any single panel cannot exceed 144 square feet (13 m²) in area. This maximum panel permissible area can be adjusted, however, for other wind pressures by the use of Code Figure 2110.3.1.

FIGURE 2110.3.1. See below.

- The wind load resistance curve represents capacities for a variety of panel conditions. The 144-square-feet (13 m²) area limit is based on a safety factor of 2.7 when the design wind pressure is 20 psf (958 N/m²).

2110.3.2 Exterior thin-unit panels. The maximum area of each individual exterior thin-unit panel shall be 85 square feet (7.9 m²).

- The maximum dimension between structural supports shall be 15 feet (4572 mm) in width or 10 feet (3048 mm) in height. Thin units shall not be used in applications where the design wind pressure exceeds 20 psf (958 N/m²).

![Design Wind Load Resistance](image-url)

For SI: 1 square foot = 0.0929 m², 1 pound per square foot = 47.9 N/m².

FIGURE 2110.3.1
GLASS MASONRY DESIGN WIND LOAD RESISTANCE
The limitations on the use of exterior panels with thin-unit glass block are more restrictive than those in Section 2110.3.1 for exterior panels with standard units, since thin units are not as strong as standard ones.

2110.3.3 Interior panels. The maximum area of each individual standard-unit panel shall be 250 square feet (23.2 m²). The maximum area of each thin-unit panel shall be 150 square feet (13.9 m²). The maximum dimension between structural supports shall be 25 feet (7620 mm) in width or 20 feet (6096 mm) in height.

Interior panels can be larger than exterior ones since wind pressures are expected to be lower.

2110.3.4 Solid units. The maximum area of solid glass-block wall panels in both exterior and interior walls shall not be more than 100 square feet (9.3 m²).

Panels constructed of solid glass block must also meet the requirements of this section.

2110.3.5 Curved panels. The width of curved panels shall conform to the requirements of Sections 2110.3.1, 2110.3.2 and 2110.3.3, except additional structural supports shall be provided at locations where a curved section joins a straight section, and at inflection points in multicroved walls.

Curved panels of glass block must meet the appropriate requirements of Sections 2110.3.1 through 2110.3.3, plus the requirements for additional supports at critical locations as defined in this section.

2110.4 Support.

This section requires that glass-unit masonry panels be laterally supported by panel anchors, channel-type restraints or a combination of both. Channel-type restraints can be made of concrete, masonry, metal, wood or other materials, provided that adequate lateral support is achieved.

2110.4.1 Isolation. Glass unit masonry panels shall be isolated so that in-plane loads are not imparted to the panel.

Isolation joints are needed at the top and sides of glass-unit masonry panels so that in-plane forces are not transferred to the panels.

2110.4.2 Vertical. Maximum total deflection of structural members supporting glass unit masonry shall not exceed 1/400.

The sizes of structural members supporting glass-block panels must be determined by structural analysis in order to avoid excessive deflections that could damage the glass-block construction. Deflections of supporting members are limited to a maximum of 1/600, where 1 is the span of the supporting member.

2110.4.3 Lateral. Glass unit masonry panels more than one unit wide or one unit high shall be laterally supported along their tops and sides. Lateral support shall be provided by panel anchors along the top and sides spaced not more than 16 inches (406 mm) o.c. or by channel-type restraints. Glass unit masonry panels shall be recessed at least 1 inch (25 mm) within channels and chases. Channel-type restraints shall be oversized to accommodate expansion material in the opening and packing and sealant between the framing restraints and the glass unit masonry perimeter units. Lateral supports for glass unit masonry panels shall be designed to resist applied loads, or a minimum of 200 pounds per lineal feet (plf) (2919 N/m) of panel, whichever is greater.

Exceptions:

1. Lateral support at the top of glass unit masonry panels that are no more than one unit wide shall not be required.

2. Lateral support at the sides of glass unit masonry panels that are no more than one unit high shall not be required.

Glass-block panels in exterior masonry walls or in openings of structural framing systems (curtain walls) are required to be restrained laterally to resist both external and internal pressures caused by wind and horizontal forces from earthquakes. Lateral support can be provided by channel-type or panel anchors.

Adhering to the dimensional limitations imposed on glass-block panels and complying with the requirements for construction will generally produce glass-block elements that adequately resist normal wind conditions. In regions with very high winds or high seismic risk, however, glass-block panels and their anchorage to supporting structural elements should be checked for adequacy.

The exceptions in this section recognize that loads and expected movement of small glass-unit panels are small enough to permit installation without isolation joints.

2110.4.3.1 Single unit panels. Single unit glass unit masonry panels shall conform to the requirements of Section 2110.4.3, except lateral support shall not be provided by panel anchors.

Single-unit panels generally have the same requirements as multiple-unit panels described in Section 2110.4.3.

2110.5 Expansion joints. Glass unit masonry panels shall be provided with expansion joints along the top and sides at all structural supports. Expansion joints shall have sufficient thickness to accommodate displacements of the supporting structure, but shall not be less than 1/4 inch (9.5 mm) in thickness. Expansion joints shall be entirely free of mortar or other debris and shall be filled with resilient material. The sills of glass-block panels shall be coated with approved water-based asphaltic emulsion, or other elastic waterproofing material, prior to laying the first mortar course.

Sills supporting glass-block panel on a mortar bed are required to be first made water resistant with a heavy coat of asphalt emulsion or other approved water-resistant material. When the emulsion on the sill has dried, the full mortar bed can be placed, followed by the lowest course of glass block.

Before any glass-block units are placed, however, the head and jamb areas over the full height and width of
the glass-block panel should be provided with expansion strips [\(1/4\) inches (9.5 mm) thick] made for this purpose.

Glass-block units should be placed in successive courses on mortar beds containing panel reinforcement as required by the project documents, either directly or through reference to the manufacturer’s instructions. Panel reinforcement should not be placed across expansion joints. Joints should be tooled smooth and concave before the mortar sets and joints around the perimeter of the panel should be raked out sufficiently to receive filler and caulking materials.

After the mortar sets, expansion joints are typically closed with a sealant.

2110.6 Mortar. Mortar for glass unit masonry shall comply with Section 2103.7.

- See the commentary to Section 2103.7. Glass-unit masonry panels are to be laid in Type N or S mortar.

2110.7 Reinforcement. Glass unit masonry panels shall have horizontal joint reinforcement spaced not more than 16 inches (406 mm) on center, located in the mortar bed joint, and extending the entire length of the panel but not across expansion joints. Longitudinal wires shall be lapped a minimum of 6 inches (152 mm) at splices. Joint reinforcement shall be placed in the bed joint immediately below and above openings in the panel. The reinforcement shall have not less than two parallel longitudinal wires spaced 2 inches (51 mm) apart with W1.7 (MW11), and have welded cross wires of size W1.7 (MW11).

- Panel reinforcement made especially for glass block is typically of the ladder type, formed of two W1.7 galvanized wires spaced 2 inches (51 mm) apart with W1.7 galvanized cross wires welded at 16-inch (406 mm) intervals. Where placed continuously, the sections are required to lap at least 6 inches (152 mm). Such reinforcement must not extend across expansion joints because it would compromise their effectiveness.

SECTION 2111
MASONRY FIREPLACES

2111.1 Definition. A masonry fireplace is a fireplace constructed of concrete or masonry. Masonry fireplaces shall be constructed in accordance with this section, Table 2111.1 and Figure 2111.1.

- The provisions of this section apply to the design and installation of concrete and masonry fireplaces, which for simplicity are referred to as “masonry fireplaces.”

TABLE 2111.1. See page 21-62.

- This table summarizes many of the requirements for fireplaces contained in Section 2111. Commentary to the listed section references should be reviewed for information on each item in the table.

This table does not address all the requirements of Section 2111. Each code section must be checked to see that a fireplace is in compliance.

FIGURE 2111.1. See page 21-63.

- This figure graphically shows many of the requirements for fireplaces contained in Section 2111. This figure does not address all the requirements of Section 2111.

2111.2 Footings and foundations. Footings for masonry fireplaces and their chimneys shall be constructed of concrete or solid masonry at least 12 inches (305 mm) thick and shall extend at least 6 inches (153 mm) beyond the face of the fireplace or foundation wall on all sides. Footings shall be founded on natural undisturbed earth or engineered fill below frost depth. In areas not subjected to freezing, footings shall be at least 12 inches (305 mm) below finished grade.

- Masonry fireplaces and chimneys must be supported on adequate footings due to their weight and the forces imposed on them by wind, earthquakes and other effects. This section prescribes minimum footing requirements that are typically adequate for standard fireplaces and chimneys. Extremely large, tall or heavy fireplaces and chimneys, however, may need more substantial foundations (see Item T in Figure 2111.1).

2111.2.1 Ash dump cleanout. Cleanout openings, located within foundation walls below fireboxes, when provided, shall be equipped with ferrous metal or masonry doors and frames constructed to remain tightly closed, except when in use. Cleanouts shall be accessible and located so that ash removal will not create a hazard to combustible materials.

- Noncombustible, tightly sealed cleanout doors are required to reduce the danger of fire spread through the cleanout openings. Cleanout openings are required to be easily accessible to allow ash to be readily removed.

2111.3 Seismic reinforcing. Masonry or concrete fireplaces shall be constructed, anchored, supported and reinforced as required in this chapter. In Seismic Design Category D, masonry and concrete fireplaces shall be reinforced and anchored as detailed in Sections 2111.3.1, 2111.3.2, 2111.4 and 2111.4.1 for chimneys serving fireplaces. In Seismic Design Category A, B or C, reinforcement and seismic anchorage is not required. In Seismic Design Category E or F, masonry and concrete chimneys shall be reinforced in accordance with the requirements of Sections 2101 through 2109.

- Unreinforced fireplaces and chimneys subjected to strong ground motion have sustained damage in past earthquakes. The requirements in this section provide minimum reinforcement in an effort to increase structural integrity during such events. More substantial reinforcement may, however, be required in areas of high seismicity or for atypical fireplaces and chimneys.

2111.3.1 Vertical reinforcing. For fireplaces with chimneys up to 40 inches (1016 mm) wide, four No. 4 continuous vertical bars, anchored in the foundation, shall be placed in the concrete, between wythes of solid masonry or within the cells of hollow unit masonry and grouted in accordance with Section 2103.10. For fireplaces with chimneys greater than 40 inches (1016 mm) wide, two additional No. 4 vertical bars shall be provided for
<table>
<thead>
<tr>
<th>ITEM</th>
<th>LETTER</th>
<th>REQUIREMENTS</th>
<th>SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearth and hearth extension thickness</td>
<td>A</td>
<td>4-inch minimum thickness for hearth, 2-inch minimum thickness for hearth extension.</td>
<td>2111.9</td>
</tr>
<tr>
<td>Hearth extension (each side of opening)</td>
<td>B</td>
<td>8 inches for fireplace opening less than 6 square feet. 12 inches for fireplace opening greater than or equal to 6 square feet.</td>
<td>2111.10</td>
</tr>
<tr>
<td>Hearth extension (front of opening)</td>
<td>C</td>
<td>16 inches for fireplace opening less than 6 square feet. 20 inches for fireplace opening greater than or equal to 6 square feet.</td>
<td>2111.10</td>
</tr>
<tr>
<td>Firebox dimensions</td>
<td>—</td>
<td>20-inch minimum firebox depth. 12-inch minimum firebox depth for Rumford fireplaces.</td>
<td>2111.6</td>
</tr>
<tr>
<td>Hearth and hearth extension reinforcing</td>
<td>D</td>
<td>Reinforced to carry its own weight and all imposed loads.</td>
<td>2111.9</td>
</tr>
<tr>
<td>Thickness of wall of firebox</td>
<td>E</td>
<td>10 inches solid masonry or 8 inches where firebrick lining is used.</td>
<td>2111.5</td>
</tr>
<tr>
<td>Distance from top of opening to throat</td>
<td>F</td>
<td>8 inches minimum.</td>
<td>2111.7</td>
</tr>
<tr>
<td>Smoke chamber wall thickness dimensions</td>
<td>G</td>
<td>6 inches lined; 8 inches unlined. Not taller than opening width; walls not inclined more than 45 degrees from vertical for prefabricated smoke chamber linings or 30 degrees from vertical for corbeled masonry.</td>
<td>2111.8</td>
</tr>
<tr>
<td>Chimney vertical reinforcing</td>
<td>H</td>
<td>Four No. 4 full-length bars for chimney up to 40 inches wide. Add two No. 4 bars for each additional 40 inches or fraction of width, or for each additional flue.</td>
<td>2111.3.1, 2113.3.1</td>
</tr>
<tr>
<td>Chimney horizontal reinforcing</td>
<td>J</td>
<td>1/4-inch ties at each 18 inches, and two ties at each bend in vertical steel.</td>
<td>2111.3.2, 2113.3.2</td>
</tr>
<tr>
<td>Fireplace lintel</td>
<td>L</td>
<td>Noncombustible material with 4-inch bearing length of each side of opening.</td>
<td>2111.7</td>
</tr>
<tr>
<td>Chimney walls with flue lining</td>
<td>M</td>
<td>4-inch-thick solid masonry with 5/8-inch fireclay liner or equivalent. 1/2-inch grout or airspace between fireclay liner and wall.</td>
<td>2113.11.1</td>
</tr>
<tr>
<td>Effective flue area (based on area of fireplace opening and chimney)</td>
<td>P</td>
<td>See Section 2113.16.</td>
<td>2113.16</td>
</tr>
<tr>
<td>Clearances</td>
<td>R</td>
<td>2 inches interior, 1 inch exterior or 12 inches from lining. 2 inches back or sides or 12 inches from lining. 6 inches from opening. 3 feet above roof penetration, 2 feet above part of structure within 10 feet.</td>
<td>2113.19, 2111.11, 2111.12, 2113.9</td>
</tr>
<tr>
<td>Anchorage strap</td>
<td>S</td>
<td>3/16 inch by 1 inch Two 12 inches hooked around outer bar with 6-inch extension. 4 joists Two 1/2-inch diameter.</td>
<td>2111.4, 2113.4.1</td>
</tr>
<tr>
<td>Footing</td>
<td>T</td>
<td>12-inch minimum. 6 inches each side of fireplace wall.</td>
<td>2111.2</td>
</tr>
</tbody>
</table>

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 degree = 0.017 rad.

(1) This table provides a summary of major requirements for the construction of masonry chimneys and fireplaces. Letter references are to Figure 2111.1, which shows examples of typical construction. This table does not cover all requirements, nor does it cover all aspects of the indicated requirements. For the actual mandatory requirements of the code, see the indicated section of text.
For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.
each additional 40 inches (1016 mm) in width or fraction thereof.

- These requirements are traditional minimum prescriptive provisions to help maintain the integrity of fireplaces and chimneys during earthquakes. To resist strong earthquakes, however, more substantial reinforcement may be required (see Item H in Figure 2111.1).

2111.3.2 Horizontal reinforcing. Vertical reinforcement shall be placed enclosed within \( \frac{1}{16} \)-inch (6.4 mm) ties or other reinforcing of equivalent net cross-sectional area, spaced not to exceed 18 inches (457 mm) on center in concrete; or placed in the bed joints of unit masonry at a minimum of every 18 inches (457 mm) of vertical height. Two such ties shall be provided at each bend in the vertical bars.

- These requirements are traditional minimum prescriptive provisions to help maintain the integrity of fireplaces and chimneys during earthquakes. The vertical reinforcement required by Section 2111.3.1 must be enclosed within the horizontal reinforcement required by this section. To resist strong earthquakes, however, more substantial reinforcement may be required (see Item J in Figure 2111.1).

2111.4 Seismic anchorage. Masonry and concrete chimneys in Seismic Design Category D shall be anchored at each floor, ceiling or roof line more than 6 feet (1829 mm) above grade, except where constructed completely within the exterior walls. Anchorage shall conform to the following requirements.

- Fireplaces and chimneys can fail by overturning during earthquakes. Seismic anchorage to floors and roof diaphragms is required to reduce the cantilevered height of the chimney and thereby help prevent overturning (see Item S in Figure 2111.1).

2111.4.1 Anchorage. Two \( \frac{1}{16} \)-inch by 1-inch (4.8 mm by 25.4 mm) straps shall be embedded a minimum of 12 inches (305 mm) into the chimney. Straps shall be hooked around the outer bars and extend 6 inches (152 mm) beyond the bend. Each strap shall be fastened to a minimum of four floor joists with two \( \frac{1}{2} \)-inch (12.7 mm) bolts.

- The prescriptive requirements in this section are traditional for typical fireplaces and chimneys. More substantial anchorage may be required in areas of high seismicity, for large fireplaces or where the distance between floor and roof diaphragms is large.

2111.5 Firebox walls. Masonry fireboxes shall be constructed of solid masonry units, hollow masonry units grouted solid, stone or concrete. When a lining of firebrick at least 2 inches (51 mm) in thickness or other approved lining is provided, the minimum thickness of back and sidewalls shall each be 8 inches (203 mm) of solid masonry, including the lining. The width of joints between firebricks shall not be greater than \( \frac{1}{16} \) inch (6.4 mm). When no lining is provided, the total minimum thickness of back and sidewalls shall be 10 inches (254 mm) of solid masonry. Firebrick shall conform to ASTM C 27 or ASTM C 1261 and shall be laid with medium-duty refractory mortar conforming to ASTM C 199.

- This section specifies the minimum thicknesses of refractory brick or solid masonry necessary to contain the generated heat.

Solid masonry walls forming the firebox are required to have a minimum total thickness of 8 inches (204 mm), including the refractory lining.

The refractory lining is to consist of a low-duty, fire-clay refractory brick with a minimum thickness of 2 inches (52 mm), laid with medium-duty refractory mortar. Mortar joints are generally \( \frac{1}{16} \) to \( \frac{3}{16} \) inch (1.6 to 4.8 mm) thick, but not thicker than \( \frac{1}{4} \) inch (6.4 mm), to reduce thermal movements and prevent joint deterioration.

Where a firebrick lining is not used in firebox construction, the wall thickness is not to be less than 10 inches (254 mm) of solid masonry. Firebrick is required to conform to ASTM C 27 or ASTM C 1261. Firebrick must be laid with medium-duty refractory mortar conforming to ASTM C 199 (see Item E in Figure 2111.1).

2111.5.1 Steel fireplace units. Steel fireplace units are permitted to be installed with solid masonry to form a masonry fireplace provided they are installed according to either the requirements of their listing or the requirements of this section. Steel fireplace units incorporating a steel firebox lining shall be constructed with steel not less than \( \frac{1}{16} \) inch (6.4 mm) in thickness, and an air-circulating chamber which is ducted to the interior of the building. The firebox lining shall be encased with solid masonry to provide a total thickness at the back and sides of not less than 8 inches (203 mm), of which not less than 4 inches (102 mm) shall be of solid masonry or concrete. Circulating air ducts employed with steel fireplace units shall be constructed of metal or masonry.

- This section provides minimum requirements for steel linings used in masonry fireplaces to improve heat flow.

2111.6 Firebox dimensions. The firebox of a concrete or masonry fireplace shall have a minimum depth of 20 inches (508 mm). The throat shall not be less than 8 inches (203 mm) above the fireplace opening. The throat opening shall not be less than 4 inches (102 mm) in depth. The cross-sectional area of the passageway above the firebox, including the throat, damper and smoke chamber, shall not be less than the cross-sectional area of the flue.

- Exception: Rumford fireplaces shall be permitted provided that the depth of the fireplace is at least 12 inches (305 mm) and at least one-third of the width of the fireplace opening, and the throat is at least 12 inches (305 mm) above the lintel, and at least \( \frac{1}{16} \) the cross-sectional area of the fireplace opening.

- The proper functioning of the fireplace depends on the size of the face opening and the chimney dimensions, which in turn are related to the room size [see Figure 2111.6(1)]. This section specifies a minimum depth of 20 inches (508 mm) for the combustion chamber because that depth influences the draft requirement. The dimensions of the firebox (depth, opening size and
shape) are usually based on two considerations: aesthetics and the need to prevent the room from overheating. Suggested dimensions for single-opening fireboxes are given in technical publications of the Brick Institute of America (BIA) and the National Concrete Masonry Association (NCMA).

This section also provides additional criteria for the throat's location and minimum cross-sectional area. Those criteria are based on many years of construction of successfully functioning fireplaces.

The exception permits the use of Rumford fireplaces and the dimensions associated with this design style. Rumford fireplaces are tall, shallow fireplaces that can radiate a large amount of heat into a room.

The code reference to the depth of the fireplace is interpreted as the depth of the firebox [see Figure 2111.6(2)]. The throat is required to be made at least 12 inches (305 mm) above the lintel and at least one-twentieth of the cross-sectional area of the fireplace opening. Smoke chambers and flues for Rumford fireplaces should be sized and built like other masonry fireplaces. While those who build Rumford fireplaces do not totally agree about how they work, many books and guides address their construction.

**2111.7 Lintel and throat.** Masonry over a fireplace opening shall be supported by a lintel of noncombustible material. The minimum required bearing length on each end of the fireplace opening shall be 4 inches (102 mm). The fireplace throat or damper shall be located a minimum of 8 inches (203 mm) above the top of the fireplace opening.

- Permanent support for the masonry above the fireplace opening is provided by noncombustible lintels of steel, masonry or concrete (see Item L of Figure 2111.1). Combustible lintels (for example, those made from wood) are not appropriate due to the risk of fire damage and the probable collapse of the masonry above the opening.

The minimum bearing requirement of 4 inches (102 mm) is empirical, based on typical masonry fireplace openings. Lintels that support more than the typical weight of masonry above the fireplace opening may require a larger bearing area.

The throat of a fireplace is the slot-like opening above the firebox, through which flames, smoke and hot combustion gases pass into the smoke chamber. The throat is as wide as the combustion chamber and is required to be located at least 8 inches (204 mm) above the lintel for conventional fireplaces. The back wall of the combustion chamber extends up to the throat, which is provided with a metal damper.

**2111.7.1 Damper.** Masonry fireplaces shall be equipped with a ferrous metal damper located at least 8 inches (203 mm) above
the top of the fireplace opening. Dampers shall be installed in the fireplace or at the top of the flue venting the fireplace, and shall be operable from the room containing the fireplace. Damper controls shall be permitted to be located in the fireplace.

- A damper is used to close the chimney flue when the fireplace is not in use. This section provides guidance on its location and construction.

2111.8 Smoke chamber walls. Smoke chamber walls shall be constructed of solid masonry units, hollow masonry units grouted solid, stone or concrete. Corbeling of masonry units shall not leave unit cores exposed to the inside of the smoke chamber. The inside surface of corbeled masonry shall be parged smooth. Where no lining is provided, the total minimum thickness of front, back and sidewalls shall be 8 inches (203 mm) of solid masonry. When a lining of firebrick at least 2 inches (51 mm) thick, or a lining of vitrified clay at least \( \frac{3}{4} \) inch (15.9 mm) thick, is provided, the total minimum thickness of front, back and sidewalls shall be 6 inches (152 mm) of solid masonry, including the lining. Firebrick shall conform to ASTM C 27 or ASTM C 1261 and shall be laid with refractory mortar conforming to ASTM C 199.

- The minimum wall thickness specified for the throat and smoke chamber is required to provide support for the flue construction, as well as adequate thermal insulation for the adjacent combustible construction.

In conventional fireplace construction, the smoke chamber is a tapering section whose vertical dimension is measured from the damper or throat to the bottom of the chimney flue. The actual height is a function of the fireplace opening.

2111.8.1 Smoke chamber dimensions. The inside height of the smoke chamber from the fireplace throat to the beginning of the flue shall not be greater than the inside width of the fireplace opening. The inside surface of the smoke chamber shall not be inclined more than 45 degrees (0.76 rad) from vertical when prefabricated smoke chamber linings are used or when the smoke chamber walls are rolled or sloped rather than corbeled. When the inside surface of the smoke chamber is formed by corbeled masonry, the walls shall not be corbeled more than 30 degrees (0.52 rad) from vertical.

- This section specifies the smoke chamber configuration that is needed for the proper function of the masonry chimney. Also see Table 2111.1, Item G, for smoke chamber requirements.

2111.9 Hearth and hearth extension. Masonry fireplace hearths and hearth extensions shall be constructed of concrete or masonry, supported by noncombustible materials, and reinforced to carry their own weight and all imposed loads. No combustible material shall remain against the underside of hearths or hearth extensions after construction.

- The fireplace hearth consists of two parts. The hearth, commonly called the “inner hearth,” is the floor of the combustion chamber and is obviously constructed of noncombustible material. The outer hearth, commonly known as the “hearth extension,” projects beyond the face of the fireplace into the room and also consists of noncombustible materials, such as brick or concrete masonry, concrete, floor tile or stone (see Figure 2111.1, Items A and D). The hearth extension may continue out from the inner hearth at the same level or be stepped down to a lower level. Minimum dimensions for the hearth extension are prescribed in Section 2111.10 and are discussed in the commentary to that section.

Combustible forms and centers could ignite from exposure to heat from the adjacent fireplace and from burning embers that escape the firebox; these and other similar concealed, combustible components must be removed.

2111.9.1 Hearth thickness. The minimum thickness of fireplace hearths shall be 4 inches (102 mm).

- The required minimum thickness of 4 inches (102 mm) is an empirical requirement that has historically been successful.

2111.9.2 Hearth extension thickness. The minimum thickness of hearth extensions shall be 2 inches (51 mm).

Exception: When the bottom of the firebox opening is raised at least 8 inches (203 mm) above the top of the hearth extension, a hearth extension of not less than \( \frac{1}{2} \)-inch-thick (9.5 mm) brick, concrete, stone, tile or other approved noncombustible material is permitted.

- These requirements are empirical and have historically been successful.

2111.10 Hearth extension dimensions. Hearth extensions shall extend at least 16 inches (406 mm) in front of, and at least 8 inches (203 mm) beyond, each side of the fireplace opening. Where the fireplace opening is 6 square feet (0.557 m²) or larger, the hearth extension shall extend at least 20 inches (508 mm) in front of, and at least 12 inches (305 mm) beyond, each side of the fireplace opening.

- The hearth extension is required to extend the full width of the fireplace opening and at least 8 inches (203 mm) beyond each side of the opening. It is also required to extend at least 16 inches (406 mm) out from the face of the fireplace. For fireplace openings larger than 6 square feet (0.557 m²) in area, the hearth extension is required to extend at least 20 inches (508 mm) beyond the face of the fireplace opening, and at least 12 inches (305 mm) beyond each side of the fireplace opening (see Figure 2111.10).

The hearth extension is intended to serve as a fire-protective separation between the firebox and adjacent combustible flooring or furnishings and to prevent accidental spills of hot embers or logs from the fire.

2111.11 Fireplace clearance. Any portion of a masonry fireplace located in the interior of a building or within the exterior wall of a building shall have a clearance to combustibles of not less than 2 inches (51 mm) from the front faces and sides of masonry fireplaces and not less than 4 inches (102 mm) from the back faces of masonry fireplaces. The airspace shall not be filled, except to provide fireblocking in accordance with Section 2111.13.
Exceptions:

1. Masonry fireplaces listed and labeled for use in contact with combustibles in accordance with UL 127, and installed in accordance with the manufacturer’s installation instructions, are permitted to have combustible material in contact with their exterior surfaces.

2. When masonry fireplaces are constructed as part of masonry or concrete walls, combustible materials shall not be in contact with the masonry or concrete walls less than 12 inches (306 mm) from the inside surface of the nearest firebox lining.

3. Exposed combustible trim and the edges of sheathing materials, such as wood siding, flooring and drywall, are permitted to abut the masonry fireplace sidewalls and hearth extension, in accordance with Figure 2111.11, provided such combustible trim or sheathing is a minimum of 12 inches (306 mm) from the inside surface of the nearest firebox lining.

4. Exposed combustible mantels or trim is permitted to be placed directly on the masonry fireplace front surrounding the fireplace opening provided such combustible materials shall not be placed within 6 inches (153 mm) of a fireplace opening. Combustible material within 12 inches (306 mm) of the fireplace opening shall not project more than \( \frac{1}{8} \) inch (3.2 mm) for each 1-inch (25 mm) distance from such opening.

- Combustible materials, such as framing studs and joists, must not be installed closer than 2 inches (51 mm) to the exterior surface of fireplace walls because of the fire hazard to materials in this location. Heat transmitted through fireplace walls can ignite combustible structural materials in contact with the walls. For this reason, a minimum required clearance has been established from the fireplace to combustibles.

- This figure clarifies Exception 3 to the clearance requirement for masonry fireplaces. The edge abutment of combustible sheathing materials where there is an adequate thickness of masonry is a long-standing practice that is considered safe, provided the minimum clearance to the firebox lining is maintained.

2111.12 Mantel and trim. Woodwork or other combustible materials shall not be placed within 6 inches (152 mm) of a fireplace opening. Combustible material within 12 inches (305 mm) of the fireplace opening shall not project more than \( \frac{1}{8} \) inch (3.2 mm) for each 1-inch (25 mm) distance from such opening.

- Combustible materials attached to the fireplace face, such as wood trim and mantels, are not permitted to be installed closer than 6 inches (152 mm) from the fireplace opening. Materials located above the opening and that project excessively create a severe fire hazard, however, and are required to have a minimum clearance of 12 inches (305 mm) from the fireplace opening.

2111.13 Fireplace fireblocking. All spaces between fireplaces and floors and ceilings through which fireplaces pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between wood joists, beams or headers shall be to a depth of 1 inch (25 mm) and shall only be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney.

- Fireblocking is required to prevent the travel of flames, smoke or hot gases to other areas of the building through gaps between the chimney and the floor or ceiling assemblies. The 1-inch (25 mm) depth requirement is intended to be both a minimum and a maximum.

2111.14 Exterior air. Factory-built or masonry fireplaces covered in this section shall be equipped with an exterior air supply to ensure proper fuel combustion unless the room is mechani-
cally ventilated and controlled so that the indoor pressure is neutral or positive.

- Adequate airflow is needed to provide exterior oxygen for the fire and to maintain draft through the chimney so that toxic combustion gases can be exhausted. Adequate airflow is especially important in modern, tightly sealed buildings.

2111.14.1 Factory-built fireplaces. Exterior combustion air ducts for factory-built fireplaces shall be listed components of the fireplace, and installed according to the fireplace manufacturer’s instructions.

- Factory-built fireplaces are required to include exterior combustion air ducts. To function properly, these units need to be installed according to the manufacturer’s recommendations.

2111.14.2 Masonry fireplaces. Listed combustion air ducts for masonry fireplaces shall be installed according to the terms of their listing and manufacturer’s instructions.

- For proper functioning and airflow, air ducts for masonry fireplaces must be installed according to the manufacturer’s recommendations (see also commentary, Section 2111.14).

2111.14.3 Exterior air intake. The exterior air intake shall be capable of providing all combustion air from the exterior of the dwelling. The exterior air intake shall not be located within the garage, attic, basement or crawl space of the dwelling nor shall the air intake be located at an elevation higher than the fireplace. The exterior air intake shall be covered with a corrosion-resistant screen of \( \frac{1}{8} \)-inch (6.4 mm) mesh.

- Air intakes are required to provide air from outside of the building. The air intakes are not permitted to be placed in garages, basements, crawl spaces or other areas where gases from the exhaust of automobiles, furnaces and other sources could be brought into the building.

Air intakes should be covered with screens to prevent pests from entering the building when the fireplace is not functioning.

2111.14.4 Clearance. Unlisted combustion air ducts shall be installed with a minimum 1-inch (25 mm) clearance to combustibles for all parts of the duct within 5 feet (1524 mm) of the duct outlet.

- The 1-inch (25 mm) clearance is required to reduce the risk of fire through the air intakes.

2111.14.5 Passageway. The combustion air passageway shall be a minimum of 6 square inches (3870 mm\(^2\)) and not more than 55 square inches (0.035 m\(^2\)), except that combustion air systems for listed fireplaces or for fireplaces tested for emissions shall be constructed according to the fireplace manufacturer’s instructions.

- These minimum requirements are intended to provide adequate airflow through the fireplace.

2111.14.6 Outlet. The exterior air outlet is permitted to be located in the back or sides of the firebox chamber or within 24 inches (610 mm) of the firebox opening on or near the floor. The outlet shall be closable and designed to prevent burning material from dropping into concealed combustible spaces.

- The requirements on the location of the outlet in the firebox chamber are needed for adequate airflow to the fire while avoiding the direct flow of air into the adjacent room. Such openings must not become clogged with ash, which would restrict airflow. Even more important, burning material must not drop into concealed combustible spaces due to the risk of fire damage to the building. Outlets must therefore be both closable and adequately designed to prevent this.

SECTION 2112

MASONRY HEATERS

2112.1 Definition. A masonry heater is a heating appliance constructed of concrete or solid masonry, hereinafter referred to as “masonry,” having a mass of at least 1,760 pounds (800 kg), excluding the chimney and foundation, which is designed to absorb and store heat from a solid fuel fire built in the firebox by routing the exhaust gases through internal heat exchange channels in which the flow path downstream of the firebox includes at least one 180-degree (3.14 rad) change in flow direction before entering the chimney, and that delivers heat by radiation from the masonry surface of the heater that shall not exceed 230°F (110°C) except within 8 inches (203 mm) surrounding the fuel loading door(s).

- Masonry heaters are appliances designed to absorb and store heat from a relatively small fire and to radiate that heat into the building interior. They are thermally more efficient than traditional fireplaces because of their design. Interior passageways through the heater allow hot exhaust gases from the fire to transfer heat into the masonry, which then radiates into the building.
2112.2 Installation. Masonry heaters shall be listed or installed in accordance with ASTM E 1602.

- ASTM E 1602 provides guidelines for installing masonry heaters.

2112.3 Seismic reinforcing. Seismic reinforcing shall not be required within the body of a masonry heater whose height is equal to or less than 2.5 times its body width and where the masonry chimney serving the heater is not supported by the body of the heater. Where the masonry chimney shares a common wall with the facing of the masonry heater, the chimney portion of the structure shall be reinforced in accordance with Sections 2113 and 2113.4.

- Because of the large bulk and squat geometry of these heaters, seismic reinforcement is not typically required. Flexural tensile stresses, which typically cause damage to unreinforced masonry, rarely occur. Where chimneys extend above these heaters, however, seismic reinforcement is required by Section 2113. See the commentary to that section for additional information on this requirement.

2112.4 Masonry heater clearance. Wood or other combustible framing shall not be placed within 4 inches (102 mm) of the outside surface of a masonry heater, provided the wall thickness of the firebox is not less than 8 inches (203 mm) and the wall thickness of the heat exchange channels is not less than 5 inches (127 mm). A clearance of at least 8 inches (203 mm) shall be provided between the gas-tight capping slab of the heater and a combustible ceiling. The required space between the heater and combustible material shall be fully vented to permit the free flow of air around all heater surfaces.

- Heat conducted through masonry heater walls can ignite combustible structural materials in contact with these walls. For this reason, a minimum required clearance to combustibles from masonry heaters has been established. Because masonry heaters typically generate more heat for a longer period of time than traditional fireplaces, greater clearances to combustible materials are needed to reduce the risk of fire.

2113 MASONRY CHIMNEYS

2113.1 General. A masonry chimney is a chimney constructed of concrete or masonry, hereinafter referred to as “masonry.” Masonry chimneys shall be constructed, anchored, supported and reinforced as required in this chapter.

- A masonry chimney is a field-constructed assembly that can consist of masonry units, grout, reinforced concrete, rubble stone, fire-clay liners and mortars. A masonry chimney is permitted to serve residential (low-heat), medium- and high-heat appliances. This section outlines the general code requirements regarding construction details for all masonry chimneys, including those serving masonry fireplaces regulated by Section 2111.

2113.2 Footings and foundations. Foundations for masonry chimneys shall be constructed of concrete or solid masonry at least 12 inches (305 mm) thick and shall extend at least 6 inches (152 mm) beyond the face of the foundation or support wall on all sides. Footings shall be founded on natural undisturbed earth or engineered fill below frost depth. In areas not subjected to freezing, footings shall be at least 12 inches (305 mm) below finished grade.

- Masonry fireplaces and chimneys must be supported on adequate foundations due to their weight and the forces imposed on them by wind, earthquakes and other effects. This section prescribes minimum foundation requirements that are typically adequate for standard chimneys.

- Extremely large, tall or heavy chimneys, however, may need more substantial foundations. Also, a chimney foundation probably will support a larger load than the adjacent building foundations. For this reason, chimney footings and foundations are often separated from the building foundation. A chimney foundation monolithic with the building foundation is permitted, provided the soil pressure and anticipated settlement are approximately uniform.

2113.3 Seismic reinforcing. Masonry or concrete chimneys shall be constructed, anchored, supported and reinforced as required in this chapter. In Seismic Design Category D, masonry and concrete chimneys shall be reinforced and anchored as detailed in Sections 2113.3.1, 2113.3.2 and 2113.4. In Seismic Design Category A, B or C, reinforcement and seismic anchorage is not required. In Seismic Design Category E or F, masonry and concrete chimneys shall be reinforced in accordance with the requirements of Sections 2101 through 2108.

- Unreinforced fireplaces and chimneys subjected to strong ground motion have been severely damaged in past earthquakes. The requirements in this section provide minimum reinforcement in an effort to keep these structures together during such events. More substantial reinforcement, however, may be required in areas of high seismicity or for atypical chimneys.

2113.3.1 Vertical reinforcing. For chimneys up to 40 inches (1016 mm) wide, four No. 4 continuous vertical bars anchored in the foundation shall be placed in the concrete, between wythes of solid masonry or within the cells of hollow unit masonry and grouted in accordance with Section 2103.10. Grout shall be prevented from bonding with the flue liner so that the flue liner is free to move with thermal expansion. For chimneys greater than 40 inches (1016 mm) wide, two additional No. 4 vertical bars shall be provided for each additional 40 inches (1016 mm) in width or fraction thereof.

- These requirements are traditional minimum prescriptive provisions to help maintain the structural integrity of fireplaces and chimneys during earthquakes. More reinforcement may be required in areas of high seismicity or for atypical chimneys.
2113.2 Horizontal reinforcing. Vertical reinforcement shall be placed enclosed within 3/16-inch (6.4 mm) ties, or other reinforcing of equivalent net cross-sectional area, spaced not to exceed 18 inches (457 mm) o.c. in concrete, or placed in the bed joints of unit masonry, at a minimum of every 18 inches (457 mm) of vertical height. Two such ties shall be provided at each bend in the vertical bars.

- These requirements are traditional minimum prescriptive provisions intended to help maintain the integrity of fireplaces and chimneys during earthquakes. The vertical reinforcement required by Section 2113.3.1 must be enclosed within the horizontal reinforcement required by this section. More reinforcement may be required in areas of high seismicity or for atypical chimneys.

2113.4 Seismic anchorage. Masonry and concrete chimneys and foundations in Seismic Design Category D shall be an -quirements.

- Anchorage shall conform to the following re-

mm) above grade, except where constructed completely within the exterior walls. Anchorage shall conform to the following re-

- Fireplaces and chimneys must be connected to floor and roof diaphragms to prevent overturning during earth-

quakes. Chimneys must be anchored at the ceiling line of roof or ceiling assemblies and at floor levels below the roof. Such anchorage is of lesser importance where the floor assembly is 6 feet (1829 mm) or less above grade.

2113.6 Changes in dimension. The chimney wall or chimney flue lining shall not change in size or shape within 6 inches (152 mm) above or below where the chimney passes through floor components, ceiling components or roof components.

- At changes in shape or direction, masonry chimneys can have thinner walls, making them susceptible to leakage of water from the outside and to hot spots and leakage of combustion gases from the inside. This is a fire hazard. The intent of this provision is to prohibit changes in shape and size near combustible construction. This section prohibits any change in dimension or direction of a masonry chimney from 6 inches (152 mm) below the combustible construction to 6 inches (152 mm) above it (see Figure 2113.6).

2113.7 Offsets. Where a masonry chimney is constructed with a fireclay flue liner surrounded by one wythe of masonry, the maximum offset shall be such that the centerline of the flue above the offset does not extend beyond the center of the chimney wall below the offset. Where the chimney offset is supported by masonry below the offset in an approved manner, the maximum offset limitations shall not apply. Each individual corbeled masonry course of the offset shall not exceed the projection limitations specified in Section 2113.5.

- An offset requires two changes in direction and causes two vertical sections of a chimney to be offset (misaligned) from each other. The intent of this section is to provide an upper portion of an offset that is structurally stable with respect to the lower portion.

- The offset limitation does not apply when the inclined portion of the chimney and the portion above the offset...
are supported in an approved manner by underlying masonry construction.

2113.8 Additional load. Chimneys shall not support loads other than their own weight unless they are designed and constructed to support the additional load. Masonry chimneys are permitted to be constructed as part of the masonry walls or concrete walls of the building.

- Because the requirements for chimneys in Section 2113 are based on past performance, chimneys should not be used to support other loads unless they are specifically designed to do so.

2113.9 Termination. Chimneys shall extend at least 2 feet (610 mm) higher than any portion of the building within 10 feet (3048 mm), but shall not be less than 3 feet (914 mm) above the highest point where the chimney passes through the roof.

- Chimneys must be terminated well above adjacent portions of the building so that flue gases are exhausted away from combustible materials and for proper airflow through the chimney (see Figure 2113.9).

2113.9.1 Spark arrestors. Where a spark arrester is installed on a masonry chimney, the spark arrester shall meet all of the following requirements:

1. The net free area of the arrester shall not be less than four times the net free area of the outlet of the chimney flue it serves.

2. The arrester screen shall have heat and corrosion resistance equivalent to 19-gage galvanized steel or 24-gage stainless steel.

3. Openings shall not permit the passage of spheres having a diameter greater than \( \frac{1}{2} \) inch (13 mm) nor block the pas-
sage of spheres having a diameter less than \( \frac{3}{8} \) inch (11 mm).

4. The spark arrestor shall be accessible for cleaning and the screen or chimney cap shall be removable to allow for cleaning of the chimney flue.

- This section provides specifications for spark arrestors, if they are provided. Their use is not mandated by the code, but owners or builders often install them.

**2113.10 Wall thickness.** Masonry chimney walls shall be constructed of concrete, solid masonry units or hollow masonry units grouted solid with not less than 4 inches (102 mm) nominal thickness.

- The minimum chimney wall thickness is necessary to achieve a thermal mass that will predictably control heat transmission through the walls of the chimney.

**2113.11 Flue lining (material).** Masonry chimneys shall be lined. The lining material shall be appropriate for the type of appliance connected, according to the terms of the appliance listing and the manufacturer’s instructions.

- The liner forms the flue passageway and is the actual conduit for all products of combustion. The flue lining is required to withstand exposure to high temperatures and corrosive chemicals. It protects the masonry construction of the chimney walls and allows the chimney to be gas tight.

**2113.11.1 Residential-type appliances (general).** Flue lining systems shall comply with one of the following:

1. Clay flue lining complying with the requirements of ASTM C 315, or equivalent.
2. Listed chimney lining systems complying with UL 1777.
3. Factory-built chimneys or chimney units listed for installation within masonry chimneys.
4. Other approved materials that will resist corrosion, erosion, softening or cracking from flue gases and condensate at temperatures up to 1,800\(^\circ\)F (982\(^\circ\)C).

- This section requires that the lining for residential-type appliances comply with ASTM C 315 or other approved equivalent and be capable of resisting degradation from flue gas. Chimney liner systems that are tested and labeled by an approved agency in accordance with UL 1777 are also permitted.

**2113.11.1.1 Flue linings for specific appliances.** Flue linings other than those covered in Section 2113.11.1 intended for use with specific appliances shall comply with Sections 2113.11.1.2 through 2113.11.4 and Sections 2113.11.2 and 2113.11.3.

- This section identifies flue lining materials to be used for specific appliances.

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For SI: 1 foot = 304.8 mm.

**Figure 2113.9**
MINIMUM TERMINATION OF CHIMNEYS
2113.11.1.2 Gas appliances. Flue lining systems for gas appli-
cances shall be in accordance with the International Fuel Gas
Code.

- The International Fuel Gas Code® (IFGC®) must be
  used to determine appropriate flue-lining systems for
gas appliances.

2113.11.1.3 Pellet fuel-burning appliances. Flue lining and
vent systems for use in masonry chimneys with pellet fuel-burn-
ing appliances shall be limited to flue lining systems complying
with Section 2113.11.1 and pellet vents listed for installation
within masonry chimneys (see Section 2113.11.1.5 for mark-
ing).

- Flue-lining and vent systems in masonry chimneys of
  pellet fuel-burning appliances can either conform to
  Section 2113.11.1 or be an approved listed system.

2113.11.1.4 Oil-fired appliances approved for use with
L-vent. Flue lining and vent systems for use in masonry chim-
neys with oil-fired appliances approved for use with Type L vent
shall be limited to flue lining systems complying with Section
2113.11.1 and listed chimney liners complying with UL 641
(see Section 2113.11.1.5 for marking).

- Flue lining and vent systems in masonry chimneys of
  oil-fired appliances with Type L vents can either con-
  form to Section 2113.11.1 or be an approved listed sys-
  tem (UL 641).

2113.11.1.5 Notice of usage. When a flue is relined with a ma-
terial not complying with Section 2113.11.1, the chimney shall be
 plainly and permanently identified by a label attached to a wall,
 ceiling or other conspicuous location adjacent to where the con-
 nector enters the chimney. The label shall include the following
 message or equivalent language: “This chimney is for use only
 with (type or category of appliance) that burns (type of fuel). Do
 not connect other types of appliances.”

- Clearly displayed information on the appropriate use
  and fuel for appliances is required to protect against the
  use of improper types of fuel that could cause fire.

2113.11.2 Concrete and masonry chimneys for medium-heat
appliances.

- This section establishes requirements for masonry chimneys
  serving medium-heat appliances, including
  the chimney materials, lining, termination height and
  proper clearances to combustibles.

2113.11.2.1 General. Concrete and masonry chimneys for me-
dium-heat appliances shall comply with Sections 2113.1
through 2113.5.

- Chimneys serving a medium-heat appliance must com-
  ply with the general chimney requirements in Sections
  2113.1 through 2113.5. These include minimum re-
  quirements for footings and foundations; seismic
  reinforcement; anchorage and corbeling.

2113.11.2.2 Construction. Chimneys for medium-heat appli-
cances shall be constructed of solid masonry units or of concrete
with walls a minimum of 8 inches (203 mm) thick, or with stone
masonry a minimum of 12 inches (305 mm) thick.

- Masonry chimneys for medium-heat appliances must
  be constructed of concrete in accordance with Chapter
  19, or of solid masonry units in accordance with this
  chapter. Chimneys constructed of solid masonry units
  or reinforced concrete are required to have a minimum
  wall thickness of 8 inches (203 mm). The minimum
  thickness requirement is necessary to achieve a ther-
  mal mass that will predictably control heat transmission
  through the walls of the chimney. Chimneys constructed
  of rubble stone masonry (irregular or roughly shaped
  stones) are required to have a wall thickness of no less
  than 12 inches (305 mm). The rate of heat transmission
  through stone walls is not predictable because of the
  varying thickness of the individual stones and the non-
  uniform mortar joints between the stones. For these
  reasons, stone wall chimneys are required to be thicker
  to provide a reasonable margin of safety.

2113.11.2.3 Lining. Concrete and masonry chimneys shall be
lined with an approved medium-duty refractory brick a mini-
mum of 4 1/2 inches (114 mm) thick laid on the 4 1/2-inch bed (114
mm) in an approved medium-duty refractory mortar. The lining
shall start 2 feet (610 mm) or more below the lowest chimney
connector entrance. Chimneys terminating 25 feet (7620 mm) or
less above a chimney connector entrance shall be lined to the

- A medium-heat appliance produces flue gas tempera-
tures up to 2,000°F (1093°C). The chimney lining re-
duces heat transmission to the walls of the chimney and
contains flue gases within a continuous duct until they are
away from the building. This section requires at least a medium-duty refractory brick. A 4 1/2-inch (114
mm) medium-duty refractory brick lining tested and
classified in accordance with ASTM C 27 meets this cri-
terion. Each course of the refractory brick liner is re-
quired to be installed on a full bed of refractory mortar to
form a structurally stable, continuous, gas-tight liner.

- Figure 2113.11.2.3 depicts a masonry chimney serv-
ing a medium-heat appliance. The liner extends from 2
feet (610 mm) below the lowest inlet to the top of the
chimney, which is located less than 25 feet (7620 mm)
above the highest inlet.

- A chimney liner is required in all portions of the chim-
ney that are exposed to flue gases. The liner is required
to extend below the lowest inlet to provide protection to
the masonry from flue gases, which can deteriorate the
masonry and the mortar joints.

2113.11.2.4 Multiple passageway. Concrete and masonry
chimneys containing more than one passageway shall have the
liners separated by a minimum 4-inch-thick (102 mm) concrete
or solid masonry wall.

- When a chimney requires multiple passageways, a
4-inch (102 mm) partition of solid masonry is required.
between them to act as a barrier between passageways and to enhance structural integrity.

2113.11.2.5 Termination height. Concrete and masonry chimneys for medium-heat appliances shall extend a minimum of 10 feet (3048 mm) higher than any portion of any building within 25 feet (7620 mm).

- Chimneys for medium-heat appliances are required to extend at least 10 feet (3048 mm) above the highest portion of the building within 25 feet (7620 mm) horizontally. This is intended to provide an acceptable height to carry away the flue gases safely and to provide adequate clearance to the roof and surrounding structures to allow any burning embers to extinguish before landing.

2113.11.2.6 Clearance. A minimum clearance of 4 inches (102 mm) shall be provided between the exterior surfaces of a concrete or masonry chimney for medium-heat appliances and combustible material.

- A 4-inch (102 mm) minimum airspace clearance to combustibles is required for a medium-heat masonry chimney. This large clearance is needed because of the higher temperatures produced by medium-heat appliances.

2113.11.3 Concrete and masonry chimneys for high-heat appliances.

- This section establishes the requirements for concrete and masonry chimneys serving high-heat appliances, including chimney materials, lining, termination height and proper clearances to combustibles.

2113.11.3.1 General. Concrete and masonry chimneys for high-heat appliances shall comply with Sections 2113.1 through 2113.5.

- Chimneys serving high-heat appliances are required to comply with the general chimney requirements in Sections 2113.1 through 2113.5, including minimum provisions for footings and foundations; seismic reinforcement; anchorage and corbeling.

2113.11.3.2 Construction. Chimneys for high-heat appliances shall be constructed with double walls of solid masonry units or of concrete, each wall to be a minimum of 8 inches (203 mm) thick with a minimum airspace of 2 inches (51 mm) between the walls.

- The flue gases produced by a high-heat appliance can have temperatures above 2,000°F (1,093°C). To prevent fire, such chimneys must be enclosed by two wythes of masonry with an airspace between them.

For SI: 1 foot = 304.8 mm.

Figure 2113.11.2.3
MASONRY CHIMNEY FOR MEDIUM-HEAT APPLIANCE
Thus, the chimney liner is required to be protected by two solid masonry unit walls or reinforced concrete walls, each a minimum of 8 inches (204 mm) thick with an airspace between them of at least 2 inches (51 mm). The airspace is intended to provide thermal insulation and to allow for thermal expansion of the chimney components.

2113.11.3.3 Lining. The inside of the interior wall shall be lined with an approved high-duty refractory brick, a minimum of 4 1/2 inches (114 mm) thick laid on the 4 1/2-inch bed (114 mm) in an approved high-duty refractory mortar. The lining shall start at the base of the chimney and extend continuously to the top.

- High-heat appliances can produce flue gases with temperatures exceeding 2,000°F (1,093°C). The chimney lining reduces heat transmission to the walls of the chimney and contains flue gases within a continuous passageway until they are outside the building. This section permits only a high-duty refractory brick having a minimum thickness of 4 1/2 inches (114 mm) to be used in a masonry chimney serving a high-heat appliance. An approved high-duty refractory lining usually consists of brick tested and classified in accordance with ASTM C 27. To provide a structurally stable and continuous gas-tight liner, each course of the refractory brick liner must be laid on a full bed of refractory mortar approved for high-heat appliances.

2113.11.3.4 Termination height. Concrete and masonry chimneys for high-heat appliances shall extend a minimum of 20 feet (6096 mm) higher than any portion of any building within 50 feet (15 240 mm).

- Chimneys for high-heat appliances must terminate at least 20 feet (6096 mm) above the highest portion of the building within 50 feet (15 240 mm) horizontally. This allows flue gases to be safely carried away and provides enough clearance to allow any burning embers to extinguish before landing on combustibles.

2113.11.3.5 Clearance. Concrete and masonry chimneys for high-heat appliances shall have approved clearance from buildings and structures to prevent overheating combustible materials, permit inspection and maintenance operations on the chimney and prevent danger of burns to persons.

- The extremely high-temperature flue gas produced by a high-heat appliance is a major fire safety concern and requiring sufficient clearance from buildings protects nearby combustible material, permits inspection and maintenance of the chimney and minimizes danger to persons.

2113.12 Flue lining (installation). Flue liners shall be installed in accordance with ASTM C 1283 and extend from a point not less than 8 inches (203 mm) below the lowest inlet or, in the case of fireplaces, from the top of the smoke chamber, to a point above the enclosing walls. The lining shall be carried up vertically, with a maximum slope no greater than 30 degrees (0.52 rad) from the vertical.

- Fireclay flue liners shall be laid in medium-duty refractory mortar conforming to ASTM C 199, with tight mortar joints left smooth on the inside and installed to maintain an airspace or insulation not to exceed the thickness of the flue liner separating the flue liners from the interior face of the chimney masonry walls. Flue lining shall be supported on all sides. Only enough mortar shall be placed to make the joint and hold the liners in position.

- The liner forms the flue passageway and is the actual conduit of all products of combustion. It must withstand exposure to high temperatures and corrosive chemicals from the flue gases. The chimney lining protects the masonry construction of the chimney walls and allows the chimney to be constructed gas tight. Installation must comply with ASTM C 1283. The liner is required to extend below the lowest inlet to provide protection to the masonry from flue gases, which can deteriorate the masonry and mortar joints. Refractory mortar must comply with ASTM C 199.

2113.13 Additional requirements.

- This section contains requirements for listed materials to be used as flue linings and for spaces surrounding chimney lining systems.

2113.13.1 Listed materials. Listed materials used as flue linings shall be installed in accordance with the terms of their listings and the manufacturer’s instructions.

- Listed materials for flue linings must be installed in accordance with the manufacturer’s instructions. Such instructions are not listed in the code since they vary with each system.

2113.13.2 Space around lining. The space surrounding a chimney lining system or vent installed within a masonry chimney shall not be used to vent any other appliance.

- Exception: This shall not prevent the installation of a separate flue lining in accordance with the manufacturer’s instructions.

2113.14 Multiple flues. When two or more flues are located in the same chimney, masonry wythes shall be built between adjacent flue linings. The masonry wythes shall be at least 4 inches (102 mm) thick and bonded into the walls of the chimney.

- Exception: When venting only one appliance, two flues are permitted to adjoin each other in the same chimney with only the flue lining separation between them. The joints of the adjacent flue linings shall be staggered at least 4 inches (102 mm).

- A single masonry chimney can contain any number of flue-gas passageways. When more than two flues are contained in the same chimney, the flue liners are required to be subdivided by masonry wythes into groups of not more than two (see Figure 2113.14). The purpose of the masonry wythes is to unify the chimney structur-
ally and to isolate pairs of flues serving dissimilar appliances.

### 2113.15 Flue area (appliance)

Chimney flues shall not be smaller in area than the area of the connector from the appliance. Chimney flues connected to more than one appliance shall not be less than the area of the largest connector plus 50 percent of the areas of additional chimney connectors.

**Exceptions:**

1. Chimney flues serving oil-fired appliances sized in accordance with NFPA 31.
2. Chimney flues serving gas-fired appliances sized in accordance with the *International Fuel Gas Code*.

- Flues are sized to match the opening at the top of the appliance so that appliances function properly. Smaller flues are not permitted since they may constrict the passage of gases out from the appliance. The *International Residential Code®* (IRC®) provides guidelines on the sizing of these flues.

### 2113.16 Flue area (masonry fireplace)

Flue sizing for chimneys serving fireplaces shall be in accordance with Section 2113.16.1 or 2113.16.2.

- This section provides requirements for the net cross-sectional area of the flue and throat between the firebox and the smoke chamber. Airflow through the fireplace is affected by the dimensions of the firebox opening, the shape and cross-sectional area of the flue and the height of the chimney (see Code Figure 2113.16).

For proper fireplace operation, the required cross-sectional area is about one-tenth that of the fireplace opening. This ratio may vary somewhat with the height of the chimney and the configuration (round or rectangular) of the chimney flue.

Section 2113.16.1 prescribes the minimum flue area based on the fireplace opening alone, while Section 2113.16.2 prescribes it based on the height of the fireplace, the fireplace opening area and flue type.

**FIGURE 2113.16.** See page 21-77.

- This figure prescribes minimum flue sizes as a function of chimney height and the fireplace opening area. For example, for a 20-foot-high (6096 mm) chimney and a fireplace opening area of 2,000 square inches (1290 320 mm²), the minimum cross-sectional area is 205 1/2 square inches (132 548 mm²) for a round flue or 241 1/2 square inches (155 767 mm²) for a square or rectangular flue. Using Table 2113.16 (1), that minimum required cross-sectional area can be met by a circular flue with a diameter of 18 inches (457 mm). Using Table 2113.16(2), the minimum cross-sectional area would require a square flue with an inside dimension of 19 1/2 inches (495 mm).

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**Figure 2113.14**

LOW-HEAT CHIMNEY WITH MORE THAN TWO FLUES

For SI: 1 inch = 25.4 mm.
2113.16.1 Minimum area. Round chimney flues shall have a minimum net cross-sectional area of at least $\frac{1}{12}$ of the fireplace opening. Square chimney flues shall have a minimum net cross-sectional area of at least $\frac{1}{10}$ of the fireplace opening. Rectangular chimney flues with an aspect ratio less than 2 to 1 shall have a minimum net cross-sectional area of at least $\frac{1}{10}$ of the fireplace opening. Rectangular chimney flues with an aspect ratio of 2 to 1 or more shall have a minimum net cross-sectional area of at least $\frac{1}{8}$ of the fireplace opening.

This section prescribes the minimum flue area based on the fireplace opening and the shape of the flue. For a given size fireplace, circular chimney flues are permitted to have a smaller area than rectangular flues. Wide, narrow flues require a larger area for adequate airflow.

2113.16.2 Determination of minimum area. The minimum net cross-sectional area of the flue shall be determined in accordance with Figure 2113.16. A flue size providing at least the equivalent net cross-sectional area shall be used. Cross-sectional areas of clay flue linings are as provided in Tables 2113.16(1) and 2113.16(2) or as provided by the manufacturer or as measured in the field. The height of the chimney shall be measured from the firebox floor to the top of the chimney flue.

This section provides an alternate method to determine flue size based on the height of the chimney, the fireplace opening area and the flue type [see commentary, Tables 2113.16(1) and 2113.16(2) and Code Figure 2113.16].
2113.16 Net cross-sectional area of round flue sizes.

This table gives the areas of circular flues of standard sizes so that users of the code can easily determine a flue size complying with Code Figure 2113.16. Because the flue corners are rounded, the flue areas shown in this table are not determined by simply multiplying the inside dimensions shown. The areas are accordingly slightly smaller than a true rectangle of the dimensions shown in the table.

**FLUE SIZE, INSIDE DIAMETER (inches)** | **CROSS-SECTIONAL AREA (square inches)**
--- | ---
6 | 28
7 | 38
8 | 50
10 | 78
10 \(\frac{3}{4}\) | 90
12 | 113
15 | 176
18 | 254

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm².

a. Flue sizes are based on ASTM C 315.

This table gives the areas of square and rectangular flues of standard sizes so that code users can easily determine a flue size complying with Code Figure 2113.16. Because the flue corners are rounded, the flue areas shown in this table are not determined by the equation \(A = \pi \times (d/2)^2\), where \(A\) is the cross-sectional area, \(d\) is the inside diameter of the flue and \(\pi\) is approximated as 3.14. Alternately, a minimum diameter can be calculated as \(d = [(A/\pi)^{1/2}]/4\).

**FLUE SIZE, INSIDE DIMENSION (inches)** | **CROSS-SECTIONAL AREA (square inches)**
--- | ---
4\(\frac{1}{2}\) × 13 | 34
7\(\frac{1}{2}\) × 7\(\frac{1}{2}\) | 37
8\(\frac{1}{2}\) × 8\(\frac{1}{2}\) | 47
7\(\frac{1}{2}\) × 11\(\frac{1}{2}\) | 58
8\(\frac{1}{2}\) × 13 | 74
7\(\frac{1}{2}\) × 15\(\frac{1}{2}\) | 82
11\(\frac{1}{2}\) × 11\(\frac{1}{2}\) | 91
8\(\frac{1}{2}\) × 17\(\frac{1}{2}\) | 101
13 × 13 | 122
11\(\frac{1}{2}\) × 15\(\frac{1}{2}\) | 124
13 × 17\(\frac{1}{2}\) | 165
15\(\frac{1}{2}\) × 15\(\frac{1}{2}\) | 168
15\(\frac{1}{2}\) × 19\(\frac{1}{2}\) | 214
17\(\frac{1}{2}\) × 17\(\frac{1}{2}\) | 226
19\(\frac{1}{2}\) × 19\(\frac{1}{2}\) | 269
20 × 20 | 286

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm².

a. Flue sizes are based on ASTM C 315.

This section requires a cleanout to be installed in a chimney to facilitate cleaning and inspection. A fireplace inherently provides access to its chimney through the firebox, throat and smoke chamber. The cleanout cover and opening frame are to be of an approved noncombustible material, such as cast iron or precast concrete and must be arranged to remain tightly closed. The requirement for placing the cleanout at least 6 inches (152 mm) below the lowest connection to the chimney is intended to minimize the possibility of combustion products exiting the chimney through the cleanout.

2113.19 Chimney clearances. Any portion of a masonry chimney located in the interior of the building or within the exterior wall of the building shall have a minimum airspace clearance to combustibles of 2 inches (51 mm). Chimneys located entirely outside the exterior walls of the building, including chimneys that pass through the soffit or cornice, shall have a minimum airspace clearance of 1 inch (25 mm). The airspace shall not be filled, except to provide fireblocking in accordance with Section 2113.20.

Exceptions:

1. Masonry chimneys equipped with a chimney lining system listed and labeled for use in chimneys in contact with combustibles in accordance with UL 1777, and installed in accordance with the manufacturer’s instructions, are permitted to have combustible material in contact with their exterior surfaces.

2. Where masonry chimneys are constructed as part of masonry or concrete walls, combustible materials shall not be in contact with the masonry or concrete wall less than 12 inches (305 mm) from the inside surface of the nearest flue lining.
3. Exposed combustible trim and the edges of sheathing materials, such as wood siding, are permitted to abut the masonry chimney sidewalls, in accordance with Figure 2113.19, provided such combustible trim or sheathing is a minimum of 12 inches (305 mm) from the inside surface of the nearest flue lining. Combustible material and trim shall not overlap the corners of the chimney by more than 1 inch (25 mm).

- Clearance between the external surfaces of the masonry chimney and all combustible materials must be maintained. The intent of this section is to require a 2-inch (51 mm) minimum airspace clearance between combustibles and surfaces of all chimneys located in the interior of a building or within an exterior wall assembly. A 1-inch (25 mm) airspace clearance is allowed only where the chimney is located entirely outside of the building.

  If any portion of a chimney is located in an exterior wall, that chimney must be considered as an interior chimney and must have a 2-inch (51 mm) minimum airspace clearance. The 1-inch (25 mm) clearance is allowed because the exterior surface of an outdoor chimney can dissipate heat. An outdoor chimney is exposed to outdoor ambient temperatures, allowing it to operate with cooler surface temperatures. Like all airspace clearances, the 1-inch (25 mm) airspace clearance is not permitted to be filled with any material except the noncombustible material necessary for fireblocking. The required clearance for exterior chimneys applies to all combustible materials, including sheathing, siding, insulation, framing and trim.

  The exception recognizes a variety of chimney liners that are tested and labeled in accordance with UL 1777. UL 1777 covers metallic and nonmetallic chimney liners intended for field installation into new and existing masonry chimneys used for natural draft venting of gas, oil and solid-fuel-burning appliances having maximum continuous flue-gas temperatures not exceeding 1,000°F (538°C). Some lining systems are labeled for reduced clearance applications and could allow the construction or rehabilitation of chimneys in contact with combustibles, without compromising the safety normally provided by the code-prescribed airspace clearances.

  Chimney liner systems are typically metal or poured-in-place concrete and incorporate insulation to retard the transfer of heat to the surrounding masonry walls of the chimney.

**FIGURE 2113.19.** See below.

- This figure clarifies Exception 3 to the clearance requirements for masonry chimneys. The edge abutment of combustible sheathing or trim where there is an adequate thickness of masonry is a long-standing practice that is considered safe, provided the minimum clearance to the flue lining is maintained.

**2113.20 Chimney fireblocking.** All spaces between chimneys and floors and ceilings through which chimneys pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between wood joists, beams or headers shall be to a depth of 1 inch (25 mm) and shall only be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney.

- Fireblocking is required to prevent the travel of flames, smoke and hot gases to other areas of the building through the gaps between the chimney and the floor or ceiling assemblies. The 1-inch (25 mm) depth requirement is intended to be both the minimum and the maximum [see Figures 2113.20(1) and (2)].
Figure 2113.20(1)
FIREBLOCKING

Figure 2113.20(2)
FIREBLOCKING (SECTION)

For SI: 1 inch = 25.4 mm.
The following resource materials are referenced in this chapter or are relevant to the subject matter addressed in this chapter.


Commentary on Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02). Farmington Hills, MI: American Concrete Institute; Reston, VA: Structural Engineering Institute of the American Society of Civil Engineers; Boulder, CO: The Masonry Society, 2002.

Commentary on Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02). Farmington Hills, MI: American Concrete Institute; Reston, VA: Structural Engineering Institute of the American Society of Civil Engineers; Boulder, CO: The Masonry Society, 2002.


