FIRE SAFETY PROVISIONS FOR SUPERTALL BUILDINGS

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ABSTRACT

Fire safety provisions required in supertall buildings will be outlined in this paper. Both passive and active systems specified in the codes for normal tall buildings are briefly listed. Evacuation is a concern.

The total fire safety concept of implementing software fire safety management to control hardware provisions in passive building construction and active fire protection system is recommended for existing supertall buildings in dense urban areas. A fire safety management scheme should be worked out with clear understanding on the fire dynamics in supertall buildings.

1. INTRODUCTION

With the rapid increase in economics and population in the Far East and the increasing number of non-accidental fires, fire ‘safety’ in dense urban areas (especially the development of big cities in China) has to be considered carefully. Big accidental fires had happened before in highrise buildings, cross-harbour tunnel and in buses in Hong Kong; and in many old highrise buildings and new shopping malls in China. Non-accidental fires reported over the world included arson fires in a bank, karaoke, elderly houses and an underground railway in Hong Kong; terrorist fires in the World Trade Centre on 11 September, 2001 (WTC-911) in USA; arson fires in universities in Beijing; and underground railway arson fires in South Korea and Russia. New architectural features such as deep plan, highrise, framed structure and well-sealed buildings; the use of new materials; new style of living; and so many people living in cities or ‘city groups’ would give new fire safety problems of concern [1]. Several big fires were reported [2-5] in tunnel, market, shopping mall and factory in the first half of 2007 in Hong Kong.

There are many highrise buildings in the Far East. Over half of the top 100 highrise residential buildings in the world are found in Hong Kong. Some of them are of height over 200 m [6]. Those buildings of more than 40 levels (about 120 m) are understood as supertall (or ultra highrise) buildings in Hong Kong. Supertall buildings are those of height over 100 m in China [7]. Now, buildings taller than 250 m should go through performance-based design [8]. Different heights are adopted such as 150 m adopted (known as super high-rise) in Ireland [9] and 350 m in Canada [10].

A very big fire happened [e.g. 11] in an old highrise building of height only about 50 m during the replacement of the lift on 20 November, 1996. A fire occurred recently [12] in the 492 m Shanghai World Financial Center, 101-level in Pudong New Area, Shanghai, China. It took over one hour to control the fire. Therefore, there are concerns on fire safety in those supertall buildings. In addition, there are possibilities [e.g. 13] to be potential targets of terrorist attack as the WTC. Even under accidental fires, tall buildings would give long evacuation time [14,15] to a ‘safe place’. Further, structural stability [16] of the tall buildings under fire and effect to adjacent highrise buildings upon collapse are the concerns. Both passive building constructions PBC and active protection systems or fire services installations FSI must be reconsidered.

Existing prescriptive codes [e.g. 17-20] are only demonstrated to be workable only for buildings of normal height, say up to 40 stories for ‘normal use’. Consequences of erecting very tall buildings (regarded as ‘tallness’ in the Council on Tall Buildings and Urban Habitat CTBUH 1995) [16] are not yet studied in depth and so not included in the codes. In implementing performance-based design (PBD) [21] through engineering performance-based fire codes (EPBFC) which is known as the fire engineering approach (FEA) [1] in Hong Kong, the fire safety objectives, methods for fire hazard assessment and risk analysis database are not yet agreed by the professionals. Therefore, PBD was based on the fire safety provisions listed in the prescriptive codes [e.g. 22].
2. FIRE CODES

Most of the existing buildings fire safety codes are for protecting against accidental fires. It was believed that a room fire would take longer time to flashover. There is plenty of time to evacuate before having a well-developed fire. However, both residential and non-residential buildings would store quite a large amount of combustibles, say up to 1135 MJm$^{-2}$ as allowed in the code. The fire can be big if there is sufficient air supplied, resulted from breaking glass facades in curtain-walled buildings.

Consequent to the WTC-911 incident [23] and so many arson fires, there are concerns that whether fires other than those starting from accidents should also be considered. With so many political and social issues, there will be a higher possibility of having terrorist attack and arson fires than in the past. All these would give a well-developed fire within a short time.

Basically, fire safety requirements are listed clearly for normal tall buildings in Hong Kong:

- Passive construction [18-20]:
  - Fire Resisting Constructions
  - Means of Escape
  - Means of Access

- Active systems known as Fire Service Installations [17]:
  - Alarm and Detection Systems
  - Fire Suppression Systems
  - Smoke Management Systems
  - Auxiliary Systems such as Essential Supply System and Emergency Lightings

3. FIRE SAFETY FOR SUPERTALL BUILDINGS

Fire safety problems for supertall buildings are:

- Long evacuation time [14].
- Direct rescue by ground applications from the building exterior is impossible.
- Direct water application by fire fighting jets from the building exterior is impossible.
- Normal escape routes for occupants are downward through staircases or lifts.
- Firemen access and equipment delivery to rescue people and fight the fire are upward through staircases or lifts.
- Fire fighting techniques (water application, fire ventilation, etc.) are to be applied inside the building for ‘suppressing’ or ‘extinguishing’ the fire, ‘controlling’ is insufficient.

Current fire safety measures in those supertall buildings are basically following codes for normal highrise buildings [e.g. 17-20,22] as listed above on passive building construction and active fire protection systems. There are no codes on fire safety management yet. Fire Engineering Approach (or Performance-Based Design) [1,21] is adopted. However, the acceptance criteria are not yet clear.

There are additional problems:

- High target potential under terrorist attack.
- Safe separation distance for adjacent buildings in dense urban areas to avoid domino effect if collapsed in a way different from WTC.

Therefore, fire safety objectives on protecting against accidental fires, arson fires or terrorist attack fires should be clarified.

4. EVACUATION

It was reported in a TV programme that using elevators for evacuation in one of the top five tallest buildings over the world of height over 400 m will not have a total evacuation time (TET) shorter than 20 minutes! Using elevators for evacuation under accidental fires might be good enough as it takes time to reach flashover to give a well-developed fire. Under terrorist attack fire such as in the WTC incident, flashover would occur rapidly. All combustibles will be ignited to give high heat release rate. Fire resisting constructions designed for a standard accidental fire with a ‘standard temperature-time’ curve might not be able to provide protection up to the fire resistance period (FRP), of say 4 hrs as in WTC. It is clear that the buildings were observed to collapse within 1.5 hrs, due to whatever reasons still under investigation.

New architectural features, such as using so many glass constructions, might give additional problems. Cracking and falling down of glass panels due to explosion or failure of the fittings for fixing the glass panels would give a higher air intake rate to sustain combustion. As a result, higher heat release rates would be emitted to cause severe damages. A big fire with long duration might be resulted due to storing large amount of combustibles, allowed to be up to 1135 MJm$^{-2}$ [17].

The elevator shaft, if attacked by terrorists or arson, might not be able to stand a bigger fire not extending the FRP. Smoke (might be even flame) spreading to the lift shaft will give additional problems.
It appears that nothing else is more efficient than providing more emergency exits for those ultra highrise buildings, unless there is further scientific research to demonstrate that fire safety requirements for normal buildings are good enough for those ultra highrise buildings.

Evacuation should include physical motion under the geometrical constraints and human factors of crowd movement under a fire. There are basically two types of evacuation software [23]:

- Fluid particle tracking technique known as ‘one-by-one’ model.
- Travelling through staircases in highrise buildings with empirical formula.

However, none of these models can predict evacuation time realistically as desired for fire engineering application at the moment. Apart from ‘verification and validation’ on different types of buildings with consideration on ‘repeatability and reproductability’ of the measured data, human factors in different conditions with different races are not yet included. The problem is far too complicated to be solved in the coming years. For example, ‘waiting time’ for crowd movement plays a key role and there are always problems in predicting it accurately. Infinitely long ‘waiting time’ might be predicted [24] even in a simple single level terminal under crowded conditions by some of these evacuation softwares.

5. PRELIMINARY PROPOSAL

All the fire safety requirements can be translated to some critical design figures such as travel distance $D_t$, fire resistance period $FRP$ [20] or number of staircases. In fact, an equivalent index $P_{eq}$ for items difficult to describe quantitatively, such as provision of protected corridor, can be worked out.

An obvious requirement for a supertall building of height $H$ is to calculate the ratio $x$ on $H$ with respect to normal building height $H_n$ (say 40 levels or 120 m in Hong Kong), and multiply the requirement by the factor $x$:

$$x = \frac{H}{H_n}$$

For example, $D_t$ will be shortened to $D_t/x$. The number of staircases required will be multiplied by $x$. The required $FRP$ might be extended by a factor related to $x$. The hazard class for designing sprinklers might be upgraded accordingly.

6. CONCLUSIONS

Long time taken in evacuation and structural stability even under an accidental fire for supertall buildings should be watched. Collapse of a supertall building to adjacent erected buildings in dense urban areas as ‘dominos’ is a big concern. Note that the safe separation distance between tall buildings is not specified clearly, especially in downtown areas developed years ago. Fire spread over buildings, crowd movement and control, and possibility of onsetting a mass fire under wind action [25] should be included in hazard assessment. In addition, there is a high target potential of terrorist attack for symbolic buildings.

Feasibility study on using new fire protection systems for extinguishing the fire rapidly should be explored. Preventive measures are required such as applying appropriate fire protective coatings to give a longer fire resistance period. The total fire safety concept [26] is recommended for existing supertall buildings in dense urban areas. Software fire safety management to control hardware provisions in passive building construction and active fire protection system should be worked out. Clear understanding on the fire dynamics in supertall buildings is necessary to draft the safety management scheme.

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REFERENCES


