Technical and Code Aspects of Investigation of Fire Impact on Buildings and Their Occupants

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I. Introduction

Safety in fires is one of the main goals of codes and regulations that govern the design, construction, maintenance, and alteration of buildings. These regulations may be embedded within different codes depending on the jurisdiction. However, there are substantial commonalities in how codes approach protecting buildings and their elements in fire. Any reference to fire safety in this paper refers to protection of buildings, their occupants, their contents, and first responders.

The purpose of this paper is to provide a broad understanding of what is in the codes for fire safety, and how they can impact an investigation. This information is essential to allow an attorney to engage the right experts and ask the right questions. This discussion is not exhaustive. Rather, the focus is to provide the right level and breadth of information to assist an attorney in envisioning the nature of the issues that they have to contend with.

The paper will cover the approach of codes to fire safety, discuss the most widely adopted model code, and present typical questions that arise in an investigation, whether before or after a fire incident, and some technical tools available to help the investigations.

II. Code Approaches to Protection of Buildings and Their Occupants in Fire

Building codes intends to reduce fire risk to buildings, their occupants, their contents, first responders, and the public. The codes use a combination of different strategies at various levels to achieve these goals. These measures are intended to facilitate evacuation, allow for early detection and alarm, enable fire suppression through active building systems or by firefighters, and provide structural resistance and barriers to fire so the building remains stable and slows the spread of fire. Some of these measures may include:

- Providing protected means of egress to evacuate quickly from the area of the fire
- Fire detection and alarm systems to allow for faster response by building occupants and firefighters
- Passive fire protection measures to extend the duration of resistance of building elements to fire
- Horizontal and vertical barriers such as floors, walls, and protected openings, joints, and penetrations to contain the fire in a local area and slow down its spread
- Fire resistant exterior walls that prevent the spread of the fire from outside the building to other floors or adjacent buildings
• Automatic sprinkler systems and smoke management systems to extinguish or control thermal and smoke effects of fire.
• Standpipes, fire department connections, fire command centers, etc. to allow for safe effective firefighting

III. Codes and Standards

Most of the fire safety regulations in the US are based on the model code of the International Building Code (IBC) and its affiliated family of codes including the International Fire Code (IFC), International Mechanical Code (IMC), International Plumbing Code (IPC), etc. The family of I-Codes are compatible with each other. Local jurisdictions might adopt some or all of these codes, with or without modifications. When it comes to fire safety provisions, most jurisdictions have relatively small modifications to the IBC provisions, if any. Therefore, this paper will reference IBC for the purpose of discussion of code provisions, recognizing that there are some local variations.

IBC establishes minimum requirements for building systems and intends to establish provisions that adequately protect public health and safety and welfare without unnecessarily increasing construction costs. This means that code provision do not eliminate risks absolutely, but rather mitigate risk, whether from fire or other hazards such as earthquakes, wind, etc. The importance of fire is reflected in that two of the four committees responsible for writing the code are related to fire safety (Fire Safety and Egress committees).

For existing buildings, local jurisdictions might mostly adopt IBC, the International Existing Building Code (IEBC), a combination, or other local laws to decide on lower requirements for existing buildings. For major rebuilding efforts including rebuilding after a fire, these differences in requirements can have a significant impact.

IV. Overview of Most Relevant IBC Chapters

Much of the specific code requirements applicable to a building, including the fire safety measures, are determined by the construction type and occupancy. Construction type depends on the combustibility of the materials used for the exterior and interior of a building. Occupancy refers to the type of use for a building such as residential, educational, business, etc. Construction type and occupancy not only impact the height, size, and location limitations for the buildings, but also drive many of the fire safety requirements. Typically, buildings with higher risks in terms of the impact on the people, the building, or the adjacent area have more strict code requirements.
The fire safety provision of IBC are interspersed, but primarily in chapters 7 to 11, 14, and 26. These provisions of the code cover many protection elements such as fire-resistance-rated construction, combustibility restrictions, fire separations, protections for openings, smoke control, active fire detection and suppression systems, protected means of egress, and systems to allow safe and effective firefighting. Here is a brief overview of the scope of each chapter:

**Chapter 7, Fire and Smoke Protection Features:** This chapter discusses materials, techniques and methods of construction to limit the impact of fire on a building. One measure is fire-resistance-rated construction requirements to allow the building to passively limit the spread and impact of fire while maintaining its integrity for potentially a limited time. The provisions also include separation of spaces using fire walls, fire barriers, fire partitions, horizontal assemblies, smoke barriers, and smoke partitions. These provisions intend to compartmentalize the thermal and smoke effects of fire and allow time for people to evacuate safely and for first responders or building fire suppression systems to extinguish the fire.

It is important to understand the exact meaning of defined terms in the code. These terms imply different construction and rating requirements and have global implications for design and investigation. For example, the areas on two sides of a fire wall may be treated as separate buildings with implications for design requirements, but also renovation and repair after a fire. However, the same is not true for fire partitions or fire barriers.

**Chapter 8, Interior Finishes:** This chapter provides specification for flame spread and smoke development for materials that can be used inside a building. These measures impact how quickly the flame and smoke impact the occupants and spread to the rest of the building.

**Chapter 9, Fire Protection and Life Safety Systems:** This chapter provides requirement for the active systems in a building that help the detection, alarm and automatic suppression of the fire, smoke management, or effective response of firefighters. Some of these elements include the sprinklers, standpipe system, portable fire extinguishers, fire alarm and detection systems, smoke control systems, and fire pumps.

**Chapter 10, Means of Egress:** This chapter specifies requirements for means of egress to allow for people to evacuate from the areas impacted by fire or other hazards. It should be noted that the adequacy of the of means of egress also depends on other assumption about the response of a building to a fire,
including fire detection and alarm, fire suppression systems, and fire resistance of building elements. It is possible for people to die from fire in a code-compliant building.

Chapter 11, Accessibility: This chapter provides broad accessibility requirements for buildings. While such measures are important for providing convenient access to buildings to all member of society, they are essential when it comes to safety in fire.

Chapter 14, Exterior Walls: This is one of the most important chapters of the code for providing fire safety. Fire in a building can spread within a floor, or from floor to floor. Many of the code requirements intend to prevent the spread of a fire from one floor to the next. If the fire impacts two floors or more, many assumptions of design such as how people will escape, how the building will stand up in fire, and how effectively to fight the fire may not be relevant anymore. Therefore, it is important that the exterior wall does not provide an easier path for the fire to jump to the next floor. A vulnerable exterior wall may result in a building with several floors engulfed in fire, a situation with substantial risk to life for the building occupants and firefighters. The unfortunate tragedy of the Grenfell Tower fire, as well as similar other high profile fires such as in Address Hotel in Dubai highlight this point.

Similarly, without the protection of an exterior wall, a fire can spread to adjacent buildings and the public, multiplying the risk to life and property and making effective firefighting more difficult.

It is important to note that exterior walls or also essential to thermal comfort, proper lighting, energy performance, and carbon footprint of buildings as well their aesthetics. The competing demands on exterior walls have resulted in significant complexity and innovation in design of building exterior walls, including use of combustible materials within building exterior walls that are classified as non-combustible. As Such, there are more code interpretation and legal responsibility questions relevant to newer exterior wall systems.

Chapter 26, Plastics: This chapters codifies the use of plastics such as foam plastic, plastic veneer, and interior plastic finishes as a fire and smoke hazard within buildings.

Appendix D, Fire Districts: This appendix provides requirement that are relevant to mitigate the risk of conflagration within dense city areas by restricting occupancies and setting higher construction standards. Local jurisdictions may choose to adopt similar measures.
V. Other Standards

IBC and similar codes reference several standards to provide more specific requirements for a systems, material, test, etc. These standards become part of the law by reference. It is important to note which version of each standard is being referenced. A list of references at the end of IBC and similar codes provides the list of the referenced standards and the applicable edition. Some of the most referenced standards related to fire safety are published by National Fire Protection Association (NFPA), ASTM International (formerly American Society for Testing and Materials), and UL (formerly Underwriters Laboratories).

VI. Investigation of Design and Construction Issues Before Fire

Given the extent of code provisions related to fire safety, design and construction issues related to them are common. Some of the challenges for investigation in a building that has not caught fire include:

- Many of the elements of fire safety are hidden by building finishes and systems and not visible at the end of construction. Investigation of any potential deficiency in these elements might be very costly and involve removing finishes and building systems and disrupting the functionality of the building.
- While more egregious deficiencies such as lack of firestops might be verified visually, checking the adequacy of other elements might require testing.
- There might be code interpretation issues related to complex building systems as well as what requirements should apply based on how the building is classified.

VII. Investigation after a Fire Incident

Investigation of the impact of a fire or roles and responsibilities can be very complex and involve multiple different set of issues. The resolution of these issues will depend on the specifics of each case. However, it is important to understand some of the main questions that might have to be answered. Here is a list of some common issues:

A. Design deficiency: Did any design deficiencies contribute to the fire impact? Did the building require a code upgrade that was not provided? Was the right edition of the code used? Are there complex
materials, building systems, façade systems, etc. that make code interpretation less straightforward?

B. **Construction deficiency:** Were there features of the building that were missing or improperly installed? Were all the building elements tested, inspected, or certified as needed? Where there changes during construction that made it not code compliant? Did the applicable code requirements change during construction, and were these changes incorporated into design and construction?

C. **Maintenance:** Were all building elements maintained per code? Are there adequate maintenance records?

D. **Adjacent buildings:** Did adjacent buildings impact the fire in the building of interest? Were there any deficiencies in those buildings that contributed to the result? Did the building of interest cause damage to adjacent buildings?

E. **Risk to life:** Were there any casualties or injuries as a result of the fire? Did any deviation from regulations contribute to the loss of life? Can advanced analytical tools be used to model what happened and understand different contributing factors?

F. **Extent of damage:** Is the building stable and repairable? Are there safety risk to building repair that have to be considered? What it the extent of damage to the building structure, façade, architectural features, functionality, and building systems such electrical and mechanical systems? Is there any portion of the building that can be maintained? Can technical tools such as non-destructive and destructive testing, or modeling of fire dynamics and building response to fire be used to help understand the impact of the fire and contribution of different factors? What was the exposure temperature and time for different building elements and systems and how hot did they get?

G. **Questions of rebuilding:** Is rebuilding in kind permissible or does the rebuild require a code upgrade? If so, is there a code upgrade requirement for structural systems (gravity or seismic and wind resisting system), accessibility, fire protection systems, mechanical and electrical systems, or a combination of the above? What are the triggers for code upgrades based on the cost, area, or nature of repair? Is code upgrade required only for the repaired portion of the building or the entire building? Are there fire walls within the construction that
can allow for separate evaluation of the rebuild question for different portions of the building? Is a code upgrade as a result of fire covered by insurance?

VIII. Conclusions

Fire safety provisions are a substantial part of building codes and impact most aspects of design and construction. For a specific building, these provisions also depend on other classification such as construction type, occupancy, floor area, and buildings heights. The various set of rules create a complex interconnected system whose satisfactory performance in fire depends on proper design, construction, and maintenance such that all the systems work together. There is ample room for mistakes in design or construction.

Fire itself is also highly complex, impacting buildings and their occupants differently in each case. Therefore, the set of challenges posed to investigate a fire, its impact, and roles and responsibilities are also complex and vary case by case and jurisdiction by jurisdiction. The questions of rebuilding and code upgrades could be particularly challenging.

The key to a proper investigation is to understand the web of regulations in the applicable code and how they interact, know the technical tools that are available to understand what happened and assess the extent of visible and hidden damage, and have a good checklist of the type of questions that are relevant in the context of fire. Ultimately, it is important to fully use technical and code expertise by subject matter experts to help navigate complex investigations of fire impact on buildings and their occupants.