The Code Corner

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High-Rise Buildings

2012 International Building Code

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Tall structures have been in existence for centuries. The Great Pyramid of Giza, built in the 26th Century BC, was as high as 480 feet high. The Towers of Bologna, constructed in the 12th Century AD, topped out at about 320 feet for the tallest tower. Although these were tall structures, they did not perform the same functions that today's modern high-rise does. The purpose of the modern high-rise building is to maximize building area in the smallest lot area. The modern high-rise rose to prominence when two significant developments were achieved: steel frame construction and the safety elevator.

Steel frame construction allowed buildings of great height without the use of loadbearing walls, since this would have required thick walls at the base that would have rendered the lower stories useless. Steel frame construction acts like a skeleton upon which the lighter weight building skin is attached. The safety elevator provided a rapid means of travel to the upper floors without having to use stairs. The "safety" aspect is a braking device that would stop the elevator cab should it drop uncontrollably from equipment or cable failure.

From a life safety perspective, the high-rise poses unique situations not found in buildings of lower height. Regarding egress, most high-rise buildings have relatively small floor areas making the travel distance to an exit stairway well within the limitations of the *International Building Code* (IBC). However, long travel down the stairs is slow compared to egress through corridors and exit passageways. Additionally, the heights associated with high-rise buildings make it more difficult to fight fires at the extreme elevations.

How 'High' is a High-Rise Building?

This discussion regarding building height leads to the prime question: at what height is a building considered a high-rise? A *high-rise building* is defined in Chapter 2 of the IBC as a "building with an occupied floor located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access." Unlike the standard building height dimension regulated by the IBC, the height for determining a high-rise building is determined by two different points of measurement: 1) the lowest level of fire vehicle access and 2) the highest occupied floor (See Figure 1).

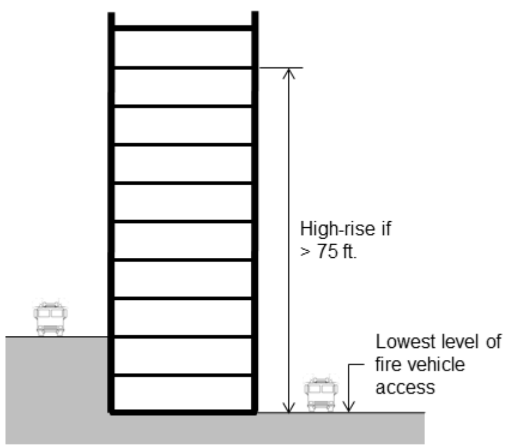

Figure 1 - Determination of a high-rise building.

Regarding the bottom point of measurement, if a building is constructed on a site that has varying grade levels around its perimeter, the measurement is not to be taken at the *grade plane* as defined by the IBC. Rather, the dimension is measured to the actual surface of the ground or pavement that is accessible by fire department vehicles. This measurement point can be above or below the grade plane.

For the upper measurement point, this is taken at the floor level and not the overall height of the building. For example, if a building has an overall height of 80 feet, but the highest occupied floor is at 70 feet, it is not considered a high-rise building. However, if the building has an occupied roof (*i.e.* roof decks, but excluding occupancy for maintenance purposes), some building officials would consider the roof as an "occupied floor," thereby making the roof and not the enclosed floor below the point of measurement.

Knowing where to take the measurement is important, but why is the measurement limited to 75 feet? To understand this, you have to understand firefighting capabilities. Although platform and aerial ladder fire trucks have reaches that exceed 75 feet, geometry may factor into the actual reach capabilities of the fire department. Although the measurement is to the ground level of the fire department access, there is no requirement for how close the access must be to the building beyond the *International Fire Code* (IFC) requirement that fire access roads extend to within 150 feet of all portions of a building's first story. Therefore, the farther the fire truck is from the building, the lower the height it can reach. The Insurance Services Office (ISO), which rates fire departments, has set a maximum reach of 100 feet to achieve maximum points in this category.[1] This gives the fire department a 25-foot margin if they encounter differing circumstances at incident sites, such as the location of the fire lane from the building.

Special Requirements for High-Rise Buildings

Section 403 of the IBC establishes the minimum requirements for high-rise buildings. This section starts off with a list of buildings that, by definition, are high-rise buildings but are considered exceptions to the special requirements. These include airport traffic control towers, open parking garages, Group A-5 buildings, special industrial occupancies, and Group H-1, H-2, and H-3 occupancies. This section adds supplementary requirements beyond the basic requirements in other sections of the IBC. However, this section also modifies some basic requirements for high-rise buildings or exempts them from some basic requirements.

As a result of the September 11, 2001, attacks on the World Trade Center (WTC) in New York City, the IBC incorporated a number of revisions over time within the 2006, 2009, and 2012 editions—the majority of which were implemented in the 2009 edition. These revisions were implemented to increase the protection of building elements and enhance the means of egress systems in high-rise buildings. In the 2006 IBC, a specific distinction was made between two types of high-rise buildings: those that are not greater than 420 feet in building height and those that are greater than 420 feet in building height. You will notice that, unlike the definition of a high-rise building, this height is measured according to the IBC definition of *building height*, which is between the grade plane and the average roof height of the highest roof.

Construction Type and Fire-Resistive Construction

Based purely on Table 503 of the IBC, high-rise buildings must be of Type I construction. However, with a sprinkler system, a Type IIA, Type IIIA, or Type IV building could become a high-rise building if an occupied floor (or occupied roof, depending on the building department's interpretation) is more than 75 feet above the fire department vehicle access.[2]

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[1] The measurement is to the roof and not the highest occupied floor level. If a community does not have a building with a roof height greater than 100 feet, then they will award maximum points if the fire department can reach the height of the highest building in the community. The ISO does not factor in the distance the apparatus is from the building; therefore, a straight up vertical reach that meets the minimum height satisfies the ISO requirement.

[2] These construction types have a maximum building height of 65 feet. With a sprinkler system, the height can be increased to 85 feet, which means a floor could possibly be located above 75 feet without exceeding the maximum number of stories if large floor-to-floor heights are used.

If a high-rise building is equipped with sprinkler control valves that have both supervisory initiating devices and water-flow initiating devices at each floor,[3] then the fire-resistive ratings associated with the construction type could be reduced. A Type IA high-rise building that is not greater than 420 feet is permitted to be constructed using fire-resistance ratings equal to that of Type IB construction, except that the fire-resistance rating of columns supporting floors cannot be reduced. A Type IB high-rise building—except for Group F-1, M, and S-1 occupancies—is permitted to be constructed using the fire-resistance ratings of Type IIA construction. For either of these two reductions, the use of the building height and area limitations for the original construction type are permitted. For example, a Type IB, Group B high-rise building may reduce the fire-resistance rating of its building elements to that of Type IIA construction per IBC Table 601, but the height and area of the building is still limited to that of Type IB construction per IBC Chapter 5.

Although not specific to high-rise buildings, the definition of *primary structural frame* in the IBC was modified as a result of the National Institute of Standards and Technology's (NIST) building code recommendations following its WTC research. The definition stipulates that lateral bracing is part of the primary structural frame if it is essential to the vertical stability of the building—even if the bracing does not carry any gravity loads. Therefore, if IBC Table 601 requires a 2-hour rating for the primary structural frame, then lateral bracing for high-rise buildings would be considered essential to the building's vertical stability and would be required to have an equal fire-resistance rating.

The IBC has one other reduction and one increase for high-rise buildings relating to fire resistance. The reduction applies to high-rise buildings not greater than 420 feet, and allows the fire barriers for vertical shafts—this does not include shafts for elevators and exit enclosures—to be reduced from 2 hours to 1 hour. The increase applies to sprayed fire-resistant materials, and increases the minimum bond strength from 150 psf (IBC Section 1705.13.6), to 430 psf for high-rise buildings up to 420 feet, and 1,000 psf for high-rise buildings greater than 420 feet (IBC Table 403.2.4).

Means of Egress

Several changes and additions to the means of egress requirements have been introduced in the IBC for high-rise buildings. Some of these new requirements were controversial and were opposed by organizations such as the Building Owners and Managers Association (BOMA).

The most controversial requirement was an additional stairway for buildings more than 420 feet in height (IBC Section 403.5.2). For example, a building with multiple stories and an occupant load of 500 or less for each story would be required to have a minimum of two exits from each story. However, if that building exceeds 420 feet in height, then a third stairway would be required. This is to overcome the problem encountered at the WTC in 2001, when occupants were egressing down the stairs while firefighters were trying to work their way up the same stairs. Furthermore, if one exit is removed, the remaining exits must provide the total exit width calculated per Section 1005.1. This additional stairway requirement applies to all applicable high-rise buildings in all occupancy groups except for Group R-2.

The exception to the additional stairway requirement is to provide an occupant evacuation elevator per IBC Section 3008. See *The Code Corner* No. 38, "Elevators," for a detailed discussion on occupant evacuation elevators.

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[3] Supervisory initiating devices monitor the status of critical operating features of an automatic sprinkler system to ensure proper operation when needed. Water-flow initiating devices send a signal to the fire alarm system when they detect water moving through an automatic sprinkler system due to an open sprinkler head.

Also related to exit stairways is the remoteness requirement (IBC Section 403.5.1). The remoteness requirement states that interior exit stairways be separated by a distance not less than 30 feet or ¼ of the overall diagonal of the building or area to be served, whichever is less. If three or more exit stairways are provided, at least two shall comply with the remoteness requirement. If interlocking stairs are provided, the stairs will be counted as a single exit stairway.

Per IBC Section 403.5.3, doors leading into exit stairways are permitted to be locked from the stairway side, provided that all doors can be unlocked—not unlatched—simultaneously upon a signal from the fire command center, which is discussed later in this article. For stairways where doors are locked from the stairway side, a two-way communication system connected to a "constantly attended station" must be provided on the stairway side at every fifth floor.

Stairways serving high-rise buildings are required to be constructed as smokeproof enclosures per IBC Section 403.5.4, which references IBC Sections 909.20 and 1022.10. Section 1022.10 establishes the basic requirements for interior exit stairways within smokeproof enclosures. The smokeproof enclosure must be accessed through a vestibule[4] unless the pressurization alternative is implemented. The smokeproof enclosure must terminate at an exit discharge or a public way; however, it can be extended using an exit passageway. To do so, the exit passageway must be separated from the smokeproof enclosure with a fire door and have no other openings other than the door to the exit discharge. Other openings are permitted into the exit passageway provided it is accessed by vestibules like the smokeproof enclosure or is pressurized in the same manner as the smokeproof enclosure. If the exit passageway is pressurized in the same manner as the smokeproof enclosure, then the fire barrier and fire door between the smokeproof enclosure and exit passageway may be eliminated. Finally, the last exception permits the smokeproof enclosure to egress through areas on the level of exit discharge per IBC Section 1027.

Another requirement specific to high-rise buildings is the use of luminous markings for the egress path per IBC Section 1024. The only occupancy groups to which this applies are A, B, E, I, M, and R-1. This section explains in great detail what needs to be marked and how. If the stairway egresses through areas on the level of exit discharge, such as a lobby, the markings are not required in those areas.

The last egress requirement for high-rise buildings is actually an exception. IBC Section 1029 requires that Group R-2 occupancies be provided with emergency escape and rescue openings for all sleeping rooms in stories below the fourth story. However, because of the added protection and safety measures required of high-rise buildings, IBC Section 403.5.6 exempts high-rise buildings from having these openings.

Structural Integrity

Structural integrity is a set of requirements that was introduced in the 2009 IBC as a result of the WTC investigations. The structural integrity requirements, located in IBC Section 403.2.3, apply to interior stairways and elevators in high-rise buildings in Risk Category III or IV per IBC Table 1604.4 and all high-rise buildings that are more than 420 feet in height. The intent of this category is to ensure that elevators and interior stairways stay intact following a significant impact to those elements.

The Code Corner No. 41, "Gypsum Board Construction," describes in greater detail the requirements for structural integrity for soft body impact. Although that article focuses on gypsum board (the most susceptible material likely to be used for these elements), the requirements apply to any material that is not masonry or concrete, which are exempted from the requirements. Additionally, any complete wall assembly that has been tested to Classification Level 3 for Hard Body Impact per ASTM C 1629,

[4] In lieu of a vestibule, an open exterior balcony may be used. However, for high-rise buildings this may be an unlikely option to consider, especially for stories at great heights.

Standard Classification for Abuse-Resistant Nondecorated Interior Gypsum Panel Products and Fiber-Reinforced Cement Panels, is permitted to be used.

Fire Protection and Emergency Systems

A fire command center (FCC) complying with IBC Section 911 is required in each high-rise building. The design professional can locate the FCC where it best suits the project, but the location must be approved by the fire official. The FCC must be separated from the rest of the building using 1-hour fire barriers, horizontal assemblies, or both. The size of the room must have a minimum area of 200 sq. ft. with a minimum dimension of 10 feet; therefore, a 20-foot by 10-foot room is the minimum requirement. IBC Section 911.1.5 provides a complete list of features that are required for the FCC. The layout of the FCC and its features must be approved prior to installation.

Standby and emergency power systems are required for specific loads indicated in IBC Sections 403.4.8 and 403.4.9, respectively. The main difference between a standby power system and an emergency power system is that the emergency power system requires its own distribution system (*i.e.* wiring, conduit, panels, etc.)—the standby power system can share the main distribution system. Standby power is required for elevators, ventilation and fire detection equipment in smokeproof enclosures, and power and lighting for the FCC. Emergency power is required for exit signs, means of egress lighting, elevator car lighting, voice/alarm communication system, automatic fire detection system, fire alarm system, and electric fire pumps. The IBC specifically requires standby power generators that are located inside the building be separated from the rest of the building with 2-hour fire barriers, horizontal assemblies, or both. However, since the National Fire Protection Association (NFPA) 110, *Standard for Emergency and Standby Power Systems*, is referenced by the IBC for both types of systems, then a room, separated as required for an indoor standby power generator, is also required for an indoor emergency power generator.[5]

It probably goes without saying that high-rise buildings are required to be equipped with an automatic sprinkler system. IBC Section 403.3 requires a system complying with NFPA 13, except for parking garages and telecommunications equipment buildings. For buildings over 420 feet in height, a second riser is required for each sprinkler system zone. Furthermore, each riser must supply water to sprinklers on alternating floors. This prevents large, continuous blocks of stories from being unprotected should one riser fail for any reason. To maximize the survivability of the risers, risers must be located in stairways that are separated by a minimum of one-third the overall diagonal dimension of the building.

In addition to a sprinkler system, standpipe systems are also required for all high-rise buildings. Since high-rise buildings are required to have a sprinkler system, a Class I standpipe is the minimum requirement per Exception 1 to IBC Section 905.3.1. Hose connections are required at all floor levels above and below grade, and they shall be placed at intermediate landings between floors or as approved by the fire code official. If the high-rise building has a heliport, helistop, rooftop gardens, or landscaped roofs, then the standpipe is required to extend to the rooftop.

Fire pumps for all high-rise buildings must be supplied by connections to two separate water mains located on two separate streets per IBC Section 403.3.2. Two connections to the same main are permitted provided that the main has valves that can isolate a break and not interrupt the supply to no less than one of the connections. The piping connecting the fire pump to the two connections must also be separate.

[5] NFPA 110 requires that an indoor Level 1 system be enclosed in a room separated from the rest of the building with 2-hour construction. A level 1 system is defined by NFPA 110 as a system that "could result in the loss of human life or serious injuries." The explanatory information for NFPA 110 indicates that the loads required by the IBC are considered those applicable to a Level 1 system.

Connections and piping for each line must be sized so that each line can individually provide the required flow and pressure for the fire pump. Lastly, the room containing the fire pump must be separated from the rest of the building by fire barriers and horizontal assemblies with a fire-resistance rating of not less than 2 hours.

Several types of alarm, notification, and communication systems are specifically mandated for high-rise buildings. The first is a voice/alarm communication system, which shall operate upon activation of a smoke detector, manual alarm box, or sprinkler water-flow device. The voice/alarm communication system must sound a tone that is followed by evacuation instructions. The second is a smoke detection system, which requires detectors in mechanical, electrical, telephone, elevator, and similar type equipment rooms, as well as elevator lobbies. Duct smoke detectors are also required in main return air and exhaust air plenums of air conditioning systems with a capacity greater than 2,000 cfm and connections to vertical ducts or risers connecting two or more stories. The third and final system is a fire department communication system, which is wired and connects the FCC to the elevators, elevator lobbies, emergency and standby power rooms, fire pump rooms, areas of refuge, and exit stairways.

High-rise buildings, like any other new building, are required to have emergency responder radio coverage throughout the building per IFC Section 510. This requires that a system be installed in a building that ensures adequate radio communications between emergency responders. Exceptions allow a wired system if approved by the fire code official, no system if the fire code official determines the coverage is not needed, or the fire code official may allow an automatically activated system if it is determined that a continuously operating system would have a negative impact on the normal operation of the building.

Smoke Removal

Another provision added to the IBC in the 2009 edition is the requirement to provide mechanical or natural ventilation. The intent of this requirement is to provide a means for firefighters to expel the smoke after a fire event without requiring a full smoke control system that is specified in IBC Chapter 9. The requirement (IBC Section 403.4.7) identifies three methods: 1) manually operated windows or panels, 2) mechanical air equipment, or 3) an alternate method.

The first method requires easily identifiable windows or panels to be located around the perimeter of the building at 50-foot maximum intervals. The area of the openable units shall be based on 40 sq. ft. for every 50 feet of building perimeter. Thus, if a building has a 300-foot perimeter, it will need to provide a minimum of 6 windows or panels with each window or panel providing a minimum of 40 sq. ft. of openable area. There are two exceptions that modify this requirement. The first exception applies to Group R-1 buildings that have sleeping units or suites located along the exterior wall. This exception allows each sleeping unit or suite to provide an operable venting unit having an area of 2 sq. ft. in lieu of the main requirement. The second exception allows fixed windows, but the glass must be able to be easily removed by breaking or other means to achieve the required area.

The second method allows the use of mechanical air-handling equipment to exhaust the smoke directly to the exterior. The mechanical equipment must provide a minimum of one air change every 15 minutes. For example, if a floor has a volume of 55,500 cubic feet, then an exhaust system that provides a minimum airflow of 3,700 cfm is needed (55,500 cubic feet ÷ 15 minutes).

The third method allows an alternative method that is approved by the building official. If a building or a portion of a building is provided with a smoke control system in accordance with IBC Section 909, the building official may allow that system to be used instead of the less sophisticated methods described above.

The Future

It is ironic that today's modern model life safety codes were developed as a result of a high-rise fire. In 1911, a fire occurred on the eighth floor of the ten-story Asch Building in New York City that left 146 occupants dead. Today, that building is called the Brown Building and is a part of the New York University campus in Greenwich Village. The fire, better known as the Triangle Shirtwaist Factory fire, was considered the deadliest building disaster in New York until the WTC collapse 90 years later.

The NFPA, after the Triangle Shirtwaist Factory fire, worked towards improving the life safety aspect of buildings and developed the *Building Exits Code* in 1927, which would over time become the NFPA 101, *Life Safety Code*. Also in 1927, the International Conference of Building Officials enacted the first *Uniform Building Code*, which incorporated construction and life safety requirements. Although a model building code did exist prior to 1911 by the National Board of Fire Underwriters, its focus was preventing collapse and limiting structural damage, and not protection of life safety.

Like the Triangle Shirtwaist Factory fire, the WTC tragedy instigated sweeping changes to building and life safety codes with a greater emphasis on high-rise buildings. Even though many requirements have been added to the IBC and other codes based on the recommendations of NIST, not all of the recommendations have been adopted. Some of the proposals still under consideration include requiring buildings over 420 feet high to survive a complete burnout with only minor structural failure, requiring buildings not to experience a collapse that is disproportionate to the initiating failure (*i.e.* progressive collapse, such as that experienced by the WTC), and requiring a video surveillance system in exit stairways, elevator lobbies, elevator hoistways, and elevator equipment rooms for emergency responder situational awareness. These proposals may or may not be included in future editions of the IBC, but there will likely be other events that will trigger new changes, and the cycle will continue.

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