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FIRE PROTECTION ENGINEERING: WHERE ARE WE HEADING FROM HERE? A LOOK AT PRESENT AND FUTURE RESEARCH AGENDAS IN TALL BUILDINGS

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Abstract

The safety of occupants in the tall building environment has been a primary concern since multiple story buildings were advocated. As new structures "towered" to 10 stories (100 ft; 31m) in the late 1800's, a natural concern was for the management of a fire event. How can the occupants be protected? How can the structure be protected? What systems could be provided to automatically intervene during a fire event? How can manual fire suppression operations be conducted in these buildings?

Through some trial designs, best practice, experience and simple common sense, the architectural and engineering profession has developed a solid approach to high-rise design and safety. Our building occupants are safe; structural components and elements are protected against fire to insure performance under stressful conditions; and multiple, redundant and robust systems are mandated for these special structures.

The September 11, 2001 attacks on major icon buildings in the US have shaken confidence in previous design philosophies. While most in the scientific and engineering community will generally describe the performance of WTC 1 and WTC 2 as exceptional (the buildings did allow for the successful evacuation of tens of thousands of people), the resultant progressive collapse of WTC 1 and WTC 2, as well as of WTC 7 is unsettling. On September 12, 2001 a debate that has engaged the developer, designer, insurer and most importantly, the general public, appears to be moving towards some changes, in some projects at some point. An agenda for parts of that discussion is outlined in this paper.

Keywords: Egress, performance, codes

1. Introduction

Fire events in high-rise buildings are nothing new. Figure 1 provides a list of fire events in buildings defined as high- rise (generally 7 stories and greater). The response of the engineering community to these fire events has been an important approach to making the structures safe. Consider "best practice" approaches in 1896.

> *"9. Stairways and Elevators to be located in brick or stone towers. Communication between towers and adjoining buildings to be protected by standard fire doors."*[i]

In addition, the "Building Code Recommended by the National Board of Fire Underwriters" 1905 edition, had a concise rule for high-rise buildings - they would not exceed 125 ft (32m) - no exceptions. Section 30 of that Code stated verbatim:

SECTION 30
Limiting the Height of Buildings

Non-fireproof buildings.

No non-fireproof building or structure hereafter erected shall exceed fifty-five feet in height, nor the heights specified for non-fireproof buildings of the several respective classes mentioned in Section 106 of this Code.

Height proportioned to width of street. *Warehouse buildings.*

No building, or structure hereafter erected, except a church spire shall exceed in height two and one-half times the width of the widest street upon which it stands, but in no case shall any building exceed one hundred and twenty-five feet, or if to be used above the ground floor as warehouses or stores for the storage or sale of merchandise shall it exceed one hundred feet in height.

Measurement for height. *Cornices.* *Tank and elevator inclosures.*

Such height shall be the perpendicular distance measured in a straight line, taken at the center of the facade of the building, from the curb level to the highest point of the roof beams, not including in such measurement of height cornices which do not extend more than five feet above the highest point of the roof beams nor inclosures for the machinery of elevators which do not exceed fifteen feet in height, or inclosures for tanks which do not exceed twenty feet in height above the roof beams and do not exceed in united area ten per centum of the area of the roof. [ii]

Fig. 1 Section 30 of the Building Code recommended by the National Board of Fire Underwriters (1905)

DATE	BUILDING	LOCATION	NUMBER OF FATALITIES	FLOOR OF ORIGIN/TOTAL HEIGHT (STORIES)
25 MAR 11	ASCH BUILDING	NY, NY	146	8/10
1 AUG 32	RITZ TOWER	NY, NY	8	SUB-BASEMENT/42
5 JUNE 46	HOTEL LASALLE	CHICAGO, IL	61	1/22
28 JUNE 63	ASTORIA BUILDING	RIO DE JANEIRO, BRAZIL	7	14/22
7 DEC 67	TIME-LIFE	PARIS, RANCE	2	8/8
24 JAN 69	HAWTHORNE HOUSE	CHICAGO, IL	4	36/39
25 DEC 71	TAE YON KAK HOTEL	SEOUL, KOREA	163	2/21
23 JULY 73	AVIANCA TOWER	BOGATA, COLUMBIA	4	13/36
1 FEB 74	CREFISUAL BANK BUILDING (JOELMA)	SAO PAULO, BRAZIL	179	12/25
21 NOV 80	MGM HOTEL	LAS VEGAS, NV	85	1/23
8 FEB 82	HOTEL NEW JAPAN	TOKYO, JAPAN	32	9/10
5 SEPT 86	HOTEL	KRISTIANSTEAD, NORWAY	14	1/13
31 DEC 86	DUPONT PLAZA HOTEL	SAN JUAN, PUERTO RICO	96	1/20
23 FEB 91	MERIDIAN PLAZA	PHILADELPHIA, PA	3	22/38
20 NOV 96	OFFICE	HONG KONG	40	BASEMENT/16
23 DEC 98	WEST 60TH. STREET TOWERS	NY, NY	4	12/40

Table 1 High Rise Fire History

The Triangle Shirtwaist fire (*ASCH Building – New York, NY, 1911*) is generally considered to be the defining event that caused codes, and the early pioneers of fire engineering, to recommend additional scrutiny to multiple story buildings. A report entitled "*Loss of Life through Carelessness and Panic – Being a Report on the ASCH Building Fire of March 25th, 1911 Involving Hundred and Forty-Five Deaths*", ironically had a different take on the role that the 10 stories played in the outcome of this fire. As noted in the preamble of this report, "The precise height of the building may have had some bearing on the exact total number of lives lost, but scarcely on the general extent and character of the calamity as a whole".

The Triangle Shirtwaist fire did result in further changes to codes. It was the trigger for the development of NFPA's Life Safety Code. Originally entitled "*Exit Drills in Factories, Schools, Department Stores and Theaters*", the document was concerned with loss of life because of inadequate or non-functional exits. It was not limited to high-rise buildings. Perhaps the items having the largest impact as a result of the Triangle Shirtwaist fire, but the least known, were the sweeping changes in labor laws – particularly as they related to women and children.

Discussions are presently underway in 2003 on some of these (and many more) issues, involving tall buildings but that in many ways are applicable to all buildings. The fire protection engineering and fire safety engineering profession has a role to contribute to this debate and to further enhance the level of safety. Topics for this agenda are wide ranging and will require years to finalize and determine how everything fits together. The following list is one set of subjects that fit into this debate. The agenda items that follow are in no particular order, and many of them have cross over functions (for example, means of egress strategies and elevator evacuation systems). Fire engineering concepts are integrated in numerous other disciplinary professions, thus this will be a team effort to achieve these research objectives.

2. Agenda Items For 2003 And Beyond

2.1 What Is A High Rise Building?

Present design philosophies provide generally the same level of fire safety features and systems for a 10-story building and a 100-story building. A more practical approach to this issue might be to segment the category of high-rise buildings into a schedule of "high rise", "mid-rise", "tall", "super tall" and "extremely tall" buildings. Threshold values might look like:

CATEGORY	STORY RANGE STORY (FT)	RISK INDEX
High Rise	7-14 (140)	1
Mid Rise	15-40 (420)	2
Tall	41-65 (650)	3
Super Tall	66-85 (850)	4
Extremely Tall	>85 (>850)	5

A risk indexing system could then be used to apply an appropriate level of redundancies and features into the entire project.

2.2 *Elevator Evacuation Systems (Ees)*

Rapid and orderly total evacuation of a high-rise building is not going to be practical unless a method and means to rely on elevators for this purpose is carried forward. The American Society of Mechanical Engineers (ASME) is hosting a conference on this subject in 2004. [iii]

General concern with the operability of elevator equipment and controls under wet and/or increased thermal environmental conditions has been a main reason that elevators have not typically been recognized as an acceptable egress component. Technological advances now appear to have improved performance levels under these conditions.

If EES concepts move forward, equipment and component wise, the other challenge will be to educate the public. Messages such as "you can use some elevators, some of the time in some buildings." will have to be concisely crafted and delivered to the public at large. This may be the biggest challenge as EES concepts move towards reality.

2.3 Fire Is A Structural Load

Specifications for establishing hourly fire resistance ratings on structural elements have traditionally been the responsibility of the architect. In most discussions post September 11, 2001, there is widespread agreement that it was ultimately a fire that resulted in the catastrophic collapse of WTC 1, WTC 2 and WTC 7. A new interest between the structural engineering and fire engineering professions is now in place. Renewed interests in the fire performance of structural members are now a mainline topic.

2.4 Fire Test Protocols

A need to evaluate the long-standing procedures for what is tested, how it is tested, and what the test results do or do not represent is in order. Expectations that a construction assembly with a 3-hour fire resistance rating will endure a thermal load of 3 hours at any temperature range is not necessarily true. Fire Test Standards such as ASTM E-119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, NFPA 251, *Standard Methods of Test of Fire Endurance of Building Construction and Materials* or UL 263, *Standard for Fire Tests of Building Construction and Materials*, need to be reviewed to determine what, if any changes are necessary. It has been suggested that the slope of the current time – temperature curves needs to be adjusted to bring the exposed assembly up to temperature much faster. Clarifications, mostly to building designers and the general public, may be in order to foster a better understanding of what the hourly ratings represent.

2.5 Single Event Hazard Scenarios

Building fire safety systems and features provide certain assumptions with respect to fire. Prime among these is that a single fire event is deemed to be the scenario that all other features and systems relate to. Multiple ignition points are typically not considered. In reality, a statistical equivalent of 0.2 percent of fires involve multiple ignition points or scenarios in the overall high-rise environment. None – the – less, some consideration for multiple fires being set simultaneously in a high-rise building might be considered.

2.6 Performance Based Code Provisions

Increased use of first principle engineering concepts will continue to grow. PB design and analysis allows fuller and broader evaluation of anticipated building performance under a wider range of potential fire scenarios. PB approaches to building design can be applied, in one way or the other, to the other 12 elements mentioned in this paper.

2.7 Redundant, Robust, Redundancies

How many primary, secondary and tertiary safety systems does a tall building need? At least two exits from each floor; a stand by power system to permit continual operation of critical fire safety systems; broad use of fire resistive construction materials; compartmentation on and between floors; fire department standpipes in every required exit stair. Providing multiple exit stairs will still be a fundamental premise of tall buildings design. Insuring that such stairs are remotely located (remote from the perspective of what event), have adequate capacity for egress purposes and have some level of inherent protection against physical damage will be the topic of any new design parameters.

2.8 Evacuation Strategies

Can all of the current thinking for a "defend in place" concept still be applied to the occupants of a tall building? Although no longitudinal studies on the relative safety that is perceived in tall buildings has been completed, anecdotal information seems to indicate that occupants are more apt to follow the 'norm' of partial evacuation/relocation strategies of pre September 11, 2001.

2.9 Egress Stair Capacity

Marginal increases in the width of exit stairs is considered to permit faster decent of stairs by the occupants. Wider stairs are also expected to permit more efficient counter flows – rescue personnel moving up, occupants moving down. Clear widths of 44 in (1.2m) and 52 in. (1.4m) have been suggested. Even an incremental increase in the stair width can affect other design considerations. The benefits to wider stairs will have to be shown as a clear improvement to safety in order to be embraced. Concepts of wider stair widths, and even an expanding stair concept are very much in focus right now.

2.10 Building Security Strategies

The goals associated with keeping the wrong people out of a building must be weighed against the potential impact of hindering the compliment of building occupants who may need to quickly evacuate the premises. Locking of stairwell doors to prevent re-entry, installation of turnstiles at building entrance points and installation of screening equipment can restrict, or outright prevent fire egress through previously available routes.

2.11 On-Traditional Egress Contrivances

A series of media and technical papers have been put forth on the use of alternative escape devices. Viewed as elements of "a last resort", such equipment runs the gauntlet. Escape parachutes, slide escape devices, cable rescue systems and even self-propelled rescue platforms have been contemplated. Alternative rescue devices provide for interesting discussion but do not appear to have an obvious use at this point.

2.11 Materials Performance

The ability of spray applied and field installed thermal protection systems to perform under more extreme conditions is being scrutinized. Adhesion properties and impact resistance qualities are among two of the elements being studied post September 11, 2001. Alternative material use, such as "fire resistive steel" (FRS) is also being studied to determine if it has additional properties that might result in some superior level of performance.

2.12 What, If Anything, Do We Need To Fix?

These are just a few of the subjects to be discussed. Once the debate settles, the fire engineering community will have a central role in helping to identify and prioritize the subjects of this research agenda. Cost-benefit, risk reduction, consequence reduction and public demands will have to be considered.

Summary

A debate on what priorities should be set, who should set them and how far they should be carried is now underway. The two extreme ends of "DO NOTHING" and "DO EVERYTHING" will ultimately find a balance at some midpoint. Comparative analogies have been made with the things that could have been done to avert or minimize the outcome of the Titanic disaster. The analogy is do we put more resources into doing a better job of hunting for icebergs (those who want to intentionally inflict harm on a civilian population) or do you provide more lifeboats on the ship (increase the level of the occupants ability to escape from an extreme event). The answer is, you do some of both – not one at the cost of the other.

Further use of risk analysis methods, performance based design approaches and a greater understanding by other professional disciplines in the role of the fire safety engineer will help to insure that the proper balance is found between the two extreme end points noted above. The fire protection engineer, or fire safety engineer has a broad span of expertise that can be applied by other disciplines. It will be a collective effort to see where all of this ends up in the future.

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[i] Handbook of The Underwriters Bureau of New England; June 1896

[ii] NBFU - 1905; Committee on Construction of Buildings

[iii] Workshop on Use of Elevators in Fire and Other Emergencies 2-4 April 2004.

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