PROPOSED DESIGN ON FIRE SAFE EVACUATION ELEVATOR FOR SUPERTALL BUILDINGS

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ABSTRACT

Many supertall buildings of height over 300 m are constructed all over the world. Evacuation during big fires in such tall buildings is identified as the key problem. Full evacuation would take over 2 hours even in a normal fire drill with occupants going out in good order. Refuge floors and refuge places are proposed for staged evacuation. However, very few people like to stay at the refuge floors for a long time after the collapse of World Trade Center in time much shorter than the design fire resistance period of 4 hours. Elevator appears to be the only choice for accelerating the evacuation process. In this short note, a design integrating refuge place and fire safety evacuation elevator is proposed. Adequate refuge place should be designated on each level. Fire safe elevators are then provided through such refuge places. Appropriate fire safety management is provided to evacuate the occupants by elevator in order.

1. INTRODUCTION

Many new tall buildings up to 850 m had been and will continue to be constructed all over the world [1-3]. There are many tall buildings over 200 m for residential use with openable windows or green balconies. Those buildings taller than 300 m are called supertall (mega-high-rise, super-high-rise, or ultra high-rise) buildings by Council on Tall Buildings and Urban Habitat. There is not yet a universal agreed height on defining a supertall building. Different values are used, say 120 m in Hong Kong [1,2], 150 m in Ireland [4], 100 m in Chinese Building Standards GB 1972 but now understood to be 250 m in China [5], and 350 m in Canada [6]. These buildings are crowded with high occupant loading and storing high amount of combustibles with fire load density even over 1400 MJm⁻² for residential buildings. The fire load density in office buildings had been surveyed to be over the maximum allowed value of 1135 MJm⁻² in the local codes [7,8]. Several big fires in supertall buildings with glass facades have been reported [9]. Big fires might result in breaking the glass windows of curtain walled buildings under high pressure differences with outside [7]. Therefore, fire safety in supertall buildings [1-3], particularly those with openable windows or green balconies in residential buildings, is a big concern.

Evacuation has been identified [1-3] as a key concern affecting the fire safety of supertall buildings. Full evacuation [10] would take a long time to evacuate all occupants, say over 2 hours in the Petronas Towers in Kuala Lumpur [11], even in a normal fire drill. Refuge floors and refuge places are proposed in staged evacuation strategy [3,12]. But the concept is not welcomed as nobody would stay at a refuge floor for a long time waiting for rescue. There had been many big flashover fires in tall buildings. It appears that elevator evacuation [13-20] has to be used in supertall buildings. The evacuation time at the Petronas Tower can be reduced to half an hour if elevators in good order are used. However, fire safety of the elevator system is a big concern. In fact, elevators are not expected to be used [21] by occupants in fire emergencies. Fireman’s lifts [22,23] are only expected to operate for a short time interval, and are not designated as evacuation elevators.

Elevators appear to be the only choice to speed up evacuation. Some projects are even approved to use elevator for emergency evacuation for several supertall buildings in Hong Kong through performance-based design. However, there were no in-depth research, leading to many debates [15]. Taking Taipei 101, the second tallest building at the moment as an example [18-20], elevator evacuation is not implemented when there is a fire! Fire safety provisions are criticized to be not designed specifically to address the concerns for evacuation elevator systems pointed out years ago [24]. This design was proposed [3] to be reviewed by upgrading at least the active fire system. How to achieve safe elevator system usage in supertall buildings when there is a big fire should be studied [25]. A fire safe elevator design is proposed for emergency evacuation of supertall buildings in this short note.
2. EARLIER DESIGN

Preliminary investigation in some supertall buildings suggested that [18-20] elevator evacuation should not be implemented under fire. This suggestion is different from other projects [15] with elevator proposed for evacuation. At least three key areas should be demonstrated before elevators can be used for fire evacuation. Those are on fire spread into the lift shaft, protection of the adjacent lobbies, and prevention of water damage due to sprinkler discharge.

Staircase design was proposed by Chow [3] to be integrated with elevator system by placing them in adjacent areas as in Fig. 1. This has the advantage that occupants can walk downstairs and take the elevator when necessary. With this design, occupants would have at least a better psychological feeling.

Earlier analytical studies [e.g. 26,27] of smoke movement and spread into lift shafts and protected lobbies can be followed up. Fire models can be applied to study possible environments for a typical lift shaft and lobby with justification by full-scale burning tests [28,19] and scale modelling [30]. Appropriate protection systems such as smoke management systems [31] in the lift shaft can then be proposed and evaluated to help work out design guides for fire safe elevator systems.

The lift shaft can be pressurized, for example, but surrounded by staircase with adequate protection. Water curtain can be used to isolate the protected lobby and lift shaft from the fire areas. Obviously, full-scale burning tests are required to demonstrate that the design would work. Appropriate design data should be worked out as well.

![Fig. 1: A proposed protection scheme by Chow (2006/07)](image-url)
3. REFUGE FLOOR

Different Hong Kong fire codes specify a need for refuge floors. First, they are required as a means of escape (MoE) in code [8,32,33] paragraph 21 as in Appendix A.

The Fire Service Installations (FSI) code [34], paragraph 4.40, meanwhile, provides for floors in the context of building installations:

The fire service installations and equipment that are required to be provided in the building in accordance with relevant sections of this Code shall also be extended to the Refuge Floor(s) as appropriate; and

an external drencher system with an independent water supply shall be provided to protect all external wall openings. The system shall be automatically operated by a quick opening valve or deluge valve which is operated by a system of approved heat detectors or sprinklers installed in the same areas as the drencher system, together with manual control.

Despite specifying a refuge floor [8,35] and related building safety installations, the codes do not offer a thorough rationale for the necessity of this building storey. The following functions of a refuge floor were summarized by Chow and Chow [3] by referring to arguments reported in the literature [35-39]:

- Floors serve as a safe place for gathering in a very tall building. The existence of refuge floors reduces evacuation time, when compared to a system in which users are evacuated to some point outside the building. In evacuation, all users need not move together. Some can stay at safe places inside the building.
- Floors may serve as a ‘command’ point in fire-fighting.
- Floors may stop or retard the upward spreading of flames.
- Floors provide an area in which to change the vertical lift shafts to reduce the stack pressure on smoke movement, further facilitating the lift design in supertall buildings.
- Floors may reduce the wind loading onto the building.
- Floors may house certain special applications such as fire services plant rooms.
- Floors may house new design features e.g. communal sky gardens [40].

The FRC code [32,33] lays down that refuge floors’ external wall openings have to be covered in adequate FRP, as denoted in Fig. 2. Otherwise, an external drencher system is required by the FSI code [34]. The current practice is to discharge a water curtain through an external drencher system [35] to protect wall openings.

Another concept is to use the areas of refuge as in NFPA 72 and NFPA 101 [41,42], or known as refuge place in Taiwan. As outlined in NFPA 72, the areas of refuge can be used as part of a required means of egress with a story in a building protected throughout by sprinkler. Detailed information is shown in Appendix B. The design had been used in many tall buildings including Taipei 101. As reviewed by Chien [20], there are two mechanical plant rooms designated in two refuge places in every eight levels. Communication, water, food and natural ventilation are provided.

4. A NEW DESIGN

The concept of refuge place might be the only feasible way to protect occupants within some time in a fire. However, there might be problems for keeping occupants in the refuge place in order for too long, say up to 2 hours matching with the fire resistance period. The main reason is because in the World Trade Center incident, the building collapsed rapidly at 1 hour and 45 mins, less than the expected fire resistance period of 4 hours. It is very difficult to persuade occupants to stay at the refuge place quietly and in order.

However, if a fire safe elevator can be provided through all the refuge places, the time for occupants in the refuge place can be largely reduced to much less than 2 hours. For example, it only took 0.5 hour for total evacuation at the Malaysian Petronas Towers in a fire drill.

Therefore, a new design is proposed by integrating refuge place with elevator for evacuation and staircase. Refuge places such as those provided in Taipei are firstly proposed. The fire resistance period (FRP) of the refuge place should be adequate, say at least 2 hours. The number of refuge places and location depend on the geometry of the supertall building, building use and the occupant loading. Fire safe elevators are then put through such refuge places as in Fig. 2 for evacuating occupants within reasonable time. Lastly, appropriate fire safety management should be worked out on keeping occupants in order and designing feasible control scheme of elevator movement such as stopping at designated levels.
5. CONCLUSIONS

It is obvious that using elevators [11] can accelerate the evacuation in supertall buildings under fire. However, there is still no fire safe elevator system demonstrated to stand big post-flashover fire for a long time at the moment [21]. The elevator system used for fire emergency evacuation following overseas practices should be reviewed carefully. Such overseas guides can only be adopted after careful justification on comparing the building characteristics, occupant loading, fire safety management scheme, past record of fires, and more important, education and social awareness of citizens. Elevator system must be tested to see how big the fire it can stand. The design should be upgraded immediately for places with occupant loading observed to be very high. Appropriate fire safe elevator evacuation in supertall buildings should be worked out through in-depth research.

A new design is proposed to investigate refuge places with fire safe elevator for evacuation.

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REFERENCES

1. W.K. Chow, “A preliminary discussion on fire safety aspects of supertall buildings”, CPD Open Seminar, The Institution of Fire Engineers (Hong Kong Branch), Hong Kong, 10 May (2007).


25. W.K. Chow, “Appropriate safety for lift shafts and adjacent lobbies of evacuation elevator systems for supertall buildings under big fires”, GRF project, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong (2008-2011).


APPENDIX A: EXTRACTED FROM MOE CODE

[21.1] Refuge floors should be provided in all buildings exceeding 25 storeys in height above the lowest ground storey, at not more than 20 storeys and 25 storeys respectively for industrial and non-industrial buildings from any other refuge floor, or above the street or the open area referred to in the code. The number of storeys may exclude storeys which contain solely mechanical plants.

[21.5] Does not apply to a domestic building or a composite building not exceeding 40 storeys in height above the lowest ground storey. In a domestic building or a composite building exceeding 25 storeys but not exceeding 40 storeys in height above the lowest ground storey, the main roof of the building should be a refuge floor and should comply with the requirements in the code.

[21.2] For every refuge floor, there can be no occupied accommodation or accessible mechanical plant room, except fire services water tanks and associated fire service installation plant room, at the same level as the refuge floor.

Refuge floors are also called for under the Means of Access (MoA) code (Buildings Department 2004) in paragraph 17:

[17.5] Every access staircase in a firefighting and rescue stairway passing through a refuge floor should discontinue at such level so that the access route is diverted to pass over the area for refuge before it is continued to access upwards.

Under the requirements for Fire Resisting Construction (FRC) in code (Buildings Department 1996b), paragraph 18 reads:

[18.1] The area for refuge on every refuge floor in a building should be separated from the rest of the building, including vertical shafts or ducts passing through such floor, by walls and floors having a fire resistance period (FRP) of not less than 2 hours. Vertical shafts or ducts passing through a refuge floor should not open directly onto that floor.

[18.2] Where the side of a refuge floor is required to be open, the open side should not directly or diagonally be within a distance of less than 6 m from:

a) the opposite side of a street;

b) a common boundary with an adjoining site;

c) any other external wall having an FRP of less than 2 hours or other opening not protected by fixed light with an FRP of not less than 1 hour of the same building;

d) any other building on the same site.

APPENDIX B: AREAS OF REFUGE IN NFPA 101 AND NFPA 72


7.2.12.1.1 An area of refuge used as part of a required accessible means of egress in accordance with 7.5.4; consisting of a story in a building that is protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 9.7; and having an accessible story that is one or more stories above or below a story of exit discharge shall meet the following criteria:

1. Each elevator landing shall be provided with a two-way communication system for communication between the elevator landing and the fire command center or a central control point approved by the authority having jurisdiction.

2. Directions for the use of the two-way communication system, instructions for summoning assistance via the two-way communication system, and written identification of the location shall be posted adjacent to the two-way communication system.

3. The two-way communication system shall include both audible and visible signals.


A.24.5.3 “Areas of refuge” or “areas of rescue assistance” are areas that have direct access to an exit, where people who are unable to use stairs can remain temporarily in safety to await further instructions or assistance during emergency evacuation or other emergency situation. It is, therefore, important that a method to communicate between that location and a central control point where appropriate action for assistance be initiated.