CHAPTER 3

Code Basis for Structural Design of Masonry Buildings

3.1 Introduction to Building Codes in the United States

The United States has no national design code, primarily because the U.S. Constitution has been interpreted as delegating building code authority to the states, some of which in turn delegate it to municipalities and other local governmental agencies. Design codes used in the United States are developed by a complex process involving technical experts, industry representatives, code users, and building officials. As it applies to the development of design provisions for masonry, this process is shown in Fig. 3.1 and is then described.

1. Consensus design provisions and specifications for materials or methods of testing are first drafted in mandatory language by technical specialty organizations, operating under consensus rules approved by the American National Standards Institute (ANSI) or (in the case of ASTM) rules that are similar in substance. Those consensus rules vary from organization to organization but include requirements for the following:
   a. Balance of interests (producer, user, and general interest).
   b. Written balloting of proposed provisions, with prescribed requirements for a successful ballot.
   c. Resolution of negative votes. Negative votes must be discussed and found nonpersuasive before a ballot item can pass. A single negative vote, if found persuasive, can prevent an item from passing.
   d. Public comment. After being approved within the technical specialty organization, the mandatory-language provisions must be published for review and comment by the general public. All comments are responded to, but do not necessarily result in further modification.
2. These consensus design and construction provisions are adopted, usually by reference and sometimes in modified form, by model-code organizations and take the form of model codes.

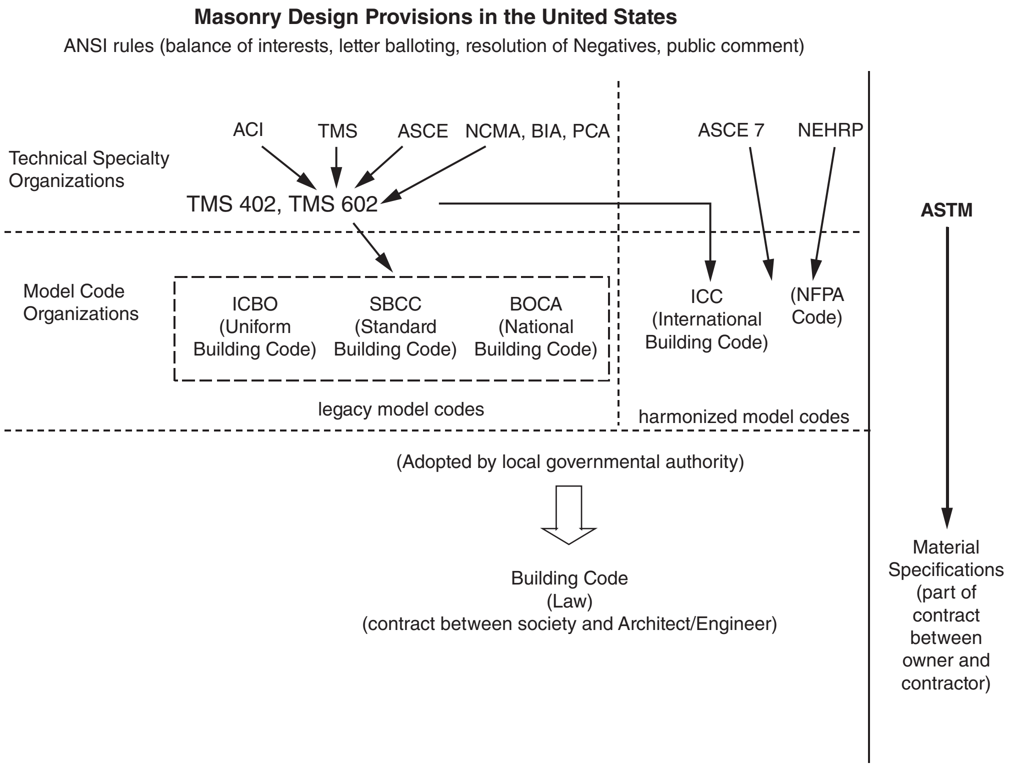

FIGURE 3.1 Schematic of process for development of masonry design codes in the United States.

3. These model codes are adopted, sometimes in modified form, by local governmental agencies (such as states, cities, or counties). Upon adoption, but not before, they acquire legal standing as building codes.

3.1.1 Technical Specialty Organizations

Technical specialty organizations are open to designers, contractors, product suppliers, code developers, and end users. Their income (except for FEMA, a U.S. government agency) is derived from member dues and the sale of publications. Technical specialty organizations active in the general area of masonry include the following:

1. *American Society for Testing and Materials (ASTM):* Through its many technical committees, ASTM develops consensus specifications for materials and methods of test. Although some model-code organizations use their own such specifications, most refer to ASTM specifications.
2. *American Concrete Institute (ACI):* Through its many technical committees, this group publishes a variety of design recommendations dealing with different aspects of concrete design. ACI Committee 318 develops design provisions for concrete structures. ACI was one of the three initial sponsors of the Masonry Standards Joint Committee (MSJC).

3. *American Society of Civil Engineers (ASCE):* Until 2016, ASCE was a joint sponsor of many ACI technical committees dealing with concrete or masonry. ASCE served as the third of the three sponsoring societies of the Masonry Standards Joint Committee (MSJC) (see above). ASCE publishes ASCE 7-10 (2010), which prescribes design loadings and load factors for all structures, independent of material type.
4. *The Masonry Society (TMS):* Through its technical committees, this group influences different aspects of masonry design. From 1978 to 2016, TMS was one of the three sponsors (along with the American Concrete Institute and the American Society of Civil Engineers) of the Masonry Standards Joint Committee (MSJC), which was responsible for producing and maintaining the masonry design standard for the United States. From 2002 through 2016, TMS was the lead sponsor of the MSJC. Starting in 2016, TMS became the sole sponsor of that committee, and the masonry design standard was re-designated as TMS 402, after the name of the TMS committee responsible for maintaining it. The corresponding specification was re-designated as TMS 602. TMS also publishes a *Masonry Designers' Guide* to accompany the TMS design standard.

3.1.2 Industry Organizations

1. *Portland Cement Association (PCA):* This marketing and technical support organization is composed of cement producers. Its technical staff participates in technical committee work.
2. *National Concrete Masonry Association (NCMA):* This marketing and technical support organization is composed of producers of concrete masonry units. Its technical staff participates in technical committee work and also produces technical bulletins, which can influence consensus design provisions.
3. *Brick Industry Association (BIA):* This marketing, distributing, and technical support organization is composed of clay brick and tile producers and distributors. Its technical staff participates in technical committee work and also produces technical bulletins, which can influence consensus design provisions.
4. *National Lime Association (NLA):* This marketing and technical support organization is composed of hydrated lime producers. Its technical staff participates in technical committee work.
5. *Expanded Shale Clay and Slate Institute (ESCSI):* This marketing and technical support organization is composed of producers. Its technical staff participates in technical committee meetings.
6. *International Masonry Institute (IMI):* This is a union contractor-craftworker collaborative supported by dues from union masons. Its technical staff participates in technical committee meetings.
7. *Mason Contractors' Association of America (MCAA):* This organization is composed of union and nonunion mason contractors. Its technical staff participates in technical committee meetings.
8. *Autoclaved Aerated Concrete Products Association (AACPA):* This organization is composed of producers of autoclaved aerated concrete units. Its technical staff participates in technical committee meetings.

3.1.3 Governmental Organizations

The Federal Emergency Management Agency (FEMA) has jurisdiction over the National Earthquake Hazard Reduction Program (NEHRP) and develops and periodically updates the NEHRP provisions, a set of recommendations for earthquake-resistant design. That document includes provisions for masonry design. The document was pioneered by ATC 3-06, issued in 1978 by the Applied Technology Council under contract to the National Bureau of Standards. The NEHRP provisions are now published at 6 year intervals by the Building Seismic Safety Council (BSSC) under contract with the National Institute of Building Sciences (NIBS). BSSC is not a consensus organization. Its recommended design provisions are intended for consideration and possible adoption by consensus organizations. Its latest recommendations, the 2015 NEHRP *Recommended Provisions* (NEHRP 2015), address the determination of the design of seismic loadings on structures and the design of structures (including masonry structures) for those loadings. The role of the NEHRP *Provisions* is evolving slightly, with the next edition anticipated to reference existing standards (ASCE 7 for loads, TMS 402 for masonry design, and so forth) much more and to emphasize the development of innovative design and construction suggestions for consensus design and construction standards.

3.1.4 Model-Code Organizations

Model-code organizations are composed primarily of building officials, although designers, contractors, product suppliers, code developers, and end users can also be members. Their income is derived from dues and the sale of publications. Historically, the United States had three legacy model-code organizations:

1. *International Conference of Building Officials (ICBO):* In the past, this group developed and published the Uniform Building Code (UBC).
2. *Southern Building Code Congress International (SBCCI):* In the past, this group developed and published the Standard Building Code (SBC).
3. *Building Officials and Code Administrators International (BOCA):* In the past, this group developed and published the National Building Code (NBC).

In the past, certain model codes were used more in certain areas of the country. The Uniform Building Code was used throughout the western United States and in the state of Indiana. It was used in California until January of 2008, in the slightly modified form of the California Building Code. The Standard Building Code was used in the southern part of the United States. The National Building Code was used in the eastern and northeastern United States.

In 1996, intensive efforts began in the United States to harmonize the three model building codes. The primary harmonized model building code is called the International Building Code. It was developed by the International Code Council (ICC) and is composed primarily of building code officials of the three legacy model-code organizations. The first edition of the International Building Code (IBC 2000) was published in May 2000. In most cases, it references consensus design provisions and specifications. It is intended to take effect when adopted by local jurisdictions and to replace the three legacy model building codes. Its latest edition was published in 2015. The International Building Code has been adopted or is scheduled for adoption in most governmental jurisdictions of the United States. Another model code, adopted in only a few jurisdictions, is published by the National Fire Protection Association (NFPA 5000).

1. *International Code Council (ICC):* This group develops and publishes the International Building Code (IBC).
2. *National Fire Protection Association (NFPA):* This group develops and publishes NFPA 5000.

3.2 Introduction to the Calculation of Design Loading Using the 2015 IBC

Design loadings for buildings in general, including masonry buildings, are prescribed by the legally adopted building code. In most parts of the United States, the legally adopted building code is based on the International Building Code (IBC). In the following sections of this chapter, background information and sample calculations are presented for each of the principal IBC-mandated design loadings:

- Gravity loads (dead load and live load)
- Wind loads
- Earthquake loads

These loads are used in many design examples in subsequent chapters of this book.

Many designers are familiar with the layout of ASCE 7 and are accustomed to using loadings and load combinations taken directly from ASCE 7, even though this is strictly legal only in jurisdictions without a legally adopted building code. For most common loading combinations, differences between the loading combinations of the 2015 IBC and ASCE 7-10 are not significant.

3.3 Gravity Loads according to the 2015 IBC

3.3.1 Dead Load according to the 2015 IBC

Dead load is due to the weight of the structure itself, plus permanently attached components. Calculation of dead loads is not discussed further at this point. It is discussed in specific examples, as are IBC loading combinations including dead load.

3.3.2 Floor Live Load according to the 2015 IBC

Live load is prescribed by the 2015 IBC. The loading provisions of the 2015 IBC are discussed here using the section numbers taken from that document. The 2015 IBC itself uses loads that are almost identical to those prescribed by *ASCE 7-10*. In the future, the IBC will tend more and more to reference ASCE 7 loads directly. Minimum live loads (L) for floors (from Table 1607.1 of the 2015 IBC) are given in Table 3.1.

By Section 1607.9.1 of the 2015 IBC, live loads are permitted to be reduced based on the tributary area over which those live loads act. Live loads in public assembly areas (balconies, corridors, and stairs) are not permitted to be reduced. The live-load

Table 3.1 Minimum Live Loads (*L*) for Floors

Occupancy or Use	Uniform (lb/ft²)	Concentrated (lb)
4. Assembly areas w/moveable seats	100	—
5. Balconies (exterior) and decks	Same as occupancy served	
9. Corridors, except as otherwise indicated	100	
26. Offices	50	2000
27. Residential	40	
27. Residential, corridors and public areas of hotels	100	
29. Ordinary flat roofs	20	300
30. School classrooms	40	1000
30. School corridors above first floor	80	1000
30. School corridors, first floor	100	1000
35. Stairs and exits	100	
35. Stairs and exits, 1- and 2-family dwellings	40	
37. Stores, retail, first floor	100	1000
37. Stores, retail, upper floors	75	1000

Source: Table 1607.1 of the 2015 IBC.

reduction factor, shown here, applies to elements for which the product $K_{LL}A_T$ equals or exceeds 400 ft²:

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right)$$

where L = reduced design live load per square foot of area supported by the member
L_o = unreduced design live load per square foot of area supported by the member (see Table 1607.1, 2015 IBC)
K_{LL} = live element factor (see Table 1607.9.1, 2015 IBC)
A_T = tributary area, in square feet

L shall not be less than 0.50 L_o for members supporting one floor, and L shall not be less than 0.40 L_o for members supporting two or more floors.

Live-load reduction factors are given in Table 1607.9.1 of the 2015 IBC, reproduced in Table 3.2.

3.3.3 Example of Floor Live-Load Reduction according to the 2015 IBC

Consider an interior beam of an office floor with a tributary area of 400 ft² ($K_{LL} = 2$).

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right) = L_o\left(0.25 + \frac{15}{\sqrt{2\times 400}}\right) = 0.78\,L_o$$

Table 3.2 Live-Load Element Factor, K_{LL}

Element	K_{LL}
Interior columns	4
Exterior columns without cantilever slabs	4
Edge columns with cantilever slabs	3
Corner columns with cantilever slabs	2
Edge beams without cantilever slabs	2
Interior beams	2
All other members not identified above including: Edge beams with cantilever slabs Cantilever beams One-way slabs Two-way slabs Members without provisions for continuous shear transfer normal to their span	1

Source: Table 1607.9.1 of the 2015 IBC.

The lower limit of 0.50 does not govern, and

$$L = 0.78\ L_o$$

3.3.4 Example of a Wall Live-Load Reduction according to the 2015 IBC

Consider an interior wall supporting 10 floors, each with tributary area 400 ft^2 (assume $K_{LL} = 4$).

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right) = L_o\left(0.25 + \frac{15}{\sqrt{4\times(10\times 400)}}\right) = 0.37\ L_o$$

The 0.40 limit governs, and

$$L = 0.40\ L_o$$

3.3.5 Roof Live Load according to the 2015 IBC

In accordance with Section 1607.11.2 of the 2015 IBC, the minimum roof live load for most roofs is 20 lb/ft^2. Roof live loads are permitted to be reduced in accordance with the following:

$$L_r = L_0 R_1 R_2$$

where L_r = reduced roof live load per square foot
L_0 = unreduced roof live load per square foot
R_1 = see Fig. 3.2
R_2 = 1.0 for flat roofs

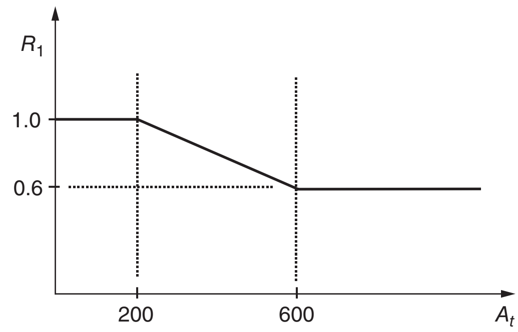

Figure 3.2 Graph showing permitted live-load reduction for roofs. (*Source:* Section 1607.11.2 of the 2015 IBC.)

The minimum reduced roof live load is 12 lb/ft^2. The reduction is shown graphically in Fig. 3.2.

3.4 Wind Loading according to the 2015 IBC

According to Section 1609.1.1 of the 2015 IBC, wind loading is to be calculated using the provisions of *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10), or the simplified alternate all-heights method in Section 1609.6 of the 2015 IBC. The wind-load calculation procedures of ASCE 7-10 are considerably different from those of ASCE 7-05, in that they use strength-calibrated wind loads, a load factor of 1.0 instead of 1.6, and no importance factor. ASCE 7 revised the procedure for evaluating wind loads and separated the material in Chapter 6 of ASCE 7-05 into six chapters. Chapter 26 covers general requirements for both the main wind force resisting system and for components and cladding. The determination of design forces on the main wind force resisting system using the directional procedure is covered in Chapter 27. A simplified method for low-rise buildings is contained in Chapter 28. Specialty elements such as roof overhangs are covered in Chapter 29. Chapter 30 addresses a simplified method for the design of components and cladding. Finally, wind-tunnel procedures are covered in Chapter 31.

We are interested in two types of design wind loads.

1. The first type is used to calculate the design base shear and base overturning moment on a building due to wind pressure. These wind loads are referred to as "Main Wind-Force Resisting System loads," commonly abbreviated as "MWFRS loads."
2. The second type is used to calculate the local design pressures acting on sections of a building envelope. These wind loads are referred to as "Components and Cladding" loads, commonly abbreviated as "C&C loads."

Section 26.1.2 of ASCE 7-10 gives the following general procedures for computing each type of wind load:

Section 26.1.2.1: Main Wind Force Resisting System (MWFRS)

1. Directional Procedure for buildings of all heights as specified in Chapter 27.
2. Envelope Procedure for low-rise buildings as specified in Chapter 28.