complexity of the building with respect to height, shape, wall location, and openings in the wall.

While empirical design is restricted by arbitrary limits on the ratio of wall height to thickness, analytical design determines the actual thickness required to resist service loads on walls of any desired height. Empirical design codes arbitrarily dictate the spacing of lateral supports, but analytical design calculates loads and provides lateral support as needed to resist specific forces and provide stability. The allowable stress method of analytical design establishes allowable compressive stresses based on the general characteristics of the units and mortar selected, the slenderness of the wall, and the eccentricity of applied loads. Both the allowable stress and strength design methods also take into account shear and flexural stresses, which are not considered in empirical design.

Empirical design methods may be used for low-rise buildings, but analytical design will produce more efficient and economical results for both unreinforced and reinforced masonry. Empirical requirements are essentially only rules of thumb, and are very simplistic in their application. Height- or length-to-thickness ratios are used in conjunction with minimum wall thicknesses to determine the required section of a given wall. Analytical design by the allowable stress method is based on the properties of the component materials in resisting calculated stresses but also includes some arbitrary empirical limits. Strength design is fully analytical in its methodology and does not rely on any empirical limitations. The application of strength design methods has finally brought masonry into the modern era alongside concrete and steel engineering, and will yield the most efficient and economical designs for both low-rise and high-rise structures.

12.1.10 Code Requirements

Design requirements for both the empirical and analytical methods are governed by the Masonry Standards Joint Committee (MSJC) *Building Code Requirements for Masonry Structures* (ACI 530/ASCE 5/TMS 402) and *Specifications for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602), which are written jointly by the American Concrete Institute (ACI), the American Society of Civil Engineers (ASCE), and The Masonry Society (TMS). Sometimes referred to simply as ACI 530, the MSJC Code also forms the basis of the *International Building Code*, and is referenced in it throughout.

12.2 EMPIRICAL DESIGN

Masonry buildings built before the twentieth century, including all historic masonry buildings throughout the world, are unreinforced, empirically designed structures. These traditional loadbearing designs used massive walls and buttresses to resist lateral loads, including those induced by roof thrusts, arches, and large domes. Empirically designed masonry today is limited to buildings of modest height where wind loads are low and seismic loading is not a consideration.

Empirical design is based on historical precedent and rules of thumb rather than detailed analysis of loads and stresses, and calculated structural response. Empirically designed buildings do not incorporate reinforcing steel for load resistance, but may include joint reinforcement for control of shrinkage cracking and thermal movement. Elements that do not contribute to the primary lateral force-resisting system in masonry structures, and masonry elements in steel or concrete frame buildings, may be designed empirically under the MSJC Code.

Under the MSJC Code, empirically designed buildings are prohibited in Seismic Performance Categories D and E and in areas where design wind loads exceed 25 psf. In Seismic Performance Categories B and C, empirically designed masonry may not be part of the lateral force-resisting system. The height of empirically designed buildings which rely on masonry walls for lateral load resistance is limited to 35 ft above the foundation or supporting element.

12.2.1 Allowable Compressive Stresses

The MSJC Code lists allowable compressive stresses for empirically designed masonry which vary with unit and mortar type. Service loads must be limited so that the maximum average compressive stress in the wall does not exceed the allowable values. To determine compressive stresses in the masonry, the combined effects of vertical dead loads plus live loads (exclusive of wind and seismic forces) must be considered.

12.2.2 Lateral Support Requirements

In lieu of analytical design, prescriptive requirements are given for the ratio of the unsupported height or length to the nominal thickness of masonry bearing walls and non-bearing partitions. Lateral support must be provided in *either* the horizontal or the vertical direction within the limits shown in *Fig. 12-21.* Cross walls, pilasters, buttresses, columns, beams, floors, and roofs may all be used to provide the required support. Typical configurations for unreinforced masonry pilasters are shown in *Fig. 12-22.* Typical reinforced single-wythe columns are shown in *Fig. 12-23.* Lateral support connections at intersecting walls can be made in a number of different ways, since they do not have to transfer shear loads (see *Fig. 12-24*).

Lateral support gives the wall sufficient strength to resist wind loads and other horizontal forces acting either inward or outward. Members providing lateral support must be adequately bonded or anchored to the masonry, and must be capable of transferring forces to adjacent structural members or directly to the ground. Pilasters may be either bonded into the wall, connected with rigid metal ties, or connected across a continuous movement joint with adjustable metal ties.

The minimum cumulative length of shear walls in each required direction, exclusive of openings, must be 40% of the long dimension of the building (*see Fig. 12-25*). The required spacing of shear walls is based on the type of floor and roof provided, because diaphragm rigidity varies with each system. Stiffer elements permit wider spacing (*see Fig. 12-26*). Shear walls must have a minimum nominal thickness of 8 in. In composite walls, the thickness is measured as the nominal thickness of the two wythes plus the mortared collar joint or grouted cavity. In cavity walls, thickness is measured as the nominal dimension of the shear-resisting wythe only (*see Fig. 12-27*).

12.2.3 Wall Thickness

Bearing walls of one-story buildings must have a nominal thickness of 6 in. Bearing walls of buildings more than one story in height must have a nominal thickness of 8 in. Parapet walls must also be 8 in. thick, and their height is limited to three times the nominal thickness (taller parapets must be designed