1 High-Rise Building Definition, Development, and Use

The interesting question is why does man want to build to the sky. What is there about the desire for domination, or to reach God, or for private pride—the Pyramids are an example of that, but the tall building is certainly another.

—Skyscrapers Introductory Interview with Philip Johnson[1]

Before entering the world of high-rise security and fire life safety, it is important to define what constitutes a *high-rise building* and to review the development and utilization of these unique structures.

What Is a High-Rise Building?

A *building* is an enclosed structure that has walls, floors, a roof, and usually windows. "A 'tall building' is a multi-story structure in which most occupants depend on elevators [lifts] to reach their destinations. The most prominent tall buildings are called 'high-rise buildings' in most countries and 'tower blocks' in Britain and some European countries. The terms do not have internationally agreed definitions."[2] However, a *high-rise* building can be defined as follows:

- "Any structure where the height can have a serious impact on evacuation" (*The International Conference on Fire Safety in High-Rise Buildings*).[3]
- "For most purposes, the cut-off point for high-rise buildings is around seven stories. Sometimes, seven stories or higher define a high-rise, and sometimes the definition is more than seven stories. Sometimes, the definition is stated in terms of linear height (feet or meters) rather than stories."[4]
- "Generally, a high-rise structure is considered to be one that extends higher than the maximum reach of available fire-fighting equipment. In absolute numbers, this

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[1]Dupré J. *Skyscraper*s. New York: Black Dog & Leventhal Publishers, Inc. (Copyright 1996, First Black Dog & Leventhal Paperbacks, edition 2001:7.)

[2]Challinger D. *From the Ground Up: Security for Tall Buildings CRISP Report*. Alexandria, VA: ASIS Foundation Research Council; 2008:4.

[3]As stated in *Wikipedia Encyclopedia*, High-rise. January 5, 2009. <http://en.wikipedia.org/wiki/High-rise_building>; January 16, 2009.

[4]Hall Jr JR. *High-Rise Building Fires*. Quincy, MA: National Fire Protection Association; August 2005:2.

has been set variously between 75 feet (23 meters)◆ and 100 feet (30 meters),"[5] or about seven to ten stories (depending on the slab-to-slab distance between floors).

The exact height above which a particular building is deemed a high-rise is specified by fire and building codes for the country, region, state, or city where the building is located. When the building exceeds the specified height, then fire, an ever-present danger in such facilities, must be fought by fire personnel from inside the building rather than from outside using fire hoses and ladders.

For practicality and convenience such a multi-level or multi-story structure uses elevators as a vertical transportation system and, in addition, some utilize escalators to move people between lower floors.

Development of High-Rise Buildings

"From the individual 'skyscraper'◆◆ to the urban clusters of 'concrete canyons,' the names for high-rise buildings have always combined a kind of admiration and reverence for the magnitude of the feat with a kind of fear about the threat to human values implicit in operating on so large a scale. The Tower of Babel◆◆◆ is cited as a warning against pride and over-reaching, not as a goal to be sought."[6]

According to the Old Testament, after the Flood, people wanted to make a name for themselves by building a city called Babel with a tower that reached into heaven. The tower was constructed using brick for stone and tar (asphalt) for mortar.

> *"Come, let us build for ourselves a city, and a tower whose top will reach into heaven, and let us make for ourselves a name; lest we be scattered abroad over the face of the whole earth."*
>
> *And the Lord came down to see the city and the tower which the sons of men had built.*
>
> *And the Lord said, "Behold, they are one people, and they all have the same language. And this is what they began to do, and now nothing which they purpose to do will be impossible to them.*

◆For example, in the United States, commonly recognized as the home of the first high-rise, "NFPA 101 [*Life Safety Code*®] defines a high-rise building as a building more than 75 ft (22.5 m) in height where the building height is measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story. This definition is consistent with many model building codes, but it should be noted that many different definitions exist in local jurisdictions that use varying height and measurement criteria. These height changes can range from 40 ft (12 m) to as high as 150 ft (45 m)." Holmes WD, PE. Occupancies in special structures and high-rise buildings. In: *Fire Protection Handbook*. 19th ed. Quincy, MA: National Fire Protection Association; 2003:13–19.

[5]Knoke ME, Managing Editor, CPP. High-rise structures: life safety and security considerations. In: *Protection of Assets Manual*. Alexandria, VA: ASIS International; 2006.

◆◆"The word *skyscraper* is just as it sounds: a fanciful, rather exaggerated term designed to communicate people's awe and excitement about tall buildings. In reality, its meaning has changed radically in the hundred or so years since it came into our language. In the 1890s a building of ten stories more than qualified as a skyscraper, but today the word is rarely used to describe a building of fewer than fifty stories" (Sonder B. *Skyscrapers*. New York: MetroBooks, Michael Friedman Publishing Group; 1999:II).

◆◆◆The word *Babel* is from the Hebrew *balal* (to mix up) (Levi M, Salvadori M. *Why Buildings Fall Down: How Structures Fail*. New York and London: W. W. Norton & Company; 1992:18). In an earlier book, Mario Salvadori refers to "mankind's aspiration to reach the sky, the 'Tower of Babel Complex'" (*Why Buildings Stand Up: The Strength of Architecture*. New York and London: W. W. Norton & Company; 1992:21).

[6]Hall Jr JR. *High-Rise Building Fires*. Quincy, MA: National Fire Protection Association; August 2005:1.

> *"Come, let Us go down and there confuse their language, that they may not understand one another's speech."*
>
> *So the Lord scattered them abroad from there over the face of the whole earth; and they stopped building the city.*
>
> *Therefore its name was called Babel, because there the Lord confused the language of the whole earth.*[7]

"During the rapid growth of the Roman Empire under the reigns of Julius and Augustus Caesar, the city of Rome became the site of a large number of hastily constructed apartment buildings—many of which were erected to considerable heights.◆ Because building collapse due to structural failure was frequent, laws were passed that limited the heights of buildings—first to 70 feet (21 m) and then 60 feet (18 m)."[8] According to Sir Peter Hall's *Cities in Civilization*,

> *Within Rome the old-style town house,* domus, *survived well into the early third century AD. But, at least as early as the third century BC, overcrowding in the city was producing a new urban form, the apartment block, or insula; Vitruvius commented that "the majesty of the city and the considerable increase in its population have compelled an extraordinary extension of the dwelling houses, and circumstances have constrained men to take refuge in increasing the height of the edifices."*[9] *Building heights rose to at least three storeys in the third century BC, to five or more by the first century BC; Julius Caesar set a limit of seventy Roman feet, Augustus reaffirmed it, Trajan reduced it to sixty feet for greater safety; later still, after the great fire, Nero prohibited the rebuilding of tenement houses and of narrow, winding lanes, laying out broad streets flanked with colonnades. In fact, from the Republic onwards the Romans found it necessary to make regulations to control the thickness of walls, the quality of building materials, and the roofs and height of buildings. Enforcement must have been a problem, for there seems to have been no requirement to notify the authorities, as opposed to possibly interested third parties, of any proposed new structure. Since there was no mechanism to require planning consent, any initiative had to be taken by some interested party.*[10]
>
> *So, despite these edicts, new apartment houses continued to be built five or six storys high...*

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[7]Genesis, Chapter 11, verses 4–9. The Scripture text of the New American Standard Bible is used by permission of the Lockman Foundation, a corporation not for profit, La Habra, CA. (Copyright 1960, 1962, 1963, 1968, 1971, 1972, 1973, 1975, 1977. All rights reserved.)

◆"Residential buildings up to 5 or 6 stories have been common from the time of ancient Rome" (Mir M. Ali, ed. *Catalyst for Skyscraper Revolution, Lynn S. Beedle: A Legend in His Lifetime*. Chicago, IL: Council on Tall Buildings and Urban Habitat, Illinois Institute of Technology; 2004:194).

[8]Cote AE, Grant CC. Codes and standards for the built environment. In: *Fire Protection Handbook*. 19th ed. Quincy, MA: National Fire Protection Association; 2003:1–51).

[9]Carcopini 1941, 25 as referenced in Sir Peter Hall. *Cities in Civilization.* New York: Pantheon Books; 1998:627.

[10]Carcopini 1945, 24; de Camp 1970, 168; Hughes and Lamborn 1923, 20; Korn 1953, 32; Morris 1979, 45; Robinson, N. 1992, 34–35, 41 as referenced in Sir Peter Hall. *Cities in Civilization*. New York: Pantheon Books; 1998:627.

> *[A]partments were mostly built with wood frames; and they were so high and poorly built that they were in constant danger of collapse or destruction by fire.*[11]

Throughout subsequent history there have been other tall structures—pyramids and towers, castles and cathedrals◆—but it was not until the end of the 19th century that the skyscraper was born.

More than 150 years ago, cities looked very different from the way they look today. The buildings that housed people and their businesses were rarely over the height of a flagpole. Urban landscapes tended to be flat and uniform in pattern, apart from monuments, temples, and town halls; and cathedrals (adorned with domes, spires, or towers) which "towered above everything else in a city or town; they were visible from miles away."[12] "Historically, the word *tower* usually designated the church and the town hall until the birth of the skyscraper. The main evolutionary change has been in function, from a Campanile watchtower of the Renaissance or minaret of Islamic architecture to the office building."[13]

Two major developments led to the skyscrapers that dominate major city skylines throughout the modern world:

1. In 1853, an American, Elisha Graves Otis, invented the world's first safety lift or elevator.◆◆ This new form of vertical transportation◆◆◆ enabled people to travel safely upward at a much greater speed and with considerably less effort than by walking (Figure 1–1).

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[11]Sir Peter Hall. *Cities in Civilization*. New York: Pantheon Books; 1998:627–629.

◆"Gothic architecture, which began with the construction of St. Denis Cathedral in 1144, flourished well into the Renaissance era" (Schmidt AJ. *Under the Influence: How Christianity Transformed Civilization*. Grand Rapids, MI: Zondervan; 2001:296).

[12]Schmidt AJ. *Under the Influence: How Christianity Transformed Civilization*. Grand Rapids, MI: Zondervan; 2001:296.

[13]Beedle LS, Mir M. Ali, Armstrong PJ. *The Skyscraper and the City: Design, Technology, and Innovation*. Lewiston, NY: The Edwin Mellen Press; 2007:12.

◆◆According to the *Los Angeles Times*, referring to comments made by Otis Company officials, "The 'vertical transportation industry' began in ancient Greece. In 236 BC, mathematician Archimedes built a hoisting device using ropes and pulleys. A few centuries later, Roman gladiators and lions rode primitive elevators to reach the floor of the Coliseum. Donkey-powered lifts were the rage of the Middle Ages.… By the 1800s, steam-powered hoists began transporting miners to and from underground veins of ore" (Rivenburg R. Going up: 150 years of advances in elevators. *Los Angeles Times*. April 5, 2003:E–1). "Otis hadn't invented the first hoist. But he had invented the first 'safe' hoist.… People had been building hoists of various kinds for hundreds of years. And they all had the same serious defect: they plunged to the bottom every time the lifting cable snapped" (*Tell Me About Elevators*. Farmington, CT: Otis Elevator Company; 1974:8–10).

In 1854, "In front of a crowd of spectators and journalists at the Crystal Palace of New York Exhibition he [Elisha Graves Otis] cut the cable of his elevator, which locked in place and did not fall [Figure 1–1]. This rack and pinion safety lock which operates between the guiding rails and the elevator if it moves too fast, is still in use today" (Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:70–71). Otis elevators were first constructed for freight purposes. The world's first passenger elevator was installed in 1857 by Otis in the five-story store of E. V. Haughwout & Company in New York City (*Tell Me About Elevators*. Farmington, CT: Otis Elevator Company; 1974:11).

◆◆◆"Elisha Graves Otis developed the first safe steam-powered roped elevators with toothed guide rails and catches in the late 1850s. The steam-powered hydraulic elevator, which was limited to buildings of about 15 stories, was developed in 1867 by the French engineer Léon Édoux. The development of the electric motor by George Westinghouse in 1887 made possible the invention of the high-speed electric-powered roped elevator (called "lightning" elevators in comparison to the slower hydraulics) in 1889 and the electric-powered moving staircase, or escalator, in the 1890s" (Building construction. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/83859/building-construction>; August 30, 2008).

2. In the 1870s, steel frames◆ became available, gradually replacing the weaker combination of cast iron and wood previously used in construction. Until then, the walls had to be very thick to carry the weight of each floor.

It usually was agreed that a 12-inch wall was needed to support the first story, and four inches had to be added to the thickness of the base to support each additional story. The depth-to-height ratio precluded building structures above 10 stories. (An exception was the 16-story Monadnock Building [Figure 1–2] in Chicago, built in 1889 to 1891. Still standing, it is the last great monument to the age of load-bearing walls. At their base, the Monadnock Building's walls are six feet thick.)[14]

FIGURE 1–1 Otis Publicly Demonstrates the World's First Safety Elevator. In 1854, Elisha Graves Otis at the Crystal Palace Exposition in New York City dramatically cuts the cable and the platform does not plummet down. Courtesy of Otis Elevator Company.

Steel frames were able to carry the weight of more floors, so walls became simply cladding for the purpose of insulating and adorning the building. This development, which included applying hollow clay tiles to the steel supports, resulted in a fireproof◆◆ steel skeleton and

◆The first method for mass-producing steel was called the Bessemer process. "Though named after Sir Henry Bessemer of England, the process evolved from the contributions of many investigators before it could be used on a broad commercial basis. It was apparently conceived independently and almost concurrently by Bessemer and by William Kelly of the United States. Bessemer developed and patented the process in 1856" (Bessemer. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/63067/Bessemer-process>; September 7, 2008).

[14]Institute of Real Estate Management of the National Association of Realtors (IREM), "Office building industry: past, present, and future" (Harris RA, Revisions Author. *Managing the Office Building*. Rev. ed. Chicago, IL: IREM; 1985:3).

◆◆"A fire proof building will minimize the destruction of fire, whenever it strikes. In order to be termed *fireproof*, a building must offer 100% fire protection. Fireproof does not mean the absence of fire. It simply refers to proper building design and detail that effectively checks the spread of fire, while allowing access for occupants to escape" (Kruse T. Designing fireproof buildings. *Skylines Magazine*. Baltimore, MD: BOMA International; March 1993:12).

FIGURE 1–2 Monadnock Building, 1889. This 16-story building is the tallest load-bearing brick structure in the world. At their base, the building walls are six feet (1.8 meters) thick. Collection of the Chicago Historical Society (HB-19320-C). (Photographer: Hedrich Blessing.)

"also permitted movable interior partitioning, which allowed office suites to be reconstructed to meet the demands of new tenants.◆"[15] "This new method of construction reduced the thickness of walls, increased valuable floor space, and because it weighed much less than masonry, allowed immense increases in height. Freed from the constraints

◆A *tenant* can be a person, a group of persons, or a company or firm that rents or owns, and occupies space within a building.

[15]Institute of Real Estate Management of the National Association of Realtors (IREM), "Office building industry: past, present, and future" (Harris RA, Revisions Author. *Managing the Office Building*. Rev. ed. Chicago, IL: IREM; 1985:3).

of traditional construction, the facade could now be opened with windows to maximize the amount of daylight reaching the interior of the building."[16]◆

Another factor that helped to make high-rises possible was the foundation upon which they stood. "The Egyptian method of spread footings didn't work for skyscrapers since too much weight would bear down on too small an area. Modern builders had to switch to another ancient method, the Roman use of piles, which were driven into the ground all the way to the bedrock"[17] to provide a strong supporting base.

According to the Institute of Real Estate Management,

> *The modern office building was created in response to rapid population increases and industrialization that occurred during the late nineteenth century. Between 1870 and 1920, the nation's [United States] population doubled, and demand for office space increased fivefold. The first commercial structures were in the East [United States], but with railroads and a dynamic economy spurring national expansion, office buildings soon appeared in the Midwest, particularly in Chicago. In 1871, a fire destroyed this city. The disaster, combined with increased urban land values, the invention of the elevator, and the development of structural steel, gave rise to the skyscraper.*[18]

Other developments, such as incandescent lamps, central heating, and forced-air ventilation, followed in the 20th century by fluorescent lights and air-conditioning,◆◆ addressed the issue of providing adequate lighting, heating, ventilating, and air-conditioning

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[16]Dupré J. *Skyscrapers*. New York: Black Dog & Leventhal Publishers, Inc. (Copyright 1996 First Black Dog & Leventhal Paperbacks, edition 2001:15).

◆"There are few advantages of structural steel that are widely known, such as: column free clear spans providing flexible space, freedom for fixing services and more natural lighting; short construction period due to fast erection and the use of composite floors; lower foundation costs due to excellent strength to weight ratio (Gauliard JL, Plank R, Wyss U, eds. *Merits of Steel Construction, European Convention for Constructional Steelwork*. 1998:1–24). Steel is a homogeneous and quality controlled material that has additional safety. It has the ability to accommodate exceptional loads, such as earthquake and explosion, and it is a recyclable structural material. All these are important advantages of steel and they help all parties involved in construction to achieve the best of everything" (Celikag M. Economic aspects of using steel framed buildings with composite floors: case studies from United Arab Emirates. Civil Engineering Department, Eastern Mediterranean University, Gazimagusa, Turkey; *Construction and Building Materials*. Elsevier; 2004;18:383–390). "Composite floors comprise slabs and beams acting compositely together. Composite slabs consist of profiled steel decking working together with in-situ reinforced concrete. The decking not only acts as permanent formwork to the concrete, but also provides sufficient shear bond with the concrete, so that the two materials act compositely together. Although principally for use with steel frames, composite slabs can also be supported on brick, masonry or concrete components" ("Composite flooring systems: Sustainable construction solutions," MCRME, UK, and The Steel Construction Institute, Berkshire, UK, August 2003).

[17]Sonder B. *Skyscrapers*. New York: MetroBooks, Michael Friedman Publishing Group; 1999:15.

[18]Institute of Real Estate Management of the National Association of Realtors (IREM), Office building industry: past, present, and future (Harris RA, Revisions Author. *Managing the Office Building*. Rev. ed. Chicago, IL: IREM; 1985:2–15).

◆◆"The 'Apparatus for Treating Air' (U.S. Patent 808897) granted in 1906, was the first of several patents awarded to Willis Haviland Carrier. The recognized 'father of air conditioning' is Carrier, but the term 'air conditioning' actually originated with textile engineer, Stuart H. Cramer…. In 1921, Willis Haviland Carrier patented the centrifugal refrigeration machine. The 'centrifugal chiller' was the first practical method of air conditioning large spaces. Previous refrigeration machines used reciprocating-compressors (piston-driven) to pump refrigerant (often toxic and flammable ammonia) throughout the system. Carrier designed a centrifugal-compressor similar to the centrifugal turning-blades of a water pump. The result was a safer and

in large buildings. Such advancements in technology have not significantly affected the design of high-rise buildings but have contributed to their use, making them more convenient and comfortable.[19]

High-Rises Arise

The 10-story Home Insurance Building (Figure 1–3), built in Chicago in 1885, is generally considered to be the world's first skyscraper.◆ As stated in the *Architectural Record*, before the Home Insurance Building was demolished to allow construction of the New Field Building, "a committee of architects and others was appointed by the Marshall Field Estate to decide if it was entitled to the distinction of being the world's first skyscraper. This committee, after a thorough investigation, handed down a verdict that it was unquestionably the first building of skeletal construction."[20] Engineer William Le Baron Jenney designed this 180-foot (55 meters) tall building using a steel frame to support the weight of the structure. Jenney stated in 1883, "we are building to a height to rival the Tower of Babel."[21]

In the 1890s, "most European cities like London, Paris, and Rome rejected tall buildings in their historical city centers meanwhile opting for height control regulations to maintain their low skylines. Today, however, we witness Paris and London giving away their horizontality in favor of the vertical scale."[22]

> *Although the term skyscraper is usually reserved for office buildings, by the turn of the twentieth century there was some justification for extending its application to hotels. Early on, hotels had played a precedent-setting role in the development of the high-rise building, with the eight-story Broadway Central Hotel [in New York] of 1869–70 worthy of "early skyscraper," if not "first skyscraper," designation. In 1890 the official hotel directory listed 128 hotels in the city [New York]; twenty or so were said to have been constructed since 1880, and hotel construction had entered a boom period. City*

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more efficient chiller" (Bellis M. The father of cool: Willis Haviland Carrier–The history of air conditioning. <http://inventors.about.com/library/weekly/aa081797.htm>; June 14, 2008). Central air-conditioning became widespread in office buildings in the 1950s (Gillespie AK. "A city within a city," and "Architecture." In: *Twin Towers: The Life of New York's World Trade Center.* Piscataway, NJ: Rutgers University Press; 1999:207). "In the early 1950s, air-conditioning systems were reduced to very small electric-powered units capable of cooling single rooms. These were usually mounted in windows to take in fresh air and to remove heat to the atmosphere. These units found widespread application in the retrofitting of existing buildings—particularly houses and apartment buildings—and have since found considerable application in new residential buildings" (Building construction. *Encyclopædia Britannica Online.* <www.britannica.com/EBchecked/topic/83859/building-construction>; August 30, 2008).

[19]Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:60.

◆"The Equitable Building was New York's only challenge to Chicago's claim to the first skyscraper. Built in 1870, it was the first to have an elevator, but was only six stories tall" (Bennett D. Soaring ambitions. In: *Skyscrapers: Form and Function.* New York: Simon & Schuster, Marshall Editions Developments Limited; 1995:41).

[20]"Was the Home Insurance Building in Chicago the first skyscraper of skeleton construction?" (Vol. 76, No. 2, August 1934:113–118) as reported in Shepherd R, ed. *Skyscraper: The Search for an American Style 1891–1941.* New York: McGraw-Hill; 2003:7.

[21]Dupré J. *Skyscrapers*. New York: Black Dog & Leventhal Publishers, Inc. (Copyright 1996 First Black Dog & Leventhal Paperbacks, edition 2001:14).

[22]Beedle LS, Mir M. Ali, Armstrong PJ. *The Skyscraper and the City: Design, Technology, and Innovation.* Lewiston, NY: The Edwin Mellen Press; 2007:13.

FIGURE 1–3 Home Insurance Building 1885. This 10-story building, designed by engineer William Le Baron Jenney, is generally considered the world's first skyscraper. It was built in Chicago in 1885, using a steel frame. It was demolished in 1931. The ABN AMRO office building now stands on this site. Collection of the Chicago Historical Society (ICHi-00990).

> *directories listed 183 in 1895, and by 1912 there were 222 that had fifty rooms or more. Although London and Paris had more hotel buildings, New York City could accommodate more people in its hotels than any other city in the world.*[23,24]

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[23]Quinn hotel files. The New-York Historical Society: "Still not enough hotels." *New York Times*. October 19, 1890; Stone MN. *Hotel Pennsylvania: Strictly First-Class Accommodations at Affordable Rates* [M.S. thesis]. Columbia University; 1988:5; The New York Hotel and its mission. *Record and Guide*. May 13, 1911;87:899. As referenced in Landau SB, Conduit CW. *Rise of the New York Skyscraper, 1865–1913*. New Haven & London: Yale University Press; 1996:338.

[24]Landau SB, Conduit CW. *Rise of the New York Skyscraper, 1865–1913*. New Haven & London: Yale University Press; 1996:338.

FIGURE 1–4 Waldorf-Astoria Hotel. This sprawling hotel was an 1898 combination of the Waldorf and Astoria hotels (1891–1893 and 1895–1897) in New York City. Collection of the New-York Historical Society from the George Hall collection.

An example of a hotel of this era was the Waldorf-Astoria (Figure 1–4) in New York City.

At the turn of the century, tall buildings began to spring up in New York City—in 1903, the triangular-shaped 22-story Flatiron (Fuller) Building, 285 feet (87 meters) high; in 1909, the 50-story Metropolitan Life Insurance Building, 700 feet (213 meters) high; and in 1913, the 57-story Woolworth Building, 792 feet (241 meters) high.

"Residential high-rises were also built near [city centers] so people could live close to their place of employment."[25]

According to Mierop,[26]

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[25]Beedle LS, Mir M. Ali, Armstrong PJ. *The Skyscraper and the City: Design, Technology, and Innovation.* Lewiston, NY: The Edwin Mellen Press; 2007:13.

[26]Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:85, 86.

People have lived in apartment buildings with elevators since the 1860s. But until the [nineteen] twenties they did not exceed about 15 floors. These "skyscratchers" were laughable to Emery Roth. To him is owed the Ritz Tower [Figure 1–5], built in 1926, the first modern residential skyscraper, 41 stories, 165 meters (540 feet) high. The Ritz Tower rapidly became the prototype for a new lifestyle. Half hotel, half apartment block, it was particularly suited to the nomadic world of business and to people who were already deciding to move to the country and to maintain only a pied-a-terre in town.

By the early thirties New York had about 150 skyscrapers of this type. Better yet, the model was exported to other cities and other continents. In 1934, the Park Hotel[◆] *was built in Shanghai on the same principle of small apartments with hotel service—22 stories high and tower-shaped; it was the tallest building in the Far East.*[◆◆] *In Buenos Aires the Kavanagh,*[◆◆◆] *at 33 stories the highest skyscraper of the period to be built in reinforced concrete, is a residential tower.*

FIGURE 1–5 First Modern Residential High-Rise. The 41-story skyscraper, Ritz Tower, 465 Park Avenue, whose architect was Emery Roth, was built in New York in 1926. Courtesy of Emery Roth Architectural Print Collection, PR 170, Department of Prints, Photographs, and Architectural Collections, the New-York Historical Society.

◆"The construction of apartment hotels was much more profitable than single apartments. The hotels were not submitted to any regulations concerning sanitation, ventilation or natural light" (Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:87).

◆◆The Park Hotel "contains 205 furnished and unfurnished rooms/apartments" (Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:87).

◆◆◆"The Kavanagh was built in Buenos Aires in 1936…. It was the tallest building in the city" (Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:87).

In 1930 and 1931, two of the tallest buildings in the world were constructed in New York City: the 77-story Chrysler Building (1,046 feet, 319 meters) and the 102-story Empire State Building (1,250 feet, 381 meters). The latter, considered the "Eighth Wonder of the World," was built in the record time of one year and 45 days.[27] Both the Chrysler Building and the Empire State Building eclipsed the Woolworth Building as the world's tallest skyscrapers. After these buildings were erected, 40-, 50-, and 60-story structures were built all over the United States.

"Skyscrapers began to appear in Shanghai, Hong Kong, São Paulo, and other major Asian and Latin American cities in the 1930s, with Europe and Australia joining in by mid-century."[28]

In the early 1970s, the 110-story Twin Towers of the New York World Trade Center (WTC) were built: the north tower, One World Trade Center (WTC 1), 1,368 feet (417 meters) in height, was completed in 1972; the south tower, Two World Trade Center (WTC 2), 1,362 feet (415 meters), was completed in 1973. At that time, the WTC towers were the tallest buildings in the world (taking the title from the Empire State Building, which for more than 40 years was the world's tallest building). In 1974, the world's tallest building became the Sears Tower. Located in Chicago, it has 110 floors, beginning at street level and ending 1,450 feet (442 meters) in the air.

The "World's Tallest" Race

Since 1885, 17 buildings have staked claim to the title "The World's Tallest Building." According to information obtained from *Skyscraper*,[29] these buildings are as follows:

Date	Building	Location
1885	Home Insurance Building	Chicago, Illinois
1890	World Building	New York City
1892	Masonic Temple Building	Chicago, Illinois
1894	Manhattan Life Insurance Building	New York City
1898	St. Paul Building	New York City
1899	Park Row Building	New York City
1908	Singer Building	New York City
1909	Metropolitan Life Tower	New York City
1913	Woolworth Building	New York City
1930	Manhattan Company	New York City
1930	Chrysler Building	New York City
1931	Empire State Building	New York City
1971–1973	World Trade Center	New York City
1974	Sears Tower	Chicago, Illinois
1998	Petronas Towers	Kuala Lumpur, Malaysia
2004	Taipei 101	Taipei, Taiwan
2009	Burj Dubai	Dubai, United Arab Emirates

[27]Wright LM. *Spiders in the Sky*. Palm Coast, FL: Smithsonian; January 2002:18.

[28]History of skyscrapers. In: *1000 Events That Shaped the World*. Washington, DC: National Geographic Society; 2007:311.

[29]The World's Tallest Buildings: Timeline of all skyscrapers holding the title of tallest buildings in the world. <www.skyscraper.org/TALLEST_TOWERS/tallest.htm>; November 25, 2008.

In 1972, the Council on Tall Buildings and Urban Habitat (CTBUH)◆ first compiled a list of "The One Hundred Tallest Buildings in the World."[30] In compiling the data "height is measured from the sidewalk◆◆ level of the main entrance to the architectural top of the building."[31]

CTBUH's website (www.ctbuh.org) provides a wealth of information on high-rise buildings. In addition to "100 Tallest Buildings in the World" (see "The World's Tallest Buildings" section at the back of this book), it lists the following (also provided in "The World's Tallest Buildings" section at the back of this book):

- Tallest Single-Function Office Buildings in the World
- Tallest Single-Function Hotel Buildings in the World
- Tallest Single-Function Residential Buildings in the World
- Tallest Mixed-Use Buildings in the World

Also, CTBUH lists detail the "Tallest Steel Structure Buildings in the World," the "Tallest Concrete Structure Buildings in the World," and the "Tallest Mixed Structure Buildings in the World," as well as the tallest completed, under construction, proposed, and demolished/destroyed buildings in the world.

"The number of skyscrapers, their height, [and] their pace of construction are barometers of business prosperity. The history of skyscrapers shows an astonishing parallel with the geographical evolution of capital movement on the map of the world. It would be possible, as an exercise, to suggest an economic interpretation of the list of 'the hundred tallest buildings in the world.'"[32]

"The Sept. 11, 2001, destruction of the World Trade Center's 110-story twin towers did not put a damper on high-rise development. On the contrary, 'over the last five years, there has been an unprecedented world-wide construction boom in tall buildings and urban development,' said [CTBUH chairman, David] Scott."[33]

The current CTBUH "100 Tallest Completed Buildings in the World" list (see "The World's Tallest Buildings" section at the back of this book) was used to compile the following information.

The tallest completed building is Taipei 101, the 101-story, 1670-foot (509 meters) mixed-use, pagoda-style structure completed in Taipei, Taiwan, in 2004.

This building is followed by Shanghai World Financial Center, the 101-story, 1641-foot (492 meters) mixed-use building completed in Shanghai, China, in 2008.

The next tallest are the mixed-use Petronas Towers (Petronas Tower I and Petronas Tower 2) in Kuala Lumpur, Malaysia. Built in 1998, each 88-story tower is 1483 feet (452 meters) high, connected at the 41st and 42nd floors by a distinctive, glass-enclosed pedestrian "skybridge."

◆The Council on Tall Buildings and Urban Habitat studies and reports on all aspects of the planning, design, and construction of tall buildings. Also of a major concern is the role and impact of tall buildings on the urban environment. <www.ctbuh.com>; June 14, 2008.

[30]The Council on Tall Buildings and Urban Habitat, LeHigh University, Bethlehem, PA.

◆◆The sidewalk is a paved walkway [for pedestrians] along the side of a street (*The Free Dictionary by Farley*, Sidewalk. <www.thefreedictionary.com/sidewalk>; September 6, 2008) or road in an urban area. Also known as a pavement in Britain and a footpath in Australia, India, Ireland, and New Zealand (*The Free Dictionary by Farley*, Sidewalk. <www.thefreedictionary.com/sidewalk>; September 6, 2008).

[31]The Council on Tall Buildings and Urban Habitat, Chicago, IL; 2008.

[32]Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:91.

[33]Post NM. Building sector needs reeducation. In: *Engineering News-Record*. New York: McGraw Hill; March 17, 2008:12.

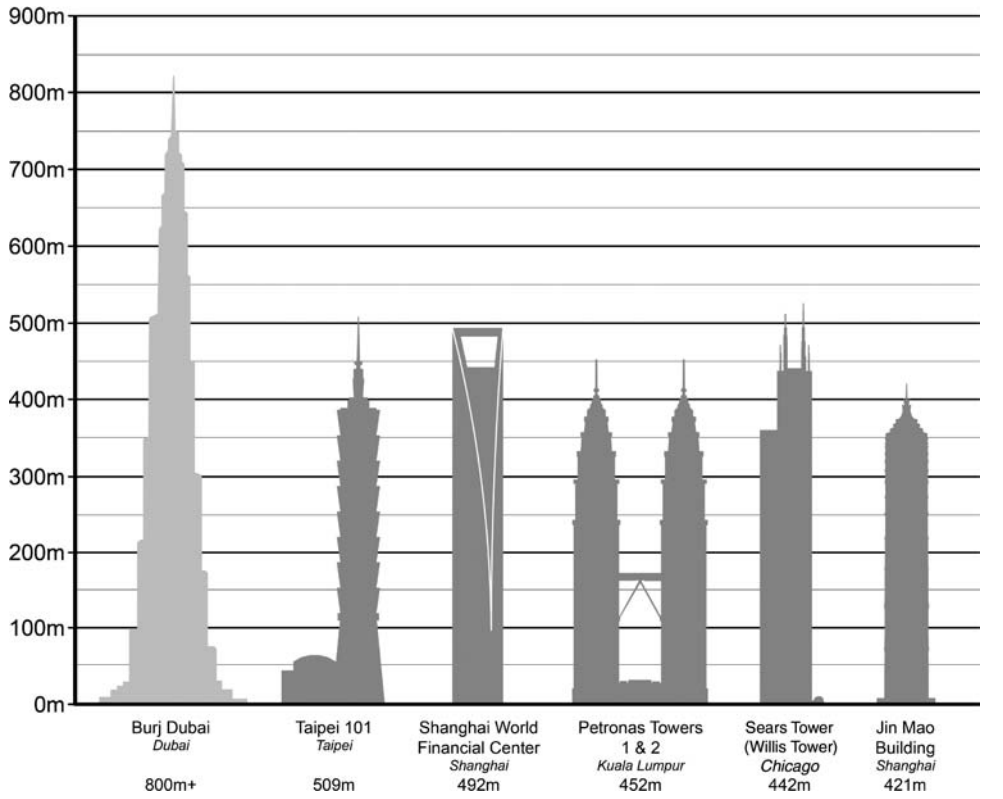

FIGURE 1–6 World's Tallest Buildings. Courtesy of the Council on Tall Buildings and Urban Habitat (www.ctbuh.org, 2009).

These buildings are followed by the 110-story office building Sears Tower (Willis Tower) at 1451 feet (442 meters); the 88-story, 1,381 feet (421 meters) mixed-use Jin Mao Building in Shanghai, China; and the 88-story office building Two International Finance Centre at 1362 feet (415 meters) in Hong Kong (Figure 1–6).

Cities in the elite 100 are Atlanta, Bangkok, Charlotte, Chicago, Chongqing, Cleveland, Dallas, Doha, Dubai, Frankfurt, Gold Coast (Australia), Guangzhou, Hong Kong, Houston, Izumisano, Kaohsiung, Kuala Lumpur, Los Angeles, Makati, Manama, Melbourne, Moscow, Nanning, New York, Philadelphia, Pittsburgh, Riyadh, San Francisco, Seattle, Seoul, Shanghai, Shenzhen, Singapore, Taipei, Toronto, Wuhan, and Yokohama.

Of the tallest 100 buildings, 64 are located outside of North America. Of these, 41 are in Asia and 16 are in the Middle East.

Burj Dubai (in Arabic "Burj" means tower) (Figure 1–7), located in Dubai, the United Arab Emirates, is the tallest structure in the world. Scheduled to be completed in 2009, this 160⁺-story monolith will stand at a stunning height (at the time of publication of this book, the estimated height of Burj Dubai was over 800 meters◆ or 2600 feet).

◆100 Tallest Buildings in the World. Council on Tall Buildings and Urban Habitat. <www.ctbuh.org>; January 2009.

It is projected to be the world's tallest mixed-use building, with a hotel, corporate suites, apartments, and an observation deck.

On the drawing board, the tallest building in the world is Illinois Tower, a 528-story, 5,280-foot (1,610 meters), plus a 400-foot (122 meters) aerial, office building (see book cover for an image of this building). In 1956, architect Frank Lloyd Wright conceived this "mile-high" office building with the intention that it would be constructed on Chicago's lakefront.[34]

Why Tall Buildings?

Leaving aside the belief that "mankind's aspiration to reach the sky, the 'Tower of Babel Complex,' drives us to erect higher and higher buildings,"[35] there are many other reasons why tall buildings are given

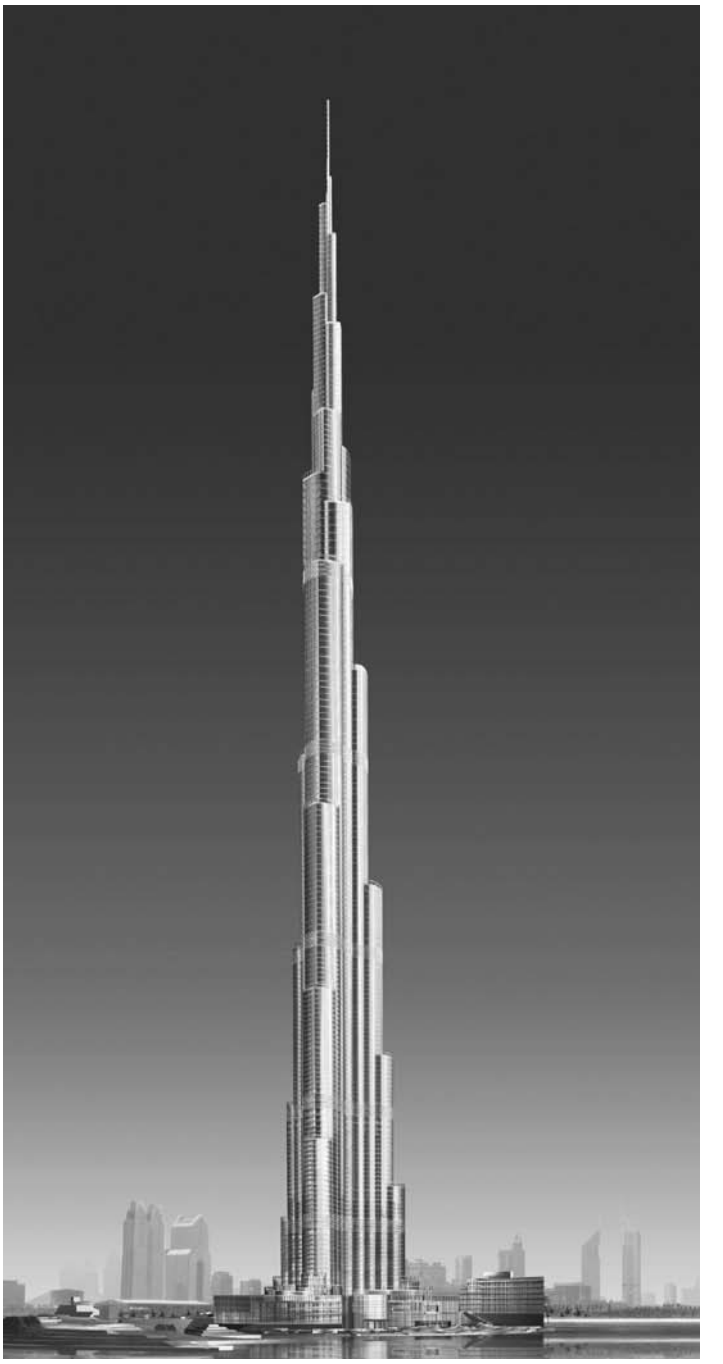

FIGURE 1–7 Burj Dubai. The world's tallest structure located in Dubai, United Arab Emirates (UAE). Courtesy of Emaar Properties, Burj Dubai (www.burjdubai.com).

[34]Fortune JW. Wright to the top. *Adapted from a paper presented at the International Association of Elevator Engineers' Elevcon '92 Conference*; first published in *Elevator Technology* (*The Construction Specifier.* September 1992:87).

[35]Salvadori M. *Why Buildings Fall Down: How Structures Fail.* New York & London: W. W. Norton & Company; 1980:21.

emphasis in modern urban architecture. According to *The Skyscraper and the City*, two reasons are paramount:

> *First, the exploding population, largely urban, creates an increasing demand for tall buildings. The ever increasing population and growing economies in major cities of the world mean increasing urbanization globally and the continuing rise in population density in urban areas. Arable land areas are constantly being eaten away by urban spreading through suburban developments. The tall building can accommodate many more people on a smaller land than would be the case with low-rise building on the same land. A tall building is in effect a vertical transformation of horizontal expansion. Second, it is generally [acknowledged] that there has been evident neglect of the human factors in urban design at the expense of livability and quality of life. The outward expansion of cities into the suburbs has resulted in increased travel time and traffic gridlock. The prospect of traveling for a long time, to and from work, is detrimental to social well-being of the commuter and results in losses of fuel and productivity. Clustering of buildings in the form of tall buildings in densely built-up areas is the opportunity for creating open spaces like playgrounds, plazas, parks, and other community spaces by freeing up space at the ground level. Besides the impact on the city skyline, tall buildings thus influence the city fabric at the level where they meet the ground. The improvement of the "public realm" has become a necessity exerted by planning authorities in major cities.*[36]

Three Generations of High-Rise Buildings

Since the first appearance of high-rise buildings, there has been a transformation in their design and construction. This has culminated in glass, steel, and concrete structures in the international and postmodernist styles of architecture prevalent today.

The following information, adapted largely from *High Rise/Fire and Life Safety*[37] by the late John T. O'Hagan, former fire commissioner and chief of the New York City Fire Department, describes three generations of high-rise buildings in the United States since their inception.

First Generation

The exterior walls of these buildings consisted of stone or brick, although sometimes cast iron was added for decorative purposes. The columns◆ were constructed of cast iron, often unprotected; steel and wrought iron was used for the beams;◆◆ and the floors

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[36]Beedle LS, Mir M. Ali, Armstrong PJ. *The Skyscraper and the City: Design, Technology, and Innovation,* Books 1. Lewiston, NY: The Edwin Mellen Press; 2007:13, 14.

[37]O'Hagan JT. *High Rise/Fire and Life Safety.* 2nd printing. Saddle Brook, NJ: Fire Engineering, A PennWell Publication; 1977:145, 146.

◆A column is "a structural member that carries its load in compression along its length. Most frequently, as in a building, the column is in a vertical position transmitting gravity loads from its top down to its base" (Answers.com, "Column" [February 18, 2007] definition from *Sci-Tech Encyclopedia*, The McGraw-Hill Companies. <www.answers.com/topic/column>; September 10, 2008).

◆◆A beam is "a term generally applied to the principal horizontal members of a building so installed to support the load of the structure" (*Construction Dictionary*. 9th ed. [Greater Phoenix, Arizona, Chapter 98. Phoenix, AZ: The National Association of Women in Construction; 1996:48]).

were made of wood. "In a fire, the floors tend to collapse, and the iron frame loses strength and implodes."[38] Elevator shafts were often unenclosed. The only means of escape from a floor was through a single stairway usually protected at each level by a metal-plated wooden door. There were no standards for the protection of steel used in the construction of these high-rises.

Second Generation

"The second generation of tall buildings, which includes the Metropolitan Life Building (1909), the Woolworth Building (1913), and the Empire State Building (1931), are frame structures, in which a skeleton of welded- or riveted-steel columns and beams, often encased in concrete, runs through the entire building. This type of construction makes for an extremely strong structure, but not such attractive floor space. The interiors are full of heavy, load-bearing columns and walls."[39]

As Brannigan described them,

> *Pre-World-War II buildings were universally of steel-framed construction. Floor construction and fireproofing of steel were often of concrete or tile, both good heat sinks and slow to transmit heat to the floor above. The construction was heavy but no feasible alternative existed.*
>
> *Relatively small floor areas were dictated by the need for natural light and air. Advertisements for the RCA Building in New York proclaimed, "no desk any farther than 35 feet from a window." This limited both the fire load and the number of occupants.... The typical office was quite spartan, though executive suites and eating clubs often were paneled with huge quantities of wood. Nevertheless, most fire loads◆ were low.*
>
> *Each floor was a well-segregated fire area in these buildings. Wall construction was frequently of wet masonry, joined to the floor so that there was an inherent firestop at the floor line. Masonry in the spandrel area (the space between the top of one window and the bottom of another) was adequate to restrict outside extension.*
>
> *In these buildings vertical shafts were enclosed in solid masonry with openings protected with proper enclosures. Fire department standpipes of adequate capacity were usually provided. These were wet and immediately pressurized by gravity from a tank in the building.*
>
> *Exterior fire tower stairways with an atmospheric break between the building and the stairway, the finest escape device available, were provided in many of the buildings. Such a stairway can be compared to an enclosed tower located away from the building which is reached by a bridge open to the weather, so that smoke cannot pollute the tower.*
>
> *Windows could be opened in buildings of this era. This provided local ventilation and relief from smoke migrating from the fire.*

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[38]Seabrook J. The Tower Builder, Why did the World Trade Center buildings fall down when they did? *The New Yorker*. November 19, 2001:66.

[39]ibid., p.66

◆*Fire load* or *fuel load* is defined by the Fire Safety Institute as "the amount of material that is contained in a building, including both contents and combustible parts of the structure" (Abbott RJ. Lesson 3. In: *Fire Science Institute Office Buildings Fire Safety Directors Course*. 212/237–8650, New York; 1994:3–59). Included in the contents are furniture and furnishings such as draperies, curtains, carpets, and mats.

> *The windows leaked, often like sieves, therefore there was no substantial stack effect.*[40]◆

In this generation of buildings, developments such as the following occurred:

- The use of noncombustible construction materials that reduced the possibility of the collapse of structural members during a fire.
- The inclusion of assemblies◆◆ rated for a particular fire resistance. The enclosure of vertical shafts with protected openings.
- The use of compartmentation.◆◆◆

Third Generation

Buildings constructed from after World War II until today make up the most recent generation of high-rise buildings. Within this generation there are those of *steel-framed construction* (*core construction* and *tube construction*), *reinforced concrete construction*, and *steel-framed reinforced concrete construction*.◆◆◆◆

Steel-Framed Core Construction

These structures are built of lightweight steel or reinforced concrete frames, with exterior all-glass curtain walls. As Salvadori stated, "The so-called *curtain walls*◆◆◆◆◆ of our high-rise buildings consist of thin, vertical metal struts or *mullions*, which encase the large glass panels constituting most of the wall surface. The curtain wall, built for lighting and temperature-conditioning purposes, does not have the strength to stand by itself and is supported by a frame of steel or concrete, which constitutes the structure of the building."[41]

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[40]Brannigan FL. *Building Construction for the Fire Service*. 3rd ed. Quincy, MA: National Fire Protection Association; 1992:458, 459.

◆"Stack effect results from the temperature differences between two areas, usually the inside and outside temperatures, which create a pressure difference that results in natural air movements within a building. In a high-rise building, this effect is increased due to the height of the building. Many high-rise buildings have a significant stack effect, capable of moving large volumes of heat and smoke through the building" (Quiter JR. High-rise buildings. In: *Fire Protection Handbook*. 20th ed. Quincy, MA: National Fire Protection Association; 2008:20–80).

◆◆*Assemblies* are barriers that separate areas and provide a degree of fire resistance determined by the specific fire resistance rating of the assembly itself. An assembly may consist of a floor, a ceiling, a wall, or a door.

◆◆◆Compartmentation or compartmentalization is the use of walls, floors, and ceilings to create barriers against the spread of smoke and fire.

◆◆◆◆"Generally, a reinforced concrete (RC) construction, a steel-frame (S) construction, and a steel-framed reinforced concrete (SRC) construction are typically used to construct buildings. In recent years, as the buildings are large-sized and high-storied, a combination of three constructions has been widely used" ("Construction method for SRC structured high-rise," [October 30, 2003], World Intellectual Property Organization. <www.wipo.int/pctdb/en/wo.jsp?IA=KR2003000643&DISPLAY=DESC>; September 2, 2008).

◆◆◆◆◆"Non-load-bearing sheets of glass, masonry, stone, or metal that are affixed to the building's frame through a series of vertical and horizontal members called mullions." (Curtain wall. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/147134/curtain-wall>; August 30, 2008).

[41]Salvadori M. *Why Buildings Stand Up: The Strength of Architecture*. New York: W. W. Norton; 1980:22.

In the center of these buildings, or infrequently to the side, there is an inner load-bearing core constructed of steel or reinforced concrete. Most building utilities and services—stairway shafts (stairwells); passenger and service/freight elevator shafts; air-conditioning supply and return shafts; communication systems (telephones, public address systems, and computer networks); water, electrical power, and gas; and restrooms (toilets)—are enclosed in this central core. The core braces the building against wind.

Steel-Framed Tube Construction

Tube structures represented a change in the design of steel-framed buildings to enable them to be built über tall and yet remain strong enough to resist the lateral forces of winds and the possible effects of an earthquake. Tube construction used load-bearing exterior or perimeter walls to support the weight of the building.

"The key to stability is a resistance to lateral wind or earthquake forces, which grow dramatically in magnitude with the building's height."[42] "If not counteracted by proper design, these forces would cause a tall building to slide on its base, twist on its axis, oscillate uncontrollably, bend excessively or break in two."[43] As Mierop explained,[44]

> *The height of a skyscraper has always been determined by the capacity of its structure to resist the lateral forces of wind and earthquake; 15 to 20 stories for a steel framework system made rigid by masonry walls; up to 60 stories, 200 meters (650 feet) high for a steel framework system made rigid by a load-bearing core, 30 meters (100 feet) wide; higher still with a bigger core, but this would be to the detriment of the economic viability of the building [since the amount of leaseable floor space would be reduced]. When the structural role is shifted from the core to the outside walls of the building, resistance is increased together, proportionally, with possible height.... This system of load bearing◆ exterior walls or "tube structure"◆◆ was developed in the early sixties in the academic context of the Illinois Institute of Technology (IIT) by the engineers Myron Goldsmith and Fazlur Khan, both of the Skidmore, Owings & Merrill Chicago Office. No spectacular advance has subsequently revolutionized the skyscraper from a structural point of view.*

"Because the core and perimeter columns carry so much of the load, the designers could eliminate interior columns, with the result that there is more open floor space

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[42]ibid., p. 116.

[43]Tucker, JB. Superskyscrapers. *High Technology.* January 1985;5(1), as quoted in Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:60.

[44]Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:60–63.

◆A load-bearing wall is defined as "a supporting wall that sustains its own weight as well as other weight. A wall that supports a portion of the building above it, usually a floor or roof; also called bearing wall" (*Glossary of Real Estate Management Terms.* Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:97).

◆◆"When the exterior walls are made rigid the building behaves like a huge hollow tube. As the interior columns no longer have to resist lateral pressure their position becomes optional and the floor layout more flexible" (Mierop C. *Skyscraper Higher and Higher.* Paris, France: Institut Francais D'Architecture; 1995:74).

for tenants."[45] Floor areas tend to be larger, with little compartmentation using floor-to-ceiling walls and barriers.

Reinforced Concrete Construction

"Concrete that has been hardened onto imbedded metal (usually steel) is called reinforced concrete,◆ or ferroconcrete…. The reinforcing steel, which may take the form of rods, bars, or mesh, contributes tensile strength."[46] Reinforced concrete is "concrete containing reinforcement and [is] designed on the assumption that the two materials act together in resisting forces."[47]

Also, according to *Encyclopædia Britannica*,

> *High-rise structures in concrete followed the paradigm of the steel frame. Examples include the 16-story Ingalls Building (1903) in Cincinnati, which was 54 metres (180 feet) tall, and the 11-story Royal Liver Building (1909), built in Liverpool by Hennebique's English representative, Louis Mouchel. The latter structure was Europe's first skyscraper, its clock tower reaching a height of 95 metres (316 feet). Attainment of height in concrete buildings progressed slowly owing to the much lower strength and stiffness of concrete as compared with steel.*[48]

"Parallel to the development of tall steel structures, substantial advancements in high-rise structural systems of reinforced concrete have been made since 1945. The first of these was the introduction of the shear wall◆◆ as a means of stiffening concrete frames against lateral deflection, such as results from wind or earthquake loads; the shear wall acts as a narrow deep cantilever beam◆◆◆ to resist lateral forces."[49] "Concrete requires no additional fireproofing treatments to meet stringent fire codes, and performs well during both natural and manmade disasters. Because of concrete's inherent heaviness,

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[45]Seabrook J. The Tower Builder, Why did the World Trade Center buildings fall down when they did? *The New Yorker*. November 19, 2001:66.

◆*Encyclopædia Britannica* states that "the first use of iron-reinforced concrete was by the French builder François Coignet in Paris in the 1850s." It also states, "Its invention is usually attributed to Joseph Monier, a Parisian gardener who made garden pots and tubs of concrete reinforced with iron mesh; he received a patent in 1867" (Reinforced concrete. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/496607/reinforced-concrete>; August 30, 2008).

[46]Reinforced concrete. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/496607/reinforced-concrete>; August 30, 2008.

[47]*Construction Dictionary*, 9th ed. (Greater Phoenix, Arizona, Chapter 98. Phoenix, AZ: The National Association of Women in Construction; 1996:432).

[48]Building construction. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/83859/building-construction>; August 30, 2008.

◆◆A shear wall is "a wall composed of braced panels (also known as shear panels) to counter the effects of lateral loads acting on a structure. Wind and earthquake loads are the most common loads braced wall lines are designed to counteract" (Shear wall. *Wikipedia*. July 17, 2008. <http://en.wikipedia.org/wiki/Shear_wall>; August 30, 2008).

◆◆◆A cantilevered beam is "a projecting beam that is supported and restrained at one end only" (*Construction Dictionary*. 9th ed. [Greater Phoenix, Arizona, Chapter 98. Phoenix, AZ: The National Association of Women in Construction; 1996:432]).

[49]Shear wall. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/539298/shear-wall>; August 30, 2008.

mass, and strength, buildings constructed with cast-in-place reinforced concrete can resist winds of more than 200 miles [322 kilometers] per hour and perform well even under the impact of flying debris."[50]

Steel-Framed Reinforced Concrete Construction

These structures are a mixture of reinforced concrete construction and steel-framed construction, hence the name *steel-framed reinforced construction*. An example would be "a steel framed structure with a concrete shear core and composite floors built with steel decking."[51] The term *mixed construction* is sometimes used to describe this type of high-rise construction.

Types of High-Rise Buildings

The use of a building has considerable influence on its security and fire life safety needs. There are different types of high-rise buildings classified according to their primary use. This book addresses the following ones:◆

1. *Office buildings*. An office building is a "structure designed for the conduct of business, generally divided into individual offices and offering space for rent◆◆ or lease."[52]
2. *Hotel buildings*. "The term 'hotel' is an all-inclusive designation for facilities that provide comfortable lodging and generally, but not always food, beverage, entertainment, a business environment, and other 'away from home' services."[53] There are also hotels that contain residences. Known as hotel-residences, this type of occupancy◆◆◆ is later addressed in mixed-use buildings.
3. *Residential and apartment buildings*. A residential building contains separate residences where a person may live or regularly stay. Each residence contains independent cooking and bathroom facilities and may be known as an apartment, a residence, a tenement, or a condominium. An apartment building is "a building

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[50]Madsen JJ. Concrete versus steel. *Buildings*, Cedar Rapids, IA; June 2005:62.

[51]Celikag M. Economic aspects of using steel framed buildings with composite floors: case studies from United Arab Emirates. Civil Engineering Department, Eastern Mediterranean University, Gazimagusa, Turkey; *Construction and Building Materials*. Elsevier; 2004;18:383–390.

◆In addition to those addressed in this book, there are other high-rise occupancies that include banking and financial institutions, day-care occupancies, detention and correctional facilities, educational institutions, government agencies, hospital and health care facilities, library and museum collections, lodging or rooming houses, and residential board and care facilities.

Also, a fairly recent development has been of vertical shopping malls in Asian cities such as Bangkok, Kuala Lumpur, and Singapore (Comments by Randy Brant, Macerich Co., in Vincent R. Developers have high hopes for vertical mall. *Los Angeles Times*. September 25, 2008:C–7).

◆◆Rent is "payment for the use of space or personal property owned by another. In real estate, a fixed periodic payment by a tenant to an owner for the exclusive possession and use of leased property" (*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:146).

[52]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:120.

[53]Beaudry MH. *Contemporary Lodging Security*. Newton, MA: Butterworth-Heinemann; 1996:ix.

◆◆◆Occupancy is "the purpose for which a building or other structure, or part thereof, is used or intended to be used" (NFPA 101. *Life Safety Code Handbook*. 10th ed. Quincy, MA: National Fire Protection Association; 2006:32, citing American Society of Civil Engineers [ASCE] 7:1.2).

containing more than one dwelling unit."[54] "Apartment buildings are those structures containing three or more living units with independent cooking and bathroom facilities, whether designated as apartment houses, … condominiums, or garden apartments."[55]

4. *Mixed-use buildings.* A mixed-use building may contain offices, apartments, residences, and hotel rooms in separate sections of the same building. Hotel-residences are another type of mixed-use occupancy. "The hotel residences trend is notably different from its predecessors such as fractional/time share hotel units, which are not wholly owned, or condo hotels, which are wholly owned hotel rooms without, for example, kitchens. Not only do hotel residences have kitchens and everything else an owner would expect in a typical abode, they also include amenities such as maid and room service, plus restaurants, spas and gyms…. Typically, [these] residences are on the top floors of hotels."[56]

In addition, there are two types of structures commonly associated with buildings that technically are classified as high-rises but usually are not required to conform to high-rise building laws, codes, and standards (particularly the laws requiring the installation of approved automatic sprinkler systems). These structures are (1) buildings used solely as open parking structures and (2) buildings where all floors above the high-rise height limit are used for open parking.

Summary

- Since their first appearance toward the end of the 19th century, the design and construction of high-rise buildings have changed considerably.
- The use of a building impacts its security and fire life safety needs. There are different types of high-rise occupancies classified according to their primary use. This book primarily addresses office buildings, hotel buildings, residential and apartment buildings, and mixed-use buildings, with some mention of the other types of high-rise occupancies.

Key Terms

Apartment. "An individual dwelling unit, usually on a single level and often contained in a multi-unit building or development."[57] See also **condominium** and **residential building.**

Apartment building. "A building containing more than one dwelling unit."[58] "Apartment buildings are those structures containing three or more living units

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[54]*Glossary of Real Estate Management Terms.* Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:8.

[55]Bush K. Apartment buildings. In: *Fire Protection Handbook.* 20th ed. Quincy, MA: National Fire Protection Association; 2008:20–37.

[56]Olmsted L. Hotel residences: all the perks, none of the work. *USA Today.* McLean, VA; September 19, 2008:8D.

[57]*Glossary of Real Estate Management Terms.* Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:8.

[58]ibid.

with independent cooking and bathroom facilities, whether designated as apartment houses, … condominiums, or garden apartments."[59] See also **condominium** and **residential building**.

Assemblies. Barriers that separate areas and provide a degree of fire resistance determined by the specific fire resistance rating of the assembly itself. An assembly may consist of a floor, ceiling, wall, or door.

Beam. "A term generally applied to the principal horizontal members of a building so installed to support the load of the structure."[60]

Building. An enclosed structure that has walls, floors, a roof, and usually windows.

Cantilevered beam. "A projecting beam that is supported and restrained at one end only."[61]

Column. "A structural member that carries its load in compression along its length. Most frequently, as in a building, the column is in a vertical position transmitting gravity loads from its top down to its base."[62]

Compartmentation. The use of walls, floors, and ceilings to create barriers against the spread of smoke and fire. Also known as *compartmentalization*.

Composite floor. "Comprise[d] of [a slab] and beams acting compositely together. Composite slabs consist of profiled steel decking working together with in situ reinforced concrete. The decking not only acts as permanent formwork to the concrete, but also provides sufficient shear bond with the concrete, so that the two materials act compositely together. Although principally for use with steel frames, composite slabs can also be supported on brick, masonry or concrete components."[63]

Condominium. "A multiple-unit structure in which the units and pro rata shares of the common areas are owned individually; a unit in a condominium property. Also, the absolute ownership of an apartment or unit, generally in a multi-unit building, which is defined by a legal description of the air space the unit actually occupies plus an undivided interest in the common elements that are owned jointly with other condominium unit owners."[64] Residential condominiums are commonplace in today's society. See also **apartment** and **residential building**.

Curtain wall. "Non-load-bearing sheets of glass, masonry, stone, or metal that are affixed to the building's frame through a series of vertical and horizontal members called mullions."[65] "Thin, vertical metal struts or mullions, which encase the large glass panels constituting most of the wall surface."[66]

Elevator. A means of vertical transportation in a building. Two main types of elevators are used in high-rise buildings: traction and hydraulic. An elevator is also known as a *lift*.

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[59]Bush K. Apartment buildings. In: *Fire Protection Handbook*. 20th ed. Quincy, MA: National Fire Protection Association; 2008:20–37.

[60]*Construction Dictionary*. 9th ed. (Greater Phoenix, Arizona, Chapter 98. Phoenix, AZ: The National Association of Women in Construction; 1996:48).

[61]ibid., p. 87.

[62]*Answers.com*, "Column" (February 18, 2007) definition from *Sci-Tech Encyclopedia*. The McGraw-Hill Companies. <www.answers.com/topic/column>; September 10, 2008.

[63]*Composite Flooring Systems: Sustainable Construction Solutions*. MCRME, UK and The Steel Construction Institute, Berkshire, UK; August 2003.

[64]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:32.

[65]Curtain wall. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/147134/curtain-wall>; August 30, 2008.

[66]Salvadori M. *Why Buildings Stand Up: The Strength of Architecture*. New York: W. W. Norton; 1980:22.

Escalator. "An escalator is just a simple variation on the conveyer belt. A pair of rotating chain loops pull a series of stairs in a constant cycle, moving a lot of people a short distance at a good speed."[67]

Fire load. "The amount of material that is contained in a building, including both contents and combustible parts of the structure."[68] Included in the contents are furniture and furnishings such as draperies, curtains, carpets, and mats. Also known as *fuel load*.

Fireproof. "Fireproof does not mean the absence of fire. It simply refers to proper building design and detail that effectively checks the spread of fire, while allowing access for occupants to escape."[69]

Footpath. See **sidewalk**.

Fuel load. See **fire load**.

High-rise. A building "that extends higher than the maximum reach of available firefighting equipment. In absolute numbers, this has been set variously between 75 feet (23 meters) and 100 feet (30 meters),"[70] or about 7 to 10 stories (depending on the slab-to-slab distance between floors). The exact height above which a particular building is deemed a high-rise is specified by the fire and building codes in the area in which the building is located.

Hotel. "The term 'hotel' is an all-inclusive designation for facilities that provide comfortable lodging and generally, but not always food, beverage, entertainment, a business environment, and other 'away from home' services."[71]

Hotel-residences. "Hotel residences have kitchens and everything else an owner would expect in a typical abode, they also include amenities such as maid and room service, plus restaurants, spas and gyms…. Typically, [these] residences are on the top floors of hotels."[72]

Hydraulic elevator. "The cabs of these elevators are moved by a telescoping tubular piston underneath, which is raised and lowered by pumping oil in and out of it with an electric pump. Hydraulic elevators move slowly, but they are the least expensive type and are well suited for low buildings."[73]

Lessee. "The tenant in a lease."[74] See also **tenant**.

Load-bearing wall. "A supporting wall that sustains its own weight as well as other weight. A wall that supports a portion of the building above it, usually a floor or roof; also called *bearing wall*."[75]

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[67]Harris T. "How escalators work." Howstuffworks? <http://science.howstuffworks.com/escalator.htm/email>; August 30, 2008.

[68]Abbott RJ. Lesson 3. In: *Fire Science Institute Office Buildings Fire Safety Directors Course*. 212/237–8650, New York: 1994:3–59.

[69]Kruse T. Designing fireproof buildings. *Skylines Magazine*. Baltimore, MD: BOMA International; March 1993:12.

[70]Knoke ME, Managing Editor, CPP. High-rise structures: life safety and security considerations. In: *Protection of Assets Manual*. Alexandria, VA: ASIS International; 2006. (Original copyright from The Merritt Company, Editor, Timothy L. Williams, 1991.)

[71]Beaudry MH. *Contemporary Lodging Security*. Newton, MA: Butterworth-Heinemann; 1996:ix.

[72]Olmsted L. Hotel residences: All the perks, none of the work. *USA Today*. McLean, VA; September 19, 2008:8D.

[73]Building construction. *Encyclopædia Britannica*. 2008. *Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/83859/building-construction>; August 30, 2008.

[74]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:94.

[75]ibid., p. 97

Mixed-use building. A building that may contain commercial offices, apartments, residences, and hotel rooms in separate sections of the same building. Hotel-residences are another type of mixed-use occupancy.

Mullion. "Thin, vertical struts … which encase the large glass panels constituting most of the wall surface"[76] of a curtain wall.

Occupancy. "The purpose for which a building or other structure, or part thereof, is used or intended to be used."[77]

Office building. A "structure designed for the conduct of business, generally divided into individual offices and offering space for rent or lease."[78]

Pavement. See **sidewalk**.

Reinforced concrete. "Concrete that has been hardened onto imbedded metal (usually steel) is called reinforced concrete, or ferroconcrete…. The reinforcing steel, which may take the form of rods, bars, or mesh, contributes tensile strength."[79]

Rent. "Payment for the use of space or personal property owned by another. In real estate, a fixed periodic payment by a tenant to an owner for the exclusive possession and use of leased property."[80]

Residence. A place where a person may live or regularly stay.

Resident. "One who lives (or resides) in a place. Referring to residential tenants as 'residents' is preferred by many real estate professionals."[81] See also **tenant**.

Residential building. A building containing separate residences where a person may live or regularly stay. Each residence contains independent cooking and bathroom facilities and may be known as an apartment, a residence, or a condominium. See also **apartment building** and **condominium**.

Shear wall. "A wall composed of braced panels (also known as shear panels) to counter the effects of lateral loads acting on a structure. Wind and earthquake loads are the most common loads braced wall lines are designed to counteract."[82]

Sidewalk. "A paved walkway [for pedestrians] along the side of a street"[83] or road in an urban area. Also known as a pavement in Britain and a footpath in Australia, India, Ireland, and New Zealand.[84]

Skyscraper. A very tall building consisting of many floors. "Today the word is rarely used to describe a building of fewer than fifty stories."[85]

Slab. "A flat, usually horizontal or nearly so, molded layer of plain or reinforced concrete usually of uniform thickness, but sometimes of variable thickness; the flat

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[76]Salvadori M. *Why Buildings Stand Up: The Strength of Architecture*. New York: W. W. Norton; 1980:22.

[77]NFPA 101. *Life Safety Code Handbook*. 10th ed. Quincy, MA: National Fire Protection Association; 2006:32, citing American Society of Civil Engineers [ASCE] 7:1.2.

[78]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:120.

[79]Reinforced concrete. *Encyclopædia Britannica. Encyclopædia Britannica Online*. <www.britannica.com/EBchecked/topic/496607/reinforced-concrete>; August 30, 2008.

[80]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:146.

[81]ibid., p. 149.

[82]*Wikipedia*. Shear wall. July 17, 2008. <http://en.wikipedia.org/wiki/Shear_wall>; August 30, 2008.

[83]*The Free Dictionary by Farley*. Sidewalk. <www.thefreedictionary.com/sidewalk>; September 6, 2008.

[84]ibid.

[85]Sonder B. *Skyscrapers*. New York: MetroBooks, Michael Friedman Publishing Group, Inc.; 1999:II.

section of floor or roof either on the ground or supported by beams, columns, or other framework."[86]

Slab floor. "A reinforced concrete floor."[87]

Stack effect. "Results from the temperature differences between two areas, usually the inside and outside temperatures, which create a pressure difference that results in natural air movements within a building. In a high-rise building, this effect is increased due to the height of the building. Many high-rise buildings have a significant stack effect, capable of moving large volumes of heat and smoke through the building."[88]

Tenant. A person, a group of persons, or a company or firm that rents or owns and occupies space within a building. "A legal term for one who pays rent to occupy or gain possession of real estate; the lessee in a lease. Real estate managers often limit the use of the term tenant to commercial tenants and refer to residential tenants as residents."[89] See also **lessee** and **resident.**

Additional Reading

1. Beedle LS, Mir M. Ali, Armstrong PJ. *The Skyscraper and the City: Design, Technology, and Innovation.* Books 1 and 2. Lewiston, NY: The Edwin Mellen Press; 2007.

2. Brannigan FL. *Building Construction for the Fire Service*. 3rd ed. Quincy, MA: National Fire Protection Association; 1992.

3. Challinger D. *From the Ground Up: Security for Tall Buildings, CRISP Report*. Alexandria, VA: ASIS Foundation Research Council; 2008.

4. "Ben" Klaene BJ, Sanders RE. *Structural Fire Fighting*. Quincy, MA: National Fire Protection Association; 2000.

5. O'Hagan JT. *High Rise/Fire and Life Safety.* 2nd printing. Saddle Brook, NJ: Fire Engineering, A PennWell Publication; 1977. John T. O'Hagan is a former fire commissioner and chief of the New York City Fire Department.

Additional Resources

1. The Council on Tall Buildings and Urban Habitat provides "studies and reports on all aspects of the planning, design, and construction of tall buildings." <www.ctbuh.org>.

2. The Emporis.com website provides information, including photographs, on buildings over 12 stories tall located throughout the world. <www.emporis.com/en>.

3. *The Fire Protection Handbook*. Quincy, MA: National Fire Protection Association.

4. Building construction. *Encyclopædia Britannica. Encyclopædia Britannica Online.* <www.britannica.com/EBchecked/topic/83859/building-construction>; 2008.

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[86]*Construction Dictionary*. 9th ed. (Greater Phoenix, Arizona, Chapter 98. Phoenix, AZ: The National Association of Women in Construction; 1996:484).

[87]ibid.

[88]Quiter JR. High-rise buildings. In: *Fire Protection Handbook*. 20th ed. Quincy, MA: National Fire Protection Association; 2008:20–80.

[89]*Glossary of Real Estate Management Terms*. Chicago, IL: Institute of Real Estate Management of the National Association of Realtors; 2003:171.