

The Society of Fire Protection Engineers Series

Fire Safety for Very Tall Buildings

Engineering Guide

Second Edition



The Society of Fire Protection Engineers Series

Series Editor

Chris Jelenewicz

Society of Fire Protection Engineers

Gaithersburg, MD, USA

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About SFPE

SFPE is a global organization representing those practicing in the fields of fire protection engineering and fire safety engineering. SFPE's mission is to define, develop, and advance the use of engineering best practices; expand the scientific and technical knowledge base; and educate the global fire safety community, in order to reduce fire risk. SFPE members include fire protection engineers, fire safety engineers, fire engineers, and allied professionals, all of whom are working towards the common goal of engineering a fire safe world.

About ICC

The International Code Council is the leading global source of model codes and standards and building safety solutions that include product evaluation, accreditation, technology, training, and certification. The Code Council's codes, standards, and solutions are used to ensure safe, affordable, and sustainable communities and buildings worldwide.

Preface

The performance history of very tall buildings, while extremely successful, has not been without major incidents causing injury and death. The modern building codes have made major progress in addressing unique issues of design and construction in very tall buildings based on scientific research and lessons learned from catastrophic fires.

From a historic perspective, the model codes included unique provisions for high-rise buildings that evolved over time. These features include separation of egress routes, additional egress shaft requirements, fire department and occupant evacuation elevators, egress markings, stairway structural integrity, and a higher level of structural fire protection. However, the current building codes still may not provide comprehensive performance solutions or adequately address other risks inherent in very tall buildings.

The complexity and unique challenges of today's very tall buildings, coupled with sustainability goals of material, energy, water, and resource savings, have created an environment where comprehensive performance-based solutions have become a necessity. Such is the reason why SFPE and the International Code Council (ICC) published the first edition of this guide in 2013. SFPE would like to thank ICC for its assistance in publishing the first edition of this guide.

The research and practical experience related to the design and construction of very tall buildings advanced substantially since the first edition of this guide was published. SFPE has been monitoring this progress, and the SFPE Task Group on Fire Safety for Very Tall Buildings has made an effort to develop and advance an updated version of this guide. The result is the second edition of the *SFPE Engineering Guide to Fire Safety in Very Tall Buildings*.

This guide is not intended to replace the adopted building and fire codes of jurisdictions; rather, it is intended to complement such codes and serves as an added tool for all those involved in the design, review, construction, inspection, and commissioning of new or existing very tall buildings.

Society of Fire Protection Engineers

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Chapter 1

Introduction



Scope

This guide provides information on special topics that affect the fire safety performance of very tall buildings, their occupants, and first responders during a fire. These topics are addressed as part of the overall building design process using performance-based fire protection engineering concepts as described in the *SFPE Engineering Guide to Performance-Based Fire Protection* [1]. This guide is not intended to be a recommended practice or a document suitable for adoption as a code.

The guide pertains to “super tall,” “very tall,” and “tall” buildings. Throughout this guide, all such buildings are called “very tall buildings.” These buildings are characterized by heights that impose fire protection challenges; they require special attention beyond the protection features typically provided by traditional fire protection methods. This guide does not establish a definition of buildings that fall within the scope of this document and does not intend to apply the definitions found in any code or standard. Rather, it directs the user to perform a risk analysis to achieve a reasonable and adequate solution for the specific building. A description of the elements of a risk analysis is presented in Chap. 7 (Hazard, Risk and Decision Analysis in Very Tall Building Design).

Many building fire risks are exacerbated by height. Challenges associated with height will vary depending upon the type of fire protection features included in the building. These features can include but are not limited to egress, smoke control, structural fire resistance, and suppression systems.

While the focus of this guide is fire safety in very tall buildings, it should be recognized by the building designers that fires may be a consequence of a primary incident, such as earthquakes, floods, tsunamis, hurricanes, tornados, cyclones, and other natural or man-made events. All these events could jeopardize one or more features or systems comprising the construction, means of egress, or fire safety systems provided in the building.

Additionally, while this guide primarily addresses new construction, designers of existing very tall buildings undergoing fire safety upgrades can benefit from the topics discussed. Existing very tall buildings are addressed in Chap. 22 (Existing Building Considerations).

Purpose

The purpose of the guide is to identify the unique fire safety challenges related to very tall buildings and provide the professionals engaged in the design of these buildings with information on the topics that affect the performance of very tall buildings and their occupants during a fire. By considering these topics, the design professional can prepare a fire protection design report, a fire strategy report, or a fire protection engineering design brief for the project. The guide expects that the design professional will have a fundamental understanding of fire dynamics and is competent in the application of scientific and engineering principles for the evaluation and design of systems and methods to protect people and their environment from the unwanted consequences of fire. The topics identified in this guide are intended to be addressed using performance-based fire protection and engineering concepts and the lessons learned from a historical context.

Background

The impetus for the first edition of this guide [2] was the global increase in the design and construction of very tall buildings. At that time, many very tall buildings used a variety of regulations, codes, and standards, many of which did not contemplate the heights of these buildings.

The World Trade Center terrorist attack on September 11, 2001, caused enhanced interest in the challenges of very tall buildings: those that are taller than what has generally been classified as a “high-rise” building. Among those challenges are:

- Egress and evacuation
- Emergency access
- Communications/situation awareness
- Fire resistance/resiliency
- Reliability of water supply and active fire protection systems
- First responder mobilization

Another factor is the increased number of very tall buildings, resulting from improvements in design technology in areas such as structural design. However, building codes address high-rise buildings but may not adequately address the additional risks inherent with very tall buildings.

This guide builds on the information included in the first edition and emphasizes the importance of taking an integrated approach to the design of fire safety in very tall buildings. An integrated approach looks beyond simply complying with codes and standards and considers how the height of the structure impacts safety and how the various fire safety features in the building complement each other to achieve the building's fire safety goals.

Chapter 2

History



Very tall buildings are not recognized as a special category of buildings in all codes and standards. “High-rise buildings,” which are defined by many codes as those 23 m (75 ft) or greater in height from the lowest level of fire department vehicle access, were not recognized as special buildings in codes and standards until the 1970s. Moreover, the term “high rise” was not mentioned until the 13th Edition of the NFPA *Fire Protection Handbook* [3] that was published in 1969 and only in the context of standpipe systems.

The experience with fires in very tall buildings contributed to the development of fire safety provisions for very tall buildings in the model codes and standards. Several fires in recent history brought attention to the fire safety risks associated with very tall buildings. This focus has increased again with several incidents around the world involving facade fires.

Among the significant very tall building incidents are fires at the following buildings:

1. One New York Plaza – August 15, 1970 [4]
2. MGM Grand – November 21, 1980 [5]
3. First Interstate Bank – May 4, 1988 [6]
4. One Meridian Plaza – February 23, 1991 [7]
5. World Trade Center Terrorist Attack – February 26, 1993 [8]
6. World Trade Center Buildings 1 and 2 Terrorist Attack – September 11, 2001 [9]
7. World Trade Center Building 7 (WTC 7) Terrorist Attack – September 11, 2001 [10]
8. Cook County Administration Building – October 17, 2003 [11]
9. Caracas Tower Fire – October 17, 2004 [12]
10. Windsor Tower, Madrid, Spain – February 12, 2005 [13]
11. The Beijing Mandarin Oriental Hotel Fire – February 9, 2009 [14]
12. Shanghai Apartment Tower Fire – November 15, 2010 [15]
13. Lacrosse Fire – November 25, 2014 [16]
14. The Address Downtown Hotel – December 31, 2015 [17]

15. The Torch – February 21, 2015 [18] and August 4, 2017 [19]

16. Grenfell Tower – June 14, 2017 [20]

While these fires were distinctive, they share common factors. The lessons derived from these factors have had an impact on the global development of codes and standards and are summarized in Table 2.1. The general lessons learned pertain to:

- Unprotected vertical openings
- Inadequate structural fire resistance
- Combustibles in concealed spaces
- Inadequate elevator operations
- Inadequate fire control (e.g., automatic sprinklers, fire barriers)
- Inadequate protection of exit stairways
- Combustible interior finish
- Combustible exterior wall systems
- Redundancy of critical systems
- Inadequate maintenance of fire protection systems and egress components
- Inadequate emergency plan
- Inadequate fire alarm notification

The following paragraphs describe some of these incidents in more detail. The buildings involved may not have met the applicable building regulations at the time of the fire for new construction. In some cases, fire experience demonstrates a lack of compliance with codes and standards at the time of construction or adequate enforcement of adopted regulations associated with post-construction occupancy and operations. Details of these fires and associated buildings are contained in the references. The cited references are not intended to be an exhaustive list of information for the reader.

One New York Plaza, New York, USA – August 15, 1970

A fire occurred on the 33rd floor of the 50-story One New York Plaza office building. Workers from the 32nd floor discovered the fire. Two guards and a telephone company employee took an elevator to the 39th story with the intention of notifying the occupants of the fire. Because the elevator was called to the fire floor by the effects of the fire, the elevator stopped at the 33rd floor. The two guards died; the telephone company employee survived.

Table 2.1 Summary of major lessons learned from major very tall building fires

Incident	Unprotected vertical openings	Inadequate structural fire resistance	Combustibles in concealed spaces	Inadequate elevator operations	Inadequate fire control, e.g., automatic sprinklers, barriers	Inadequate protection of exit stairways	Combustible interior finish	Combustible exterior wall systems	Redundancy of critical systems	Inadequate maintenance of fire protection systems and egress components	Inadequate emergency plan	Inadequate fire alarm notification
One New York Plaza, New York, USA – August 15, 1970		X		X								
MGM Grand Hotel, Las Vegas, USA – November 21, 1980	X		X	X		X	X				X	
First Interstate Bank, Los Angeles, USA – May 4, 1988				X	X	X					X	X

(continued)

Table 2.1 (continued)

Incident	Unprotected vertical openings	Inadequate structural fire resistance	Combustibles in concealed spaces	Inadequate elevator operations	Inadequate fire control, e.g., automatic sprinklers, barriers	Inadequate protection of exit stairways	Combustible interior finish	Combustible exterior wall systems	Redundancy of critical systems	Inadequate maintenance of fire protection systems and egress components	Inadequate emergency plan	Inadequate fire alarm notification
One Meridian Plaza, Philadelphia, USA – February 23, 1991					X					X		X
World Trade Center Explosion and Fire, New York, USA – February 26, 1993									X			
World Trade Center Buildings 1 and 2, New York, USA – September 11, 2001		X							X			

Incident	Unprotected vertical openings	Inadequate structural fire resistance	Combustibles in concealed spaces	Inadequate elevator operations	Inadequate fire control, e.g., automatic sprinklers, barriers	Inadequate protection of exit stairways	Combustible interior finish	Combustible exterior wall systems	Redundancy of critical systems	Inadequate maintenance of fire protection systems and egress components	Inadequate emergency plan	Inadequate fire alarm notification
World Trade Center Building 7, New York, USA – September 11, 2001		X							X			
Cook County Administration Building, Chicago, USA – October 17, 2003					X	X					X	
Caracas Tower Fire, Caracas, Venezuela – October 17, 2004										X		

(continued)

Table 2.1 (continued)

Incident	Unprotected vertical openings	Inadequate structural fire resistance	Combustibles in concealed spaces	Inadequate elevator operations	Inadequate fire control, e.g., automatic sprinklers, barriers	Inadequate protection of exit stairways	Combustible interior finish	Combustible exterior wall systems	Redundancy of critical systems	Inadequate maintenance of fire protection systems and egress components	Inadequate emergency plan	Inadequate fire alarm notification
Windsor Tower, Madrid, Spain – February 12, 2005	X	X			X							
The Mandarin Oriental Hotel, Beijing, China – February 9, 2009								X				
Shanghai Apartment Tower Fire, Shanghai, China – November 15, 2010								X			X	

Incident	Unprotected vertical openings	Inadequate structural fire resistance	Combustibles in concealed spaces	Inadequate elevator operations	Inadequate fire control, e.g., automatic sprinklers, barriers	Inadequate protection of exit stairways	Combustible interior finish	Combustible exterior wall systems	Redundancy of critical systems	Inadequate maintenance of fire protection systems and egress components	Inadequate emergency plan	Inadequate fire alarm notification
Lacrosse Fire, Melbourne, Australia – November 25, 2014								X				
The Address Downtown Hotel, Dubai, UAE – December 31, 2015 [15]								X				
The Torch, Dubai, UAE – February 21, 2015 and August 4, 2017								X				
Grenfell Tower, London, UK – June 14, 2017					X	X	X	X		X	X	X

Lessons Learned

The consequences of this fire led to improvements, including revisions to the elevator code, specifically:

1. Protection of steel members with appropriate materials
2. Automatic elevator recall
3. Elevator call buttons that cannot be activated by fire or smoke
4. “Fire fighter’s service” that allows elevators to be recalled to the “home” floor manually by a key-operated switch at the elevator access lobby and to be operated by a fire fighter from within the car with a key-operated switch

MGM Grand Hotel, Las Vegas, USA – November 21, 1980

A fire at the MGM Grand Hotel resulted in the deaths of 85 guests and hotel employees. About 600 others were injured, and approximately 35 fire fighters sought medical attention during and after the fire. The very tall building, constructed in the early 1970s, consisted of 21 stories of guest rooms above a large, ground-level complex comprised of a casino, showrooms, convention facilities, jai alai fronton, and a mercantile complex. The hotel was partially sprinklered, but major areas including the main casino and The Deli restaurant, the area of fire origin, were not sprinklered. About 3,400 registered guests were in the hotel at the time of the fire. The most probable cause of the fire was heat produced by an electrical ground fault within a combustible concealed space in a waitresses’ serving station of The Deli restaurant [5].

Lessons Learned

1. Vertical openings, including seismic joints, stairways, and elevator shafts, must be protected to limit smoke and fire spread between floors.
2. Combustible concealed spaces in fire-resistive and noncombustible buildings should be limited.
3. Automatic elevator recall is needed.
4. Flame spread of interior finish can contribute to rapid fire spread.
5. Stairway doors should allow reentry to floors at not more than five floor intervals.
6. HVAC systems must be protected to avoid distributing smoke during a fire.
7. Large assembly buildings need a pre-fire emergency plan.