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Fire/Life Safety in High-Rise Buildings

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James Carrigan has 33 years of experience in Fire and Life Safety System Engineering, 28 with Syska Hennessy Group. His career has focused on design and analysis of Fire/Life Safety in high-rise buildings; where he has successfully completed hundreds of large scale projects. James has published many articles nationally on the subject. He is nationally certified Firefighter-1; former paramedic and Chief Officer with the Nassau County Fire Service; coordinating several responses to the World Trade Center site on 9/11 for rescue & recovery. James currently heads Syska's Fire/Life Safety Group; also serving as the United Nations Liaison to the FDNY.

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Brian Blicher has over 7 years of experience including work on multiple high-profile construction projects. His work includes preparing fire safety/emergency action plans, fire protection plans, consulting for historic, ICC, and NFPA codes, commissioning fire alarm systems, Statement of Conditions surveys, fire safety evaluation system assessments, and due diligence assessments. He also has experience in fire alarm and sprinkler system design and PBD equivalences involving smoke management and fire spread analyses. Brian supervises the preparation of all required documentation to ensure that requirements are met, as well as coordinate the needs of the selected system with the other engineering disciplines.

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Laura Bennett has over 8 years of experience in the Fire Protection Engineering industry. Her work in fire protection engineering is extensive, including design and analysis of fire alarm, mass communication, and fire suppression systems. Laura is experienced in system design and analysis for a wide variety of clients and building types, specifically including healthcare facilities, stadia, laboratory/science and technology facilities, and historical landmarks. She has a sound understanding of national and local fire protection and building codes and standards has allowed her to assist clients in developing successful building code variances and equivalencies.

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Abstract

Syska Hennessy Group and the Fire Department of the City of New York propose a paper and presentation detailing an overview of Fire/Life Safety in High-Rise Buildings in New York City. The paper will focus on a history of notable high-rise building fires; a history of the New York City Building Code (NYCBC); an overview of the latest (2014) NYCBC and an overview from the Fire Department of the City of New York on the World Trade Center (WTC) Building Code Task Force, detailing specific code updates for resilient high-rise buildings.

Keywords: Building Code, Fire Safety, Life Safety, Resilient, Technology

Preface

The Council on Tall Buildings and Urban Habitat (CTBUH) defines a high-rise building as "a building whose height creates different conditions in the design, construction, and use than those that exist in common buildings of a certain region and period" (CTBUH, 1995). Various international code bodies, including the 2014 New York City Building Code (NYCBC) define a high-rise building as "a building with an occupied floor located more than 75 feet (23m) above the lowest level of fire department vehicle access." High-rise buildings exist in practically all major cities throughout the United States and in over forty countries worldwide. High-rise buildings date back to ancient times, where such structures were constructed for religious and/or defensive purposes. In the late 1800's high-rise buildings were constructed in urban areas of the United States, where population densities spurred a demand for high-rise buildings which occupied less valuable land area. These structures were primarily built for residential and business use. Today high-rise buildings are used for almost all occupancy types including assembly; educational; institutional; mercantile and storage; with a more recent world-wide trend toward mixed occupancy super high-rise buildings in excess of 984 feet (300m), which provide a more efficient use of these tall buildings. The resurgence of the high-rise building is viewed as an important component of economic power and prestige of the many cities and countries who invest in high-rise building projects. New York City has historically contained more high-rise buildings than anywhere else in the world, ranking second only to Hong Kong when comparing completed **super high-rise** buildings in excess of 492 feet (150m) in height.

While high-rise buildings provide many economic and social benefits to the regions they serve, these buildings have garnered considerable attention in the fire/life safety community over the past decade. Unfortunate and tragic fire "events" affecting high-rise buildings, dating back to the early 1900's, have caused dramatic loss of life and property. Many governments, authorities having jurisdiction (AHJ), labor groups, design professionals, owners and fire prevention and safety agencies are affected by these tragic events and high-rise building fire/life safety.

By learning about the history of tragic fires in high-rise buildings, one can best understand the fire/life safety regulations of today. These notorious fires have taught fire protection professionals valuable lessons and many fire safety codes and standards were developed after such unfortunate events.

High-rise buildings present several unique challenges not found in traditional low-rise buildings: longer egress times, evacuation/in-building relocation or defend-in-place strategies, fire department accessibility, smoke movement and fire control. Several major high-rise fires in the past decade have demonstrated the complexities of dealing with these incidents and the potential for major disaster due to the failure of one or more components of the building's fire protection systems. These incidents also show how the presence of a properly maintained and functioning fire protection system, including automatic sprinklers, could have minimized the damage and the number of fatalities.

History of Building Codes and Notable Fires Pertaining to New York City High-Rise Buildings

In 1850, New York City adopted its first building code. After another 32 years of development and growth within the City and a higher demand for taller buildings that were not addressed by the building code in place, Chapter 410 of the Laws of 1882 passed in the New York State Senate. Chapter XI of Chapter 410 covered the New York City Fire Department (FDNY), which included the requirements for "Construction of Buildings" under Title 5. Title 5 contained a few provisions with regards to fire protection for buildings based upon increased height. These provisions called for fireproof doors, blinds, and shutters to be installed on exterior openings for most multi-story buildings, fireproof trap-doors at elevator openings at each floor of a building, and the installation of fire escapes on most new and existing multi-story buildings.

By 1882, the New York City Department of Buildings (DOB) was established as the governing body for building construction and was equipped with a much more detailed and comprehensive building code. The new building code was based upon Chapter 410 of the Laws of 1882, yet contained several amendments from 1885, 1887, 1889, and 1892. The 1892 NYCBC required all bui ldings over 85 feet in height to be constructed as fireproof. This requirement to construct fireproof buildings, in turn, required egress stairs to be constructed "entirely of brick, stone, iron or other hard, incombustible materials" and for exposed portions of structural beams comprised of wrought-iron or rolled-steel to be encased in hard-burnt clay or porous terra-cotta. Additionally, certain tall buildings were required to enclose egress halls and stairs with 12 inch thick brick walls.

The 1899 NYCBC provided a format change that would serve as the model building code for nearly 40 years. The new code lowered the height cut-off for fireproof construction in new buildings from 85 to 75 feet and brought new requirements that included:

- Encasing all interior cast-iron, wrought-iron, or rolled steel columns in fireproof buildings with a minimum two inches of fireproofing
- Providing standpipes in existing buildings exceeding 100 feet in height and new buildings exceeding 85 feet in height
- Providing a secondary water source for standpipes, a steam fire pump, and an elevator in readiness for the FDNY in all buildings exceeding 150 feet in height
- Protecting the cellar levels of "high-rise" business and manufacturing buildings via perforated iron pipes attached to the standpipe system or automatic sprinklers
- Providing multiple exit stairs per floor based upon the area of the floor plate

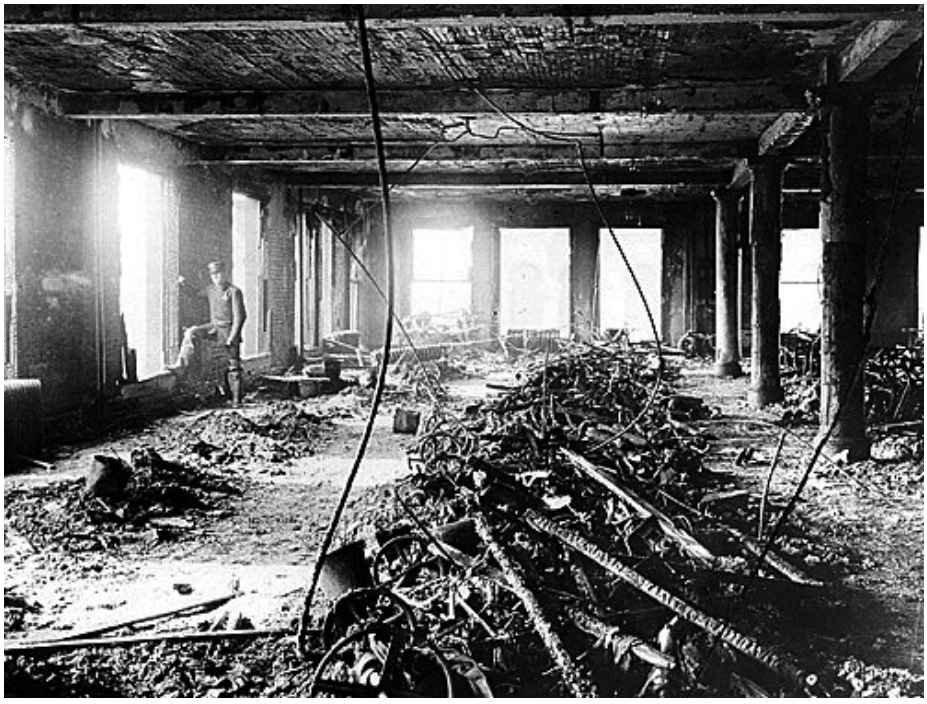

Figure 1. The Triangle Shirtwaist Factory Fire (Source: Milwaukee Journal, 1911)

Triangle Shirtwaist Factory Fire (occupied the top 3 floors of the Asch Building, constructed in 1901):

Date: March 25, 1911 (4:40PM)
Description: The deadliest industrial disaster in the history of the city of New York caused the injury of 71 garment workers and the deaths of 146. It is remembered as one of the most infamous incidents in American industrial history, as the deaths were largely preventable. Most of the victims died as a result of neglected safety features and locked doors within the factory building (Figure 1).
Results: Within three years, more than 36 new state laws had passed regulating fire safety and the quality of workplace conditions. The landmark legislation gave New Yorkers the most comprehensive workplace safety laws in the country and became a nationwide model.

Figure 2. The Equitable Life Assurance Society Office Building Fire (Source: nyc-architectural.com)

Equitable Building Fire (constructed in 1869 and expanded in 1886):

Date: January 9, 1912 (5:00AM)
Description: An employee of the Cafe Savarin, located on the first floor of the 'fire proof' Equitable Life Assurance Society Office

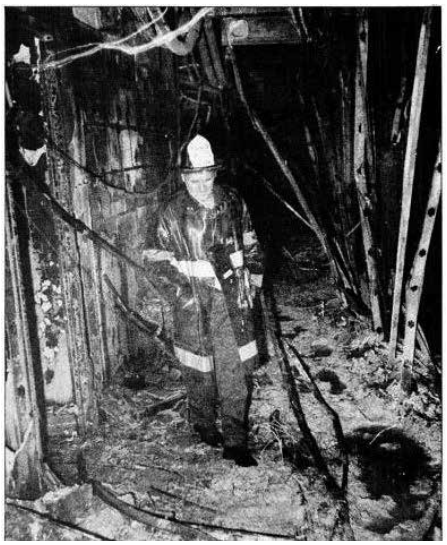

Figure 3. 33rd Floor of One New York Plaza (Source: New York Magazine, 1974 © New York Magazine, 1974)

Figure 4. 919 Third Avenue (Source: Wikimedia Commons)

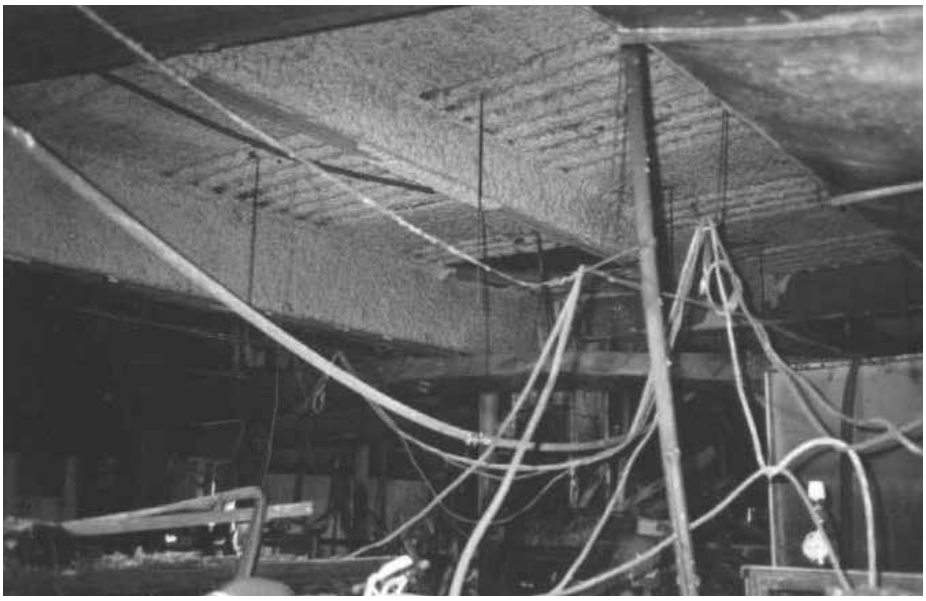

Figure 5. Bankers Trust Fire (Source: J. Gordon Routley. USDHS, USFA-TR-071, 1993)

Building, threw a lit match into the garbage, which engulfed his office in flames. The flames spread to the unprotected elevators and dumbwaiter shafts, and within minutes the entire building was aflame. Below-freezing weather coupled with sustained winds of 40 miles per hour, as well as an estimated 30 minute delay in notifying the fire department, hampered extinguishing efforts. This fire called attention to the inability of any fire department to effectively fight a fire in the upper stories of a tall building lacking such essential fire appliances as an adequate standpipe equipment in conjunction with smoke-proof stair towers. In total, five civilians and one firefighter perished in this fire and the subsequent building collapse, which caused in excess of $3.5 million in damage (Figure 2).
Results: The New York Board of Fire Underwriters were commissioned to conduct a full investigation of the fire and made several recommendations: protect stairs, elevators and openings with fire stops and fire doors; provide automatic sprinklers in all portions of office buildings where fire is most likely to occur or spread; increase standpipe diameter to 6 inches minimum; provide at least two enclosed fireproof stairways; provide smoke proof tower; and fireproof structural metal.

While still considered an amendment to the 1899 NYCBC, the 1916 version brought many changes, several of which were inspired by recommendations from the National Board of Fire Underwriters published in 1915. The 1916 NYCBC included new, detailed sections dedicated to egress and the prevention of fire spread. The "Exit Facilities" section provided new methods of determining occupant load, had much more stringent requirements for exits, and specifically required business buildings more than 75 feet in height (125 feet if fully sprinkler protected) to be equipped with smoke-proof exit enclosures, also known as fire towers.

The "Safeguards Aginst Spread of Fire" section required shafts to be provided at each series of floor openings within both fireproof and non-fireproof buildings.

The 1938 NYCBC brought about another format change that would last for 30 years, but most of the requirements of the 1938 NYCBC with respect to fire protection in "high-rise" buildings mirrored those of the 1916 NYCBC. The development of the 1968 NYCBC would result in the last major change in format unique to New York City, one that would last for 40 years. The 1968 NYCBC lessened some of the restrictions within the 1938 NYCBC, making high-rise buildings –a term first defined in New York City in the 1968 NYCBC cheaper and easier to construct while taking advantage of modern developments in construction:

- Fireproof construction could be used for non-sprinklered, high-rise buildings of unlimited area and height for multiple occupancy types with reduced fire-resistance ratings on structural members (compared to the 1938 Building Code)
- Fire tower stairs were no longer required
- Egress capacities per exit were increased
- Fire alarm systems were largely not required (standpipe fireline telephone and signaling system were required in buildings over 300 feet in height)
- Sprinklers were typically only required for sub-grade floors.

One New York Plaza & 919 Third Avenue Fires (constructed in 1969 and 1970, respectively, to the 1938 NYCBC):

Date: August 5, 1970 (6:00PM)
Description (One New York Plaza): This office tower in lower Manhattan suffered a severe fire, which started in a 33rd Floor telephone closet and burned for more than 6 hours, spreading throughout the 33rd and 34th floors. This fire injured 20 occupants and killed two. Use of the elevators during this incident resulted in the two deaths when the car inadvertently stopped at the fire floor (Figure 3).

Date: December 4, 1970 (9:45PM)
Description (919 Third Avenue): The 4-alarm fire in this office building started when a contractor's torch touched ignited fire in a pile of carpet remnants, partially destroying the fifth floor and killing three occupants. 52 other occupants were injured,

including a dozen firefighters. Total property damage to the building and its contents was estimated at $2.5 million. Use of the elevators during this incident resulted in the three deaths when the car inadvertently stopped at the fire floor (Figure 4).

Results: These fires resulted in the passage of Local Law 5 of 1973, which created the Fire Safety Plan, the entire Fire safety team, and the Fire Safety Director. In 1984 Local Law 16 was adopted for fire safety in high-rise buildings. These Local laws had a profound effect on fire safety in the city[1&2].

Bankers Trust Building Fire (constructed in 1962, to the 1938 NYCBC):

Date: January 31, 1993 (10:45PM)
Description: This high-rise office complex was the scene of a major fire resulting in more than $10 million of direct property damage and a much larger loss due to business interruption and secondary effects. The fire, which originated on the sixth floor ceiling plenum, spread to the seventh and was extending into the eighth floor before it was controlled. It was the most destructive high-rise fire in New York City in more than a decade (Figure 5).

Results: This fire is particularly significant as an evaluation of the effectiveness of Local Law 5, the retroactive requirements that were enacted for all high-rise office buildings in New York City. It suggests that the compartmentation option offered by Local Law 5 may be inadequate to prevent fires from growing to extremely destructive proportions. This reinforces the opinion of many fire experts and authorities having jurisdiction that automatic sprinklers should be required in all existing high-rise buildings and new construction.

World Trade Center (WTC) (Towers 1 and 2 constructed in 1970 and 1971, respectively, to the 1968 NYCBC):

WTC Terrorist Events:
Date: February 26, 1993 (12:18PM)
Description: A terrorist truck bomb exploded in the underground garage of the 110-story WTC complex. The massive explosion sparked several car fires and destroyed most of the building's primary and backup emergency systems. Smoke infiltrated the stair shafts because doors at the basement level were blown off and pressurization fans could not operate due to the destruction of the electrical systems. Six people died and more than 1,000 others were injured, not including 105 firefighters were also injured. Total property damage to the building and its contents was estimated at $250 million (Figure 6).

Results: This event demonstrated the magnitude of problems that result when there is a complete failure of the emergency systems in a high-rise building. Thousands of occupants were trapped on office floors, many of which were filling with smoke that was rising through the stair shafts. Others were trapped in elevators which stopped

Figure 6. February 26, 1993; Smoke billows out of the World Trade Center (WTC) (Source: NY Times, 1993)

Figure 7. Flames erupt from the South Tower of the World Trade Center (Source: Reuters/Sean Adair)

1: The provisions of Local Law 5 of 1973 pertained mostly to new and existing high-rise office buildings 100 feet or more in height: Compartmentalization of large floor plates of high-rise office to prevent the spread of fire (not required in fully sprinkler protected buildings) Smoke and heat venting via smoke shafts during a fire event or, for existing buildings only, pressurization of the exit stairwells (not required in fully sprinkler protected buildings) Sprinkler protecting large showroom spaces on floors more than 40 feet above the curb level Providing fire alarm and two-way emergency voice communication systemsProgramming elevators to recall in the event of smoke detection in the elevator lobbies

2: The provisions of Local Law 16 of 1984 focused on high-rise buildings (changing the definition to buildings more than 75 feet in height rather than 100 feet in height) of multiple occupancy types:

- Allowable areas and heights of new non-sprinklered, fireproof buildings were limited
- Minimum distances between exit door openings for most occupancies were increased
- Installation of emergency power systems in new high-rise buildings; exit signs and lighting were required to be connected to emergency power or battery backup in new buildings and existing high-rise mercantile, industrial, and institutional buildings
- Separation of corridor and sleeping room ventilation systems and installation of post-fire smoke purge systems in existing high-rise hotels; new buildings in most occupancy groups were required to have separate ventilation systems supplying different occupancies, corridors, and means of egress and post-fire smoke purge systems
- Providing sprinkler protection throughout new high-rise office, assembly, educational, and hotel buildings; compartmentalization was no longer an option for new high-rise office buildings
- Elevator in readiness for all new high-rise buildings and existing high-rise mercantile, assembly, educational, and institutional buildings; firemen service operations were required for existing elevators in high-rise mercantile buildings and all assembly, educational, institutional, and hotel buildings.
- Installation of fire alarm and emergency voice communication systems in new high-rise mercantile buildings and new and existing high-rise hotels
- Installation of smoke detectors in mechanical rooms, electrical switchgear rooms, and electric and telephone closets over 75 square feet in gross floor area

when the power was interrupted. Many of the occupants suffered smoke inhalation while descending from as high as the 110th floor in the smoke-filled stairways. Many lessons were learned about egress management, training and security following this event; but there were no formal mandated revisions to codes and standards as a result.

Date: September 11, 2001 (08:46AM)
Description: In a coordinated act of terrorism, Al-Qaeda affiliated hijackers crashed two Boeing 767 airliners into the WTC Towers 1 & 2. Both towers sustained severe structural damage on impact, with ensuing uncontrolled fires burning on multiple upper floors of both towers. This led to fire-induced structural failure of both towers, which started complete progressive collapse. It is estimated that approximately 1955 occupants were trapped on or above the burning impact floors. A total of 2,996 occupants and first responders were killed and over 10,000 were injured. An additional 1,400 rescue workers have died since due to attack-related mental and physical illnesses. Total property damage for cleanup and rebuilding is estimated at $15 billion (Figure 7).

Results: Based on the U.S. Commerce Department's National Institute of Standards and Technology (NIST) investigation, future buildings - especially tall structures - should be increasingly resistant to fire, more easily evacuated in emergencies, and safer overall thanks to 23 major and far-reaching building and fire code changes approved recently by the International Code Council (ICC), based on recommendations from the NIST. The recommendations were part of NIST's investigation of the WTC towers' collapse, and these changes are detailed below.

The Development of New Safety Regulations and Standards as a Result of the Terrorist Attacks on September 11th, 2001

WTC Building Code Task Force

The events of September 11, 2001, at the WTC complex provided the impetus for a re-evaluation of construction design techniques and building codes. On March 19, 2002, the NYC DOB convened the WTC Building Code Task Force to collect and review information related to the performance of buildings affected by the terrorist attacks. The Task Force's main focus was enhancing public safety in high-rise office buildings.

Members of the Task Force met for approximately 11 months, and in February 2003, released the New York City Department of Buildings World Trade Center Building Code Task Force report containing findings and 21 recommendations for review by the DOB Commissioner. Issues that required extensive scientific research were referred to the National Institute of Standards and Technology (NIST). This 46-page document is available on-line at http://www.nyc.gov/html/dob/pdf/wtcbctf.pdf. On June 7, 2004, the NYC Council passed new building code legislation based on 14 of the 21 Task Force recommendations, and on June 24, 2004, Mayor Michael Bloomberg signed into law, Intro 126/04, the WTC/Skyscraper Safety Bill at City Hall.[3]

The Task Force included an 11-member Executive Board and five Working Group Committees. Information was gathered from other governmental agencies, professional design and engineering associations, the

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3: World Trade Center Building Code Task Force Recommendations Incorporated by Local Law 26 of 2004

1. Moratorium on the use of open web, steel bar trusses in new commercial high-rise construction over 75 feet in height, pending the development of an appropriate standard recommended by NIST. Classes covered: high-rise buildings, 75 feet in height or greater, nonresidential buildings.
   - Open web, steel bar trusses are lightweight structural elements. They have the potential of failing in a short period of time when exposed to fire if not properly protected.
2. Encourage the use of available impact resistant materials in the construction of stair and elevator shaft enclosures until appropriate standards can be developed. Classes covered: high-rise buildings, 75 feet in height or greater.
   - The ASTM 2-hour fire resistance rating standard for materials enclosing stairwells and elevator shafts (wall board, gypsum board) is insufficient protection during firefighting operations. Impact loading studies relating to firefighter hose streams were recommended for ASTM and NIST to perform.
3. Prohibit the use of scissors stairs in high-rise commercial buildings with a floor plate of over 10,000 square feet. Classes covered: high-rise office buildings, 75 feet in height or greater where stairs serve a floor 10,000 sf or greater.
   - Scissor stairs are two stairwells that adjoin each other and share a common shaft, although they are separately enclosed. Remote location of stairwells provides redundancy given the possibility of a catastrophic incident (bomb blast) isolating a portion of the floor.
4. Improve marking of the egress path, doors and stairs with photo-luminescent materials. Additional signage where egress path is not clear and retrofit existing signs with either battery or generator backup power. Classes covered: high-rise office buildings, 75 feet in height or greater (photo-luminescent markings and additional signage) and all office, educational and hotel buildings and all high-rise mercantile, industrial and institutional buildings 75 feet in height or greater.
   - Requirement to install photo-luminescent markings on exit doors and in exit stairs. This recommendation also requires the installation of signage where exit stairs have horizontal extensions, stairwell re-entry doors are recessed and re-entry in a stairwell is restricted for more than four consecutive stories. Additionally requires exit sign power source.
5. 5. Mandate a full building evacuation plan for non-fire related incidents. Classes covered: office buildings
   - At the time, only partial evacuation plans and fire drills were required.
6. Work with the Department of City Planning to exclude floor area of "fire towers" from zoning Floor Area Ratio (FAR) calculations to encourage their use. Classes covered: all buildings, regardless of height or occupancy.
   - Fire Towers have enclosed, robust stairwells (walls have a fire-resistance rating of at least four hours), accessed only by first stepping onto an outer balcony or vestibule. They are an ideal means of egress for building occupants during fire conditions. The use (design installation) of fire towers in the NYC Building Code at the time, was discouraged because the fire tower's floor area was required to be included as part of the FAR. Currently, at applicant's option, fire towers are permitted in lieu of interior stairs and exterior stairs.
7. Require protected vestibules at elevator lobbies in newly constructed occupancy group E buildings greater than 75 feet. Classes covered: high-rise buildings with office space, 75 feet in height or greater.
   - In order to meet the fire and smoke protection requirements, fire-rated swing doors with gaskets are commonly utilized to enclose a lobby. When the swing doors close, the gasket fills in the empty space between the door and the frame, creating a seal to prevent smoke from leaking. This lobby becomes a barrier on the fire floor keeping smoke from penetrating the elevator shaft and, simultaneously, prevents smoke from migrating out of the elevator shaft onto a non-fire floor.
8. Require all high-rise commercial buildings over 100 feet without automatic sprinkler protection to install a sprinkler system throughout the building with 15 years. Classes covered: office buildings 100 feet or more in height.
   - Experimental findings demonstrate that passive fire protection and smoke detectors do not provide the same level of fire protection as compared to a full coverage sprinkler system.
9. Mandate controlled inspections to ensure that fireproofing is fully intact on all structural building members exposed by subsequent renovations to ensure continued compliance with applicable code requirements. Classes covered: alterations in office spaces.
   - A controlled inspection is the monitoring of certain critical building components requiring the attention of certified professionals with highly specialized skills and qualifications. The controlled inspection shall be signed and sealed by either a licensed architect or engineer and filed with DOB prior to the issuance of a Building Permit.
10. Mandate controlled inspections of fire dampers. Classes covered: all buildings regardless of height or occupancy.
    - Installation of new ventilation systems in all buildings regardless of size will be subject to controlled inspections of fire dampers.
11. Require air intakes in all new construction to be located at least 20' above grade and away from exhaust discharges or off street loading bays. Classes covered: new high-rise office buildings, 75 feet in height or greater.
    - Air intakes serving spaces that are greater than 10,000 sf and are greater than 2nd story must be 20 feet above grade, 20 feet from exhaust discharges and 20 feet from loading bays.
12. Formulate standards for fuel oil piping above the lowest floor. Classes covered: all buildings regardless of height or occupancy.
    - Establish standards for piping that is utilized to distribute fuel oil to equipment without the use of a day tank. Limit diameter of fuel oil transfer piping in systems using day tanks. Oversized fuel oil piping above the lowest floor is prohibited.
13. Exclude floor drains for elevators vestibule and shafts from being counted as fixtures in calculating normal waste water pipe capacity. Classes covered: all buildings regardless of height or occupancy.
    - Where applicant chooses to put floor drains in an elevator vestibule or elevator shaft, these drains are excluded from fixture count calculations.

construction industry, private real estate owners and academic experts. In addition, inspections reports, news articles and research reports were reviewed. The Federal Emergency Management Agency (FEMA) World Trade Center Building Performance Study Report (BPS Report) was yet another important source of reference.

Executive Board

Based on the sources above, issues were presented to the Executive Board and Working Group Committees for deliberation and recommendations. The Executive Board of the Task Force included representatives from DOB, Fire Department of the City of New York (FDNY), the New York City Office of Emergency Management (OEM), New York City Department of Design and Construction (DDC), Real Estate Board of New York (REBNY), Building Trade Employers Association (BTEA), New York State Society of Professional Engineers and the Architects Council of New York. All recommendations were adopted by the entire Executive Board prior to inclusion.

FDNY Participation

During the commencement of the Task Force, FDNY's Chief of Operations Salvatore J. Cassano designated Deputy Chief Thomas Cashin to represent the Fire Department on this Board. Chief Cashin, in conjunction with the Bureau of Fire Prevention, subsequently selected FDNY members to attend and participate in the Working Group Committees of the Task Force. Their input--derived from many years of firefighting and fire prevention experience--played a vital role in formulating the recommendations designed to protect the public and rescue workers.

Working Groups

Working Groups included representatives from DOB, FDNY, OEM, DDC, REBNY, BTEA, New York State Society of Professional Engineers, Architects Council of New York and the Port Authority of New York and New Jersey (PANYNJ). They were formed to review four major areas (Structural strength, Fire protection, Emergency evacuation, Mechanical systems) that have a tremendous impact on building performance and occupant safety during fire and emergency incidents. Additionally, a fifth Working Group was established by the DOB to review the enforcement of potential new building requirements and the enactment of recommendations by their agency. Led by Executive Board members, Working Groups invited experts to participate in discussions by attending meetings, making presentations and submitting reports.

In the Working Groups, Fire Department representatives voiced their opinions on topics such as sprinkler protection, fire towers, heating/ventilation and air conditioning (HVAC) systems, truss construction, communication technology, elevator shaft and vestibule drainage systems, fireproofing of structural elements, fuel oil transfer systems, emergency evacuation planning, controlled inspections, building information systems, enhanced egress design, scissor stairs, progressive collapse guidelines and impact-resistant stair/elevator enclosures.

Public Forum

In August 2002, the DOB held a public forum in Manhattan to ensure ideas from all concerned parties were heard. Experts in the field of architecture, structural engineering, firefighting protection, building code development and building operations gave testimony. Families of rescue workers and civilians personally involved in the events of 9/11 also conveyed valid concerns for consideration. Public Forum speakers were selected based upon the proposed presentations correlation to the Working Group areas.

NYC Building Code Revision

The NYC Local Law 26 of 2004 revolutionized the way New York City evaluated high-rise buildings with respect to life safety and property preservation. Furthermore, the NYC DOB has committed to a 3-year code revision cycle. Upward development, as well as the events of September 11th, have demonstrated a very real need to move away from the old building codes and standards of 1968 and earlier. In order to embrace new technology and methods of building, the 2008 NYCBC, an amended version of the 2003 International Building Code, was adopted.

Taking the lessons learned from the initial code revision cycle, the DOB again coordinated technical committees in 2011 in order to amend the 2009 International Codes for acceptance. As a result, the 2014 NYCBC was created and further acknowledged the need to embrace new technology and methods of building. As such, the 2014 NYCBC saw code additions above and beyond the aforementioned Local Law, in order to recognize the unique qualities of the New York City building environment.

One of the most outstanding findings from NIST's WTC report was that while the building's original steel structure was designed appropriately with sprayed fire resistant materials (SFRM), the impact of the aircraft subsequently dislodged the SFRM. Since the SFRM provided the structural steel members with a fire-resistance rating, the removal of said materials degraded the fire resistance of the WTC structure, thusly was subject to a prolonged period of fire. One of the resulting recommendations was to improve the performance of SFRM on structural members. In response, the 2009 International Building Code (and therefore the 2014 NYCBC adopted section 403.2.4, "Sprayed Fire Resistant Materials." For buildings other than high-rise buildings, the minimum bond strength (the strength of the bond of the SFRM to the structural member) is required to be 150 pounds per square foot. However, for high-rise buildings, (75-feet to 420-feet high), the bond strength increases to 430 pounds per square foot, and further increases to 1,000 pounds per square foot for buildings higher than 420-feet.

In addition to passive protection, the NIST report recommendations included new active protection systems design methodology, more specifically for fire alarm and sprinkler systems. Understanding that as the height of a building rises, the difficulty in fighting fires on higher floors increases, the NIST WTC report recommended sprinkler riser redundancy. The intent of this recommendation is to provide two separate risers for each sprinkler zone in buildings higher than 420-feet. Therefore, in the case where one riser is out of service for any reason, the redundant riser will provide water supply to the floors above and below the floor of incident. Containing the fire to the floor of incident allows fire personnel more time to get to the floor of the fire event.

By far, the biggest first responder issue discussed in the wake of September 11th was the inability for firefighters to communicate with each other. As such, the adoption of the 2014 NYCBC included provisions for all high-rise buildings to include Fire Department In-Building Auxiliary Radio Communication Systems (ARCS). An ARCS system is intended to amplify the radio communication systems of fire personnel, allowing for two-way communication.

Conclusion

Development of fire/life safety codes and standards over the past decade, coupled with adoption of these code bodies by federal, state and local governments; has led to safer high-rise building.

The National Fire Protection Association (NFPA) detailed that from 2007-2011, an estimated 15,400 reported high-rise structure fires per year resulted in annual associated losses of 46 civilian deaths, 530 civilian injuries, and $219 million in direct property damage (2013 NFPA Fire Analysis & Research Report on High-Rise Building Fires).
Four property use groups account for half of high-rise fires:

- Apartments (45% of all high-rise fires)
- Hotels (3% of high-rise fires)
- Facilities that care for the sick (1% of high-rise fires)
- Offices (2% of high-rise fires)
- The rest were mostly property uses found in mixed-use residential or office buildings (such as restaurants, stores, and parking garages)
- A major reason why risks are lower is due to the greater use of fire protection systems and features in high-rise buildings.
- High-rise buildings have lower percentages of fires with flame damage beyond room of origin, providing further evidence of impact from fire protection systems and features :
  - Apartments (6% of high-rise fires vs. 10% in shorter buildings)
  - Hotels (6% of high-rise fires vs. 10% in shorter buildings)
  - Institutional (5% of high-rise fires vs. 8% in shorter buildings)
  - Offices (14% of high-rise fires vs. 21% in shorter buildings)

Proper application of these codes and standards by design professionals and enforcement by the local AHJ will lead to a safe and secure future for high-rise buildings. Many of the updated codes and standards of today have embraced that the presumption of "deemed to satisfy" can be dangerous and that tall and complex buildings need to be risk assessed as part of the design process, so that the appropriateness of the code application can be properly assessed. Installation of both passive and active fire protection systems in conjunction with fire safety training and emergency action planning have yielded reduced high-rise fire fatalities and property damage. As proven throughout the last century, the installation and proper maintenance of automatic sprinkler systems throughout all high-rise buildings will continue to have the most positive affect on fire/life safety in high-rise buildings throughout the world.

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