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Fire Engineering Super-Tall: A New Approach to Escape

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Biography

Martin Kealy has over 17 years experience in fire safety engineering consultancy. He is currently employed by Schirmer Engineering Corp and is Director of International Practices, he has worked extensively on high rises in Europe, Middle-east, Africa and Asia. He previously worked for Arup Fire, Buro Happold Fire and WSP Fire in the UK. Martin is responsible for fire safety engineering consultancy to SEC clients worldwide working on projects that include airports, high rise commercial buildings, shopping complexes, tunnels, and very large mixed use buildings.

Schirmer Engineering Corp is a Global Fire and Security Business employing over 260 fire professionals and is one of the largest fire consultancies in the USA. SEC have previously designed fire safety strategies for tall buildings including the Sears Tower and the new Trump Tower in Chicago.

Martin is currently working on some of the tallest buildings in the world including the Pentominium in Dubai, Calatrava Tower in Chicago, the Dubai Water Front, Dubai. Martin's past design experience includes the tallest buildings in a number of countries, Commerzbank, Frankfurt, Al Faisaliah, Riyadh, Lotte, Seoul, Bahrain Financial Harbour, Manama, Doha Convention Centre and Tower, Doha.

Martin chaired the Steering committee for CIBSE Guide E Fire Engineering and is principle author of the section on smoke control and fire dynamics, this fire engineering design guide is a useful reference in the design of tall and complex buildings.

Martin is a fellow of the Institution of Fire Engineers (IFireE) and represented the IFE as a member of the Royal Institute of British Architects (RIBA) and Institution of Structural Engineers' committees convened after the events of September 11. That committee produced a design guide for tall buildings. IStructE Safety in tall buildings and other buildings with large occupancy.

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Abstract

This paper addresses some of the main fire protection engineering challenges associated with designing the tallest structures in the world by using super tall projects in three locations as case studies. Current country codes do not adequately address fire safety of super-tall buildings. An intelligent fire engineering approach is required which needs to be addressed early in the design process.

Super-tall buildings challenge some of the fire protection community's most basic concepts, such as "never use elevators during a fire" and "two stairs are required from every story". This paper makes the case for additional enhancements to super tall buildings based on performance design and concludes that it is not practical to design to standard buildings codes. The argument is made for the practical use of elevators for emergency evacuation.

Keywords: Fire Protection, Performance based design, Elevator Evacuation

Introduction

There are significant fire engineering challenges associated with designing buildings that exceed 100 stories. The benchmark height of 100 stories has been chosen for the simple reason that the tallest occupied building in the world Taipei 101 is just over 100 stories and 100 is a round number. This paper uses the term *Super Tall* to mean a building over 100 stories in Height.

The specialist experience and design knowledge gained during the design process contained within this paper have been gathered from a diverse number of projects. However, at the time of writing this paper some of the buildings due to their height must unfortunately remain confidential.

Some of the example buildings that are not confidential and that can be used to illustrate the new fire engineering features are:

- Chicago Spire, Chicago by Santiago Calatrava
- Lotte World 2 Tower, Seoul by SOM
- Pentominium Tower, Dubai by Aedas

These building locations represent different fire jurisdictions (building codes) and local levels of familiarity with new technology and high rise designs.

Chicago Spire

The Chicago Spire project is a 610m (2000ft) tall high-rise condominium building and will be the tallest building in the USA. It is located at the mouth of the Chicago River and it will form a new landmark on the city's skyline. Designed by world renowned architect Santiago Calatrava, these luxury condominiums will be marketed to an international clientele.

Figure 1. Chicago Spire, Chicago USA.

Image Courtesy of Shelbourne Developments

Lotte World 2 Tower

The Lotte World 2 Tower was design by SOM in New York and is a mixed use tower, it is a total of 555m in height and composed of 112 stories above ground floor.

The base of the building is a square and it rises to a circle at the top.

Figure 2. Lotte Tower, Seoul, South Korea.
Image Courtesy of SOM, New York

Figure 3. Pentominium Tower, Dubai UAE.
Image Courtesy of Aedas Architects Hong Kong

The Pentominium Tower

The Pentominium Tower in Dubai currently consists of a 119 story residential tower with multiple public gardens and observation decks.

The predominant use of the structure is for high-scale residential units. A typical residential level contains two residential units, one on each side of the centre core. The floor levels on each side of the core are staggered so that one floor level is approximately 2m higher than the adjacent residential unit on each floor.

Significant Fire Design Issues

Significant issues affecting high rise fire safety design for a specific location are:

1. Local Building codes and the expertise and flexibility of the local Authority Having Jurisdiction (AHJ)

2. Local expertise and equipment availability

3. Technology available at the time of design

Traditional Code Approach

Traditionally building fire safety has been based on meeting a series of prescriptive requirements such as those contained in the British Standards, *Approved Document B to the Building Regulations* (UK) (ADB) and ICC *International Building Code* (USA) which set out specific requirements that must be met such as maximum compartment sizes and maximum travel distances for means of escape.

Furthermore building codes are primarily concerned with life safety. The traditional prescriptive recommendations are not intended to take account of property and contents protection or the cost of disruption to an operational process arising from fire.

In modern high-rise and super tall tower buildings it is often impractical to apply the traditional prescriptive requirements to achieve life safety. It is, therefore, necessary to have an alternate means of identifying the fire safety measures required for super-tall towers.

The process takes an innovative functional approach to the super tall tower and its operation as a basis for establishing fire safety requirements, design and management principles. The process enables the critical importance of management to fire safety to be recognized as well as the more conventional fire safety systems and structural fire safety.

Fire Safety Engineering Approach

Since the 1980s there has been considerable effort put into the development of fire safety engineering and it is now a well established discipline that is recognized within statutory guidance documents. (ABCD 2005) This is fundamentally different from the conventional prescriptive approach to fire safety in that it uses scientific, engineering and risk assessment principles to evaluate fire safety requirements in buildings. A fire safety engineering approach may for example look critically at how fire can start in a building, how it can spread, and the possible consequences of the fire and how these can be mitigated by different fire safety strategies. These include management, operational and functional practices.

The Society of Fire Protection Engineers has produced a guide on how fire safety engineering should be applied to buildings.(SFPE 2007) The principles and procedures set down in the *SFPE Engineering Guide to Performance-Based Fire Protection* are often adopted as the basis for fire safety for Super Tall buildings. It provides a coherent and logical framework within which all aspects of fire safety can progress, including negotiations with statutory authorities, and is similar in scope to British Standard BS 7974:2004 (BSI 2004), "The application of fire safety engineering principals to fire safety design of buildings".

High Rise Challenges

A high rise building is typically characterized by the following: Long evacuation times, often requiring a defend-in-place approach to fire safety. Manual fire suppression efforts are limited to an internal fire attack.

Significant air and or smoke movement within the building due to stack effect or reverse stack effect.

When designing a Super Tall building the above characteristics are even more significant. Building codes have typically defined a building as a high-rise, requiring special fire safety features to be installed, if it has occupied floor levels located more than 30m in the UK (HMSO 2002) and 23m (75 ft) above grade in the USA (NFPA 2006). However, it is only recently that building codes have begun to recognize that high-rise buildings should be further categorized based on their height, because the taller the building the more significant the stack effect, the longer the evacuation times and the more difficult it is to manually fight a fire. ASHRAE, for example, defines a "tall" building as one having a height of 91m (300 ft) or greater.

In tall buildings, evacuation times are so long that full evacuation is not envisioned and occupants are instead directed to remain where they are, unless they are on or near the floor of fire origin, in which case they may be directed to relocate a few floors down. The building's fire protection features must be designed so that occupants can safely remain in the building. This is commonly referred to as a "defend-in-place" approach.

In high-rise buildings, manual fire suppression efforts are not available from the exterior of the building, so an internal fire attack is required. Depending on circumstances, it is possible that fire fighters might have to walk up stairs to reach the fire floor, a daunting task in a tall building if elevators are not available.

Stack Effect

In high-rise buildings air movement due to stack effect can cause smoke from a fire to travel from one part of the building to other floor levels that are very far removed from the floor of fire origin. The stack effect is amplified in tall buildings. In addition to be being very tall, the buildings are also generally very slender. This combination results in a large exterior wall to floor area ratio, meaning leakage through the exterior walls could be more significant than in a typical high-rise building. Also, the ratio of floor openings (shafts) to floor area are greater than in a typical high-rise building, again a possible contributing factor to increased stack effect. The introduction of operable windows further complicates any analysis of potential stack effect issues.

Building Codes

The model building codes, such as the *International Building Code* (IBC), have only recently begun to deal with fire protection features in tall high-rise buildings. They are able to do this because they are a consensus standard and recommended changes are permitted to be submitted by any interested parties and are acted on over an 18-month (or 3-year) cycle. This is considerably different than the code change process provided for some local codes for example the *Chicago Building Code* (CBC).

Chicago Building Code

The high-rise provisions of the CBC were introduced into the Code in the mid-1970's and have remained essentially unchanged ever since (in fact, a non-sprinklered high-rise building is still a design option).

Dubai Codes

The UAE has its own set of codes that have been around for some time, and have been updated from time to time, however, the local codes are not high rise friendly and are not suitable for super tall buildings. The Authorities in Dubai (Dubai Municipality) allow the use of internationally recognized codes including UK and US codes. UK codes are also not high rise friendly and in fact until 2007 it was acceptable to design residential high rises (any height) without sprinklers and a single stair. Environmental Health & Safety the AHJ for (Jebel Ali Free Zone Authority) JAFZA are less flexible in that they only allow the use of NFPA codes and NFPA5000.

The Korean Building Code .

The Lotte World 2 project was generally designed to meet the applicable requirements of the Korean Building Code and Regulations. However, certain features of the tower are not addressed in these code and regulations.

For example the Korean Building Regulations do not specify occupant load factors and only require a minimum of two exits based on the areas of use area and the area being over $200m^2$, whereas the IBC bases the number of exits on population.

1. 1 to 500 occupants – 2 exits.

2. 501 to 1000 occupants – 3 exits.

3. Greater than 1000 occupants – 4 exits.

Travel distances are also limited to 50m to a stair (100m at grade level), which is very restrictive.

The Korean Building Regulations do not specify a minimum exit stair headroom clearance.

The Korean Building Regulations require all buildings where total area exceeds $10{,}000m^2$ and over 11 stories to be equipped with a helicopter landing area.

Exit Widths of Stairs (Code)

Recent research into high rise fires has led the US code body NFPA to require additional exits stair width based on super tall buildings or building with large population. The NFPA Life Safety Code (LSC) (NFPA 2006) Table 7.2.2.2.1.2(B) requires a minimum exit stair width of 1420mm (56 inches) when the stair serves a cumulative occupant load in excess of 2,000 persons.

The increase in stair width is bases on providing adequate width for people to pass each other on the stair and for fire fighters to climb a stair as people come down the stair.

Existing prescriptive building codes do not adequately address fire safety in very tall high rise buildings. In fact very tall buildings challenge some of the fire communities most basic fire safety principles, such as never use elevators during a fire emergency, or even the need for 2 exits stairs from every storey.

The fire design of super tall buildings, therefore, should not be limited to the fire protection features of any of the *Building Codes*.

One view is that exotic or unique fire protection systems or features may not be required for super tall buildings, but instead, the commonly used fire safety systems and building features provided in high-rise buildings must be designed with a high level of reliability and possibly greater performance capabilities than that of a typical high-rise building. Again, this is because the evacuation times are greater, manual fire fighting more difficult and stack effect more pronounced than in lower less slender high-rise buildings.

The design of the fire protection systems and performance improvements to be used may be generically considered as "enhancements", however, this term refers more to enhancements over the minimum requirements of local codes and not necessarily enhancements over and above other model codes or the recommendations of the design team.

At an early stage of design, it is often useful to discuss fire safety features in terms of the fundamentals of building fire safety, as presented in the flow chart below (see Figure 4). (NFPA 2002)

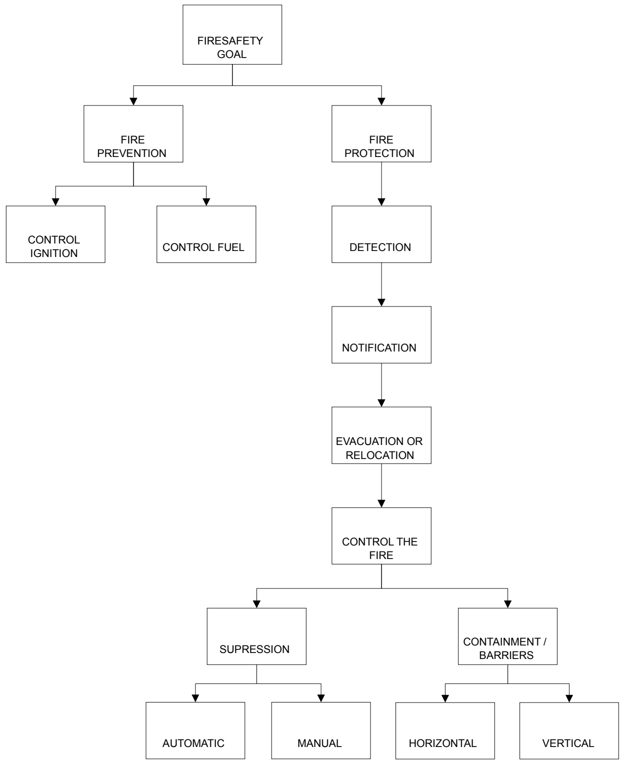

Figure 4. Fundamentals of building fire safety, flow chart

Fire prevention activities are generally thought of as our first line of defense against fire, however, given that fire prevention activities (control ignition & control fuel), over the life of a building, are unlikely to be able to prevent all ignitions, we then must ensure that adequate fire protection is provided.

The first consideration then, once ignition has occurred, is to detect the fire. Detection can be made manually, by people observing fire or smoke in the building, or automatically via smoke detectors, heat detectors, or even the fusible link element of an automatic sprinkler. Once the fire is detected, notification means must be provided to notify the occupants of the building that a fire condition has been detected, and what actions they should take. Notification also means informing the local fire department, in house fire brigade, and other emergency response teams, of the presence of a fire in the building.

The next consideration is for evacuation or relocation of the building's occupants. This requires a protected exit path by which they can either leave the building, or relocate to a safe area within the building. Redundant exit routes, possible use of elevators, areas of refuge for persons with disabilities, and way finding are all considerations included under evacuation.

Lastly, means should be provided to control the fire, either by means of suppression or containment. Containment relies on fire barriers, both horizontal fire barriers and vertical fire barriers (such as floors, walls, roofs, shafts, structural frames, etc.) to contain a fire to a room, area, and/or floor of fire origin. In addition to fire barriers, fire suppression systems and smoke management systems are often relied on to contain the smoke from a fire to the floor of fire origin. Fire suppression then seeks to control and/or extinguish the fire. Fire suppression efforts may be by manual means, such as occupant use of fire extinguishers or the use of standpipe systems by the local fire department, or by automatic means, such as via automatic sprinkler systems or other special suppression systems.

We can now use the fundamentals of building fire safety to help analyze the basic requirements mandated by the local building code and the IBC model codes. The applicable building code for the Chicago Spire is the *Chicago Building Code* (CBC), 2007 edition. While plans are underway to rewrite the CBC using the *International Building Code* (IBC) as the basis for the new code, it is not yet known when the new building code will be implemented, and what provisions specifically will be included in it.

Elevators for Escape

The use of elevators to assist in emergency evacuation is a controversial subject, and has received considerable debate over the last several years. The US elevator industry has been very conservative when it comes to the possible use of elevators for emergency evacuation, however, the ASTM Committee on Elevators have moved forward and are preparing criteria for evacuation elevators. Nevertheless, given higher buildings and greater associated risks we need to consider the various ways how a structure is to be evacuated, including the use of elevators to assist in rapid evacuation of an entire building and/or to assist in evacuating disabled or mobility impaired occupants.

Life Safety Code addresses elevators utilized as a means of egress and permits elevators to be used as a second means of egress from a tower. While tall buildings do not qualify as a "tower" as defined by the LSC, this reference identifies a condition where elevators are recognized as an acceptable means of egress. For tall towers, all exiting capacity will be fulfilled via the two primary smoke proof enclosures. Elevators may be utilized as a secondary means of egress from a building. Using elevators as a means of egress is not required by the IBC nor the LSC.

The concept of using elevators to assist in emergency evacuation is not new, (CTBUH. 2004) but its actual implementation and use, particularly in the United States, is new. Push back from the elevator manufacturers and local code officials is to be anticipated given the concept is only just emerging in the U.S.A. The UK experience is similar, elevator suppliers are not keen to use elevators for escape.

The time is right for change, and super tall towers are the right projects, to implement an emergency evacuation strategy that includes use of the building's elevator systems to assist in evacuation. In addition to the necessary hardware upgrades necessary to make the elevator systems safe to use during an emergency, a program will be needed to train building occupants and staff in the proper use of the elevator system for emergency evacuation. Such training is vital because for decades now, building occupants have been instructed that "in case of fire use stairs" don't use the elevators. Also, adequate communication systems must be provided so that building occupants can be directed when to use the elevators and where the elevators will be located.

The following two elevator evacuation scenarios may be considered:

Fire Evacuation Mode – During the period of time between the receipt of the first fire alarm system notification of a fire in the building, and the time for the local fire department to respond, Fire Fighter's elevators may be used to assist in evacuating disabled and mobility impaired occupants of the fire floor, floor above and floor below (though one cannot prevent other, able bodied occupants from using it). This "protected" elevator system will be put into this "Fire Evacuation Mode" automatically, and the elevator will only serve the 3 floors affected by the fire and the ground floor. This automatic mode will be overridden by either Phase I or Phase II recall for key smoke or heat detection devices associated with the Fire Fighter's elevator system.

Total Evacuation Mode – This mode of operation is intended to assist in "quickly" evacuating the entire building, possibly due to a bomb threat or other incident. In this mode all or most of the buildings elevators will be used in order to get as many people out of the building as fast as possible. This mode will be activated manually; either by building staff or the responding fire department personnel (so training for both will be required). In this mode all of the passenger elevators (or those elevators that are safe to use) could be put into "shuttle" service between the ground floor and designated floors up the building.

With proper training and use of the building's communication systems occupants would know that in a total evacuation they can either choose to walk down the stairs or wait for a shuttle elevator on the designated floor levels. This approach provides an effective and quick means to totally evacuate the building. In this mode the Fire Fighters elevator could be used, in normal mode, to help evacuate occupants on all floors that are either disabled or have sufficient mobility impairments that they can not traverse stairs to reach the designated shuttle floors.

The provision for elevator lobby doors is closely related to the need to control unwanted air movement (and smoke spread) due to the stack effect.

Elevator lobbies/vestibules are often time necessary for the Fire Fighter's elevator and the Service Elevators. The need for elevator lobbies for passenger elevators must also be carefully considered.

Pressurization of elevator hoistways is another option to or in addition to elevator lobbies. Detailed studies are required in order to provide a definitive recommendation on the use of passenger elevators for emergency evacuation.

EVACUATION-ENABLED ELEVATOR SYSTEMS

Our philosophy is that occupants of Super Tall Towers should not only be provided with a very high level of fire protection, but also be provided with various evacuation options so that unforeseen scenarios can be accommodated. The various evacuation options may include the following:

1. Occupants in the immediate fire area (fire floor, floor above and floor below) can relocate down several stories so that they are below the fire floor, and on floors of relative safety.

2. Occupants can choose to stay in their apartments, employing the "defend-in-place" concept.

3. Occupants can use the exit stairs to travel down to designated areas of refugee located on specified levels, such as mechanical levels. Here occupants can wait for the fire department to assist them with further evacuation or they can simply stop at these floor levels to rest, and then continue on down the building via the stairs.

4. Occupants can use the exit stairs to evacuate the building.

5. Occupants, particularly those with disabilities or mobility impairments, can go to the Fire Fighter's elevator vestibule and wait there, in a protected environment, until the protected elevator arrives, either as a result of being put automatically into "Fire Evacuation Mode" or when the Fire Department takes manual control of the elevator.

6. Occupants, in a total evacuation mode, can travel to designated elevator shuttle floors, to use the passenger elevators to bring them down to the ground floor level.

Consistent with the philosophy of providing multiple evacuation options, it is reasonable to propose that elevator systems be used for evacuation of building occupants during an emergency. Some of the concepts associated with this design decision include:

1. Enabling self-evacuation to start before emergency responders arrive

2. Given higher buildings and greater associated risks we need to consider the various ways how a structure is to be evacuated.

3. Total evacuation in less than 30 minutes may be a goal.

4. Consider using automatic operation of an emergency evacuation elevator system after the onset of a fire, bomb threat, blast, or seismic event, and before the arrival of the Fire Dept.

5. A Building Emergency Operation Plan & building personnel would coordinate and facilitate the use of the system prior to F.D. arrival.

Conventional egress planning in high-rise buildings involves staged evacuation of the fire floor, floor above and floor below to refuge floors or out the building. Remaining occupants are defend-in-place. In unmanageable fires, or other extraordinary events, total evacuation, although rare, must be contemplated. The current approach (staged evacuation via stairs), employed by most building codes these days, does not leave many options for those with impaired mobility.

To fully use an elevator evacuation system, increased reliance on building personnel and use of information and communication systems to notify and inform occupants of proper actions to be taken, will be critical for any total building evacuation scenario.

Why should super tall buildings include an Emergency Evacuation Elevator System (EEES)? The following arguments can be made in favor of providing an EEES:

1. Buildings that afford evacuations by emergency elevator systems will be seen as safer than those without this option.

2. Having elevator systems that can be used during total

building evacuations will add to the orderly process (assuming adequate staff training and communication and information systems are provided)

3. It will reduce congestion on stairs, allowing quicker and safer evacuation.

4. It is a better evacuation method for people with disabilities and physically challenged.

5. A protected emergency evacuation elevator can also be used for ingress of emergency responders.

6. Marketing - "this penthouse unit is very nice, but in an emergency you want me to walk down 100 stories?"

The following discussion highlights some of the issues, safety features that may be provided, and some of the terminology used with respect to evacuation via elevators.

Evacuation Schemes

Three basic types of evacuation schemes may generally considered they are:

Total Evacuation - the goal is to completely remove all occupants from the building. Those in greatest need (depending on type of threat and occupants' mobility) should be primary users of elevators. Driving force behind using elevators is to get all occupants out the fastest way possible. Therefore, all building elevators should be considered for use or made useable during total evacuation. Some enhancements may be needed to use passenger elevators for total evacuation.

Staged Evacuation - the goal is to relocate those occupants in the area nearest the incident to protected areas of the building. Elevators may be considered to assist in achieving staged evacuation, particularly for mobility impaired occupants that can't use stairs to relocate down several floor levels. An "enhanced elevator system" will likely be needed to allow elevator use during an emergency.

Fractional Evacuation – the goal is to evacuate a focused group of occupants (such as mobility impaired occupants on the fire floor, floor above or floor below). Greater protection measures are required as the elevators may be their only way out, therefore a "protected elevator system" should be considered for one or more elevators. Dual function of these elevators is permitted, so that they can be used for fractional evacuation as well as for ingress of emergency responders.

Elevator Design Options

Three basic approaches on how to design elevators for evacuation are as follows:

Standard Elevator System – the standard elevator arrangement is one where the passenger elevators open on to an elevator vestibule at each floor that is NOT separated from the adjoining floor by fire or smoke barriers. Standard elevators could be used in non-fire scenarios for emergency evacuation, where no damage to the elevator system has occurred. The features associated with a standard elevator system are:

- Elevator car in standard hoistway
- Unenclosed elevator lobby

Enhanced Elevator System – An enhanced elevator system is similar to a standard elevator with only minor changes. The most significant enhancement is that the elevator vestibule or lobby is separated from the adjoining floor by means of a smoke barrier with smoke resisting doors. The elevator lobbies are key to limiting smoke spread via the hoistway, which would limit its use during a fire emergency. Enhanced elevators can be used in total and staged evacuation in non-fire and restricted fire scenarios, provided no damage to the elevator system has occurred. The principal features associated with an enhanced elevator system are:

- Hoistways improved with sensors (smoke & heat)
- Heat and water resistant electrical components
- Lobbies provided with smoke resisting doors
- Self-evacuation using these elevators is possible and remote control and monitoring systems provided.

Protected Elevator System – Protected elevators are equipped with extra protection to prevent possible damage caused by various threat scenarios. Protected elevators are best used for fractional evacuation of select occupant populations and for ingress of responding emergency personnel. The best example of a "Protected" emergency elevator is the dedicated firefighter's lift described in European Union elevator standard EN81-72. (CEN 2003) Slight modifications only are needed to allow these elevators to be used for both normal day-to-day service car operations and for use by the responding fire department. Typically only one or a few of a building’s elevators are of the “protected” type. The principle features provided for a protected elevator are:

- Pressurized elevator car in a hoistway improved with sensors (smoke & heat), heat and water resistant electrical components, and pressurization and blast resistant walls,
- Lobby/vestibule provided with 1-1/2 hour rated fire doors,
- Direct access to emergency stairs within a separate fire and/or blast protected compartment, 2-hr fire rated enclosure that encompasses the hoistway, stairway, lobby/vestibule and pressurization shaft(s).

- Standpipe and hose racks provided in the protected lobby/vestibule
- Self-evacuation using these elevators is possible and remote control and monitoring systems provided.

Risk Management

In a complex building environment, management effort towards Fire Safety must center on a risk based approach.

Fire Safety Engineering introduces risk based decision making to the design process. Applying a prescriptive approach that is "deemed-to-satisfy" the risk based process will still have its place and the two can be used effectively together.

Concepts of Fire Safety Engineering and Risk Management are fully compatible and must be used together. Technical discussion of risk in a Fire Safety Engineering sense must be part of the Project Risk Management process.

The strategy described herein does not specifically address the threat of fire arising from terrorist or arson attack. However, the fire safety plans which result from this strategy should be adequate to address minor terrorist or arson attack. The fire safety plan should address ordinary and a specific extraordinary event. Prevention of terrorist or arson attack however will be largely dependant on the Security Strategy for the buildings and facilities.

An ordinary fire emergency incident is considered an unintentional event and includes the following fire scenarios:

- Residential occupancy room and contents fire with exterior wall glazing panel failure within the room of fire origin
- Vehicle fire on a Basement level with extension to other vehicles; fire consuming three vehicles total
- Transport vehicle (delivery truck) fire on the Basement level / loading dock
- Vehicle fire (automobile or truck) at ground Level with exposure to the building
- Retail space fire
- Regional & Local power blackout with loss of one source for power with an ensuing fire emergency within the building

An extraordinary emergency incident is intentional or a severe unintentional event and includes the following scenarios:

- Simultaneous ordinary events
- Electrical failure with loss of power to one sub-tower with simultaneous ordinary fire emergency incident occurring
- Explosives (vehicle, personal or IED)
- Armed assault with occupant panic
- Marine external event
- Tsunami, earthquake or other natural disaster
- Aircraft impact

Conclusion

The use of elevators for evacuation of a super tall tower is an essential requirement. With additional compensatory fire safety features in place to overcome practical design challenges and an intelligent emergency management plan in place elevator assisted evacuation will become normal practice for super high rise design.

The issue of stack effect and the influence that it has on elevator assisted escape and smoke spread is complex and should not be under-estimated. Any design therefore requires detailed fire modeling analysis to be carried out to ensure that the egress systems perform as designed.

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