INTERNATIONAL
FIRE PROTECTION

ARTICLES

The reliability of fire protection features in high-rise buildings

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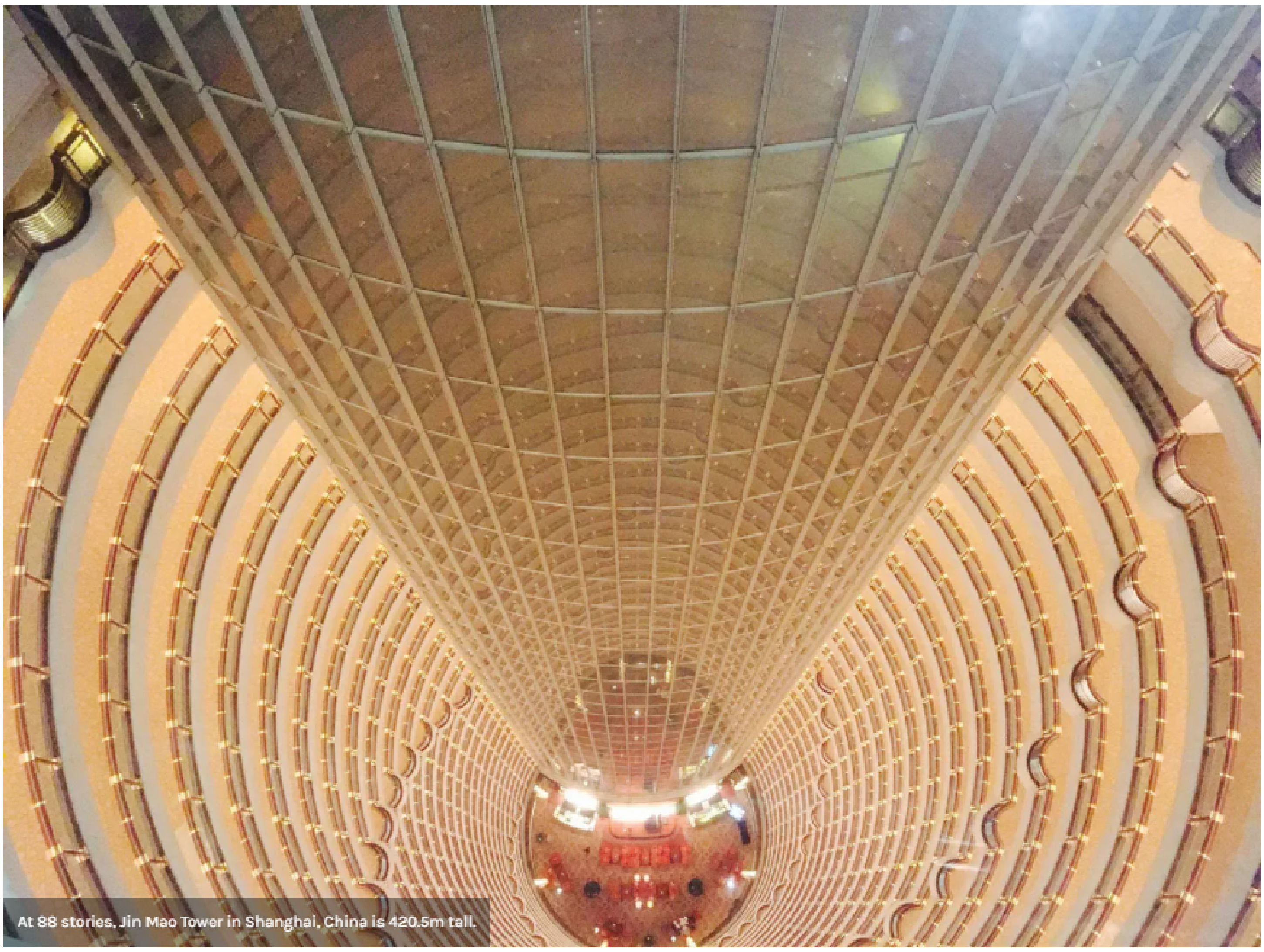

At 88 stories, Jin Mao Tower in Shanghai, China is 420.5m tall.

One of the key components of fire safety in high-rise buildings is the reliability of the fire protection systems and features. We tend to use the terms reliability, redundancy and resilience interchangeably and in fact they are all aspects of our overall goal that the fire safety features perform as intended under a broad range of emergent conditions. This article will look at reliability of fire protection systems in high-rise buildings – why it is important and how it can be achieved.

It is important to understand that to provide a safe building environment active and passive features must function reliably in adverse conditions. This involves three aspects:

1. Design – incorporating features that improve reliability.
2. Installation – installing and commissioning fire systems to assure they perform as intended
3. Operation & maintenance – inspection, testing and maintenance of fire safety features throughout the life of the building.

This article will focus primarily on the design aspect of reliability.

The Burj Khalifa in Dubai stands 829.8m high, making it the tallest building in the world.

Why is reliability important in high-rise fire safety?

There are several unique characteristics of high-rise buildings that present a challenge for fire safety.

a. If allowed to spread beyond the area of origin, an uncontrolled fire and its effects can impact a large building population

b. Occupants of tall buildings are far from exterior exits resulting in long evacuation distances that can be physically strenuous and may involve travel through the fire floor to reach grade

c. Firefighting must occur from inside the building using highly specialized firefighting techniques and equipment.

To address these unique characteristics, a fire safety strategy for high-rise buildings must include active and passive building features that accomplish the following goals:

a. Control fire and its effects to the floor or area of origin.

b. Maintain tenable conditions for occupants during fire – defend in place

c. Firefighting must occur from inside the building using highly specialized firefighting techniques and equipment.

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a. Control fire and its effects to the floor or area of origin.

b. Maintain tenable conditions for occupants during fire – defend in place

c. Provide infrastructure to facilitate firefighting inside the building.

The result of this fire safety strategy is a highly complex arrangement of active and passive fire protection features to meet the demands of keeping a building fire safe. For these features to operate as intended in an emergency, they must be highly reliable.

A review of building code provisions related to reliability

Most building codes include prescriptive requirements that are intended to increase the reliability of fire protection systems. The International Building Code (IBC) is the predominant building code used in the United States. Historically, this code has evolved in response to a wide variety of fire challenges. For high-rise building design, the IBC has evolved over the years to mandate structural fire resistance, fire-separated exit paths and active fire suppression, alarm and smoke-management systems.

As a result of the events of 9/11, the National Institute of Standards & Tests (NIST) made several recommendations to improve the reliability of fire protection features of high-rise buildings. These recommendations were incorporated into the 2009 edition of the IBC, section 403 for high-rise buildings greater than 420ft (128m) in height. These new provisions of IBC include the following:

1. Higher fire resistance for the building's structural frame (3-hour fire resistive construction) and floor assemblies (2-hour fire resistive construction) to enhance survivability from a prolonged fire event and allow occupant evacuation.
2. Structural integrity of exit stairs and hoist ways to resist impact loads based on ASTM C 1629/C 1629M and increase their usability during a fire.
3. Bond strength of sprayed fire-resistant materials (SFRM) increased to 1,000psf to improve the reliability of spray fireproofing on structural steel elements during adverse fire conditions.
4. Multiple risers to supply water to Sprinkler and standpipe systems and redundant water supply sources to improve the reliability of these systems to fight fire.
5. An additional exit stair so that if one stair is being used for firefighting operations, sufficient exits are still available for building occupants.
6. Occupant Evacuation Elevators as an additional measure to facilitate full building evacuation in the event this becomes necessary.

It is important to understand that different codes use different strategies to achieve reliability. An example of this is the design of fire pumps. The IBC and its associated NFPA standard for fire pumps include highly rigorous technical requirements for fire pump design and operation that are designed to maximize reliability of each individual fire pump during adverse conditions. At the same time, there is no requirement in IBC or NFPA for redundant or backup fire pumps in case of failure of the primary pump.

Other international codes use a slightly different '+1' approach. This approach assumes a single failure and builds in redundancy by requiring '+1' above the minimum required to function. For example, Duty plus standby fire pumps to increase reliability of overall pumping system, or +1 exit stair so that if one stair is blocked, the exits are still sufficient for evacuation of the buildings occupants.

Both approaches are designed to improve the reliability of the overall fire protection systems in the building.

Located in Kuala Lumpur, the Merdeka 118 tower is over 600m in height.

Some best practices and solutions to address reliability

There are several design solutions for tall buildings that have become best practices and in some cases code requirements. As tall buildings are designed and the fire safety strategy is developed, each building is benchmarked against other similar buildings. In this way the strategies continue to evolve and refine.

The structural design of tall buildings has evolved to include the widespread use of a poured-in-place concrete core structure. This creates an opportunity to locate the building critical life safety features within this core providing the highest level of protection from fire and other events to these critical elements. This strategy was quickly adopted and it is now considered a best practice to locate the exit stairs, firefighting elevator and lobby, as well as critical life safety risers for fire suppression, fire alarm, emergency communication and power, within the concrete core structure whenever possible.

Fire protection water supply is one of the critical elements for tall buildings as the active suppression systems that control fire growth rely heavily on the reliability of the water supply that gets water on the fire effectively. In many locations, public utilities may not be sufficient or reliable to serve these buildings. In several cases, this has been addressed by providing the fire protection water supply within the building. An early example of this is the Jin Mao building in Shanghai. The 88-storey mixed-use structure was developed in an area of the city where there was not sufficient public infrastructure in the region to support it. As a result, the design solution was to provide dedicated fire protection water tanks at each mechanical level. Each tank was sized to supply 1-hour of water to sprinkler systems. To improve the reliability of this system, all the tanks were interconnected so that each could provide backup water to other tanks throughout the building.

A third level of redundancy was provided by interconnecting the sprinkler system water supply to both the standpipe system tanks (separate network of tanks) and to the domestic water tanks throughout the building. One additional measure to improve reliability was to design the sprinkler systems so that to the extent possible, the sprinkler systems are fed by gravity from the water supply tank located above. This eliminates the failure of a fire pump as a potential impairment of the suppression system. This approach has been used on several tall buildings including Burj Khalifa and the Jeddah Tower in Jeddah, Saudi Arabia.

One critical aspect of life safety in tall buildings is protecting building occupants during evacuation. In very tall buildings (over 80 stories) this becomes more complex than simply providing exit stairs. For a variety of reasons, most building occupants are not able to evacuate from tall buildings using the stairs. As a result, we have developed a strategy based on defending occupants in place and only moving them when necessary. In most tall buildings defending in place includes some form of 'safe areas' or safe floors. Many codes in Asia and the middle east mandate the use of *Refuge Floors or Refuge Areas*. These are spaces within the building designed to the same level of protection as exit stairs but offering a place where building occupants can be held to rest and, if necessary, can be staged for further evacuation using exit stairs or evacuation elevators.

In many locations where refuge floors are not required, the sky lobbies that connect shuttle elevators at various points in the building often serve the same purpose of providing a safe area for occupants during evacuation. Sky lobbies are used primarily for circulation of large numbers of building occupants during normal operations, so they generally have sufficient space to stage large portions of the building's occupants during evacuation.

One final feature is the use of elevators for evacuation in tall buildings. Recognized in the 2009 IBC as an alternative to providing an additional exit stair, evacuation elevators are well suited to facilitating the evacuation of large building populations. Generally, evacuation elevators are required to be provided with emergency power so they can be relied on in an emergency and provided with a means of communicating to occupants during emergencies.

Conclusions

It is recognized that tall buildings above 420ft require increased reliability of critical fire safety features. A number of these are prescribed by code based on a study of fires in tall buildings. Other strategies to improve reliability have evolved as buildings continue to increase in height. The key is to look at fire safety of tall buildings holistically recognizing that one size does not fit all and that code minimums may not achieve the desired level of reliability that the building will perform as intended in a broad range of emergencies.

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