# A BRIEF REVIEW ON FIRE REGULATIONS FOR OLD HIGHRISE COMMERCIAL BUILDINGS IN HONG KONG

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## ABSTRACT

Fire safety regulations for old highrise commercial buildings in Hong Kong were briefly reviewed and compared with those required for new buildings. Key areas on the proposed improvement appeared in the government consultation paper were identified. A comparison with the fire regulations for highrise buildings in China Mainland was made.

## 1. INTRODUCTION

'Concrete jungles' in Hong Kong (now the Hong Kong Special Administrative Region HKSAR), include modern buildings with new design features and old highrise buildings constructed years ago. Highrise buildings are defined [1] in the regulations as in Table 1. In general, those are buildings of height exceeding 30 m. Highrise buildings constructed before 1972 are classified as old highrise buildings and they can be found everywhere even in the Central District where land price is the most expensive. About 40% of the 50,000 private buildings can be classified as old buildings as announced by the SAR government [2]. Since they were constructed at least 28 years ago when the fire safety were not so seriously considered as in nowadays [1,3-8], there might be problems on the fire safety design, fire services system installed and the fire safety management. Unfortunately, nobody worried about the potential fire risk in those buildings for many years.

Consequent to several big fires occurred in those old highrise buildings in the past two years, people are now starting to be aware of the fire safety issues [9-13]. Fire safety measures for the old highrise buildings seem to be unsatisfactory. The SAR government has decided to improve the fire safety aspects and will set up appropriate regulations. A consultation paper on fire safety improvements for old highrise commercial buildings [14] was distributed for comments but whether this works or not is to be watched. Anyway, this is a big step advanced by the local government where there is likely to have longer term plannings for the region. Before implementing workable regulations, a detailed study [15] in old highrise building fires was proposed. The first step is to understand the current fire regulations and see whether they can satisfy the local fire safety desires.

A critical review on the current fire regulations for old highrise buildings in Hong Kong is reported in this paper. Comparison with the regulations for new buildings (refers to those constructed after 1987 when very tight fire regulations appeared) was made. After smooth reunification of Hong Kong to China in July, 1997, reviewing the fire regulations related to highrise buildings in the Mainland and comparing them with those in Hong Kong is good for strengthening the interflow of technology between the two parts of the country. The consultant paper for fire safety improvements [14] was briefly reviewed with key areas identified.

## 2. LOCAL FIRE SAFETY REQUIREMENTS

Residential and non-residential buildings have different fire safety requirements. People staying in residential buildings are supposed to be familiar with the building environments and location of escape routes. High fire load density is not expected, though there is reservation on this statement because some records on residential building fires indicated that fire load density was likely to be higher than the specified upper limit of 1,135 $MJm^{-2}$ [1] based on the fire duration observed. But it is difficult to set up regulations for old residential buildings because of the social pressure. For example, there were serious criticisms even on carrying out routine checking of alarms and conducting fire drills. Therefore, only non-residential buildings are considered.

At least two key factors on fire safety must be considered: the amount of combustibles described by the fire load density; and the number of people staying inside the building expressed in terms of the occupancy levels. As a result of the probable

high fire load density and high population density, a list of fire safety provisions (summarized in the following sections) is required in new highrise commercial buildings [1,2]. There are two key areas on:

- Building Structures
- Fire Safety Measures

Requirements are clearly described in the Fire Safety (Commercial Premises) Ordinance [6] for new commercial buildings (premises with floor area over 230 $m^2$).

In contrast, only fire hydrant and hose reel systems are required in old highrise buildings. Sprinkler system and fire detection system are not commonly found. There might be problems in locating the means of escape and means of access. Further, it is difficult to identify the fire resisting construction elements because of unreported refurnishing works carried out in the past 28 years. Therefore, a consultation paper [14] on upgrading the fire safety in old highrise buildings was distributed to the public for comments, subsequent to the democratic policy of the new government. Basically, the two key areas on 'Building Structure' and 'Fire Safety Measures' in the new Fire Safety (Commercial Premises) Ordinance [6] are referred to.

## 3. REQUIREMENTS ON BUILDING STRUCTURES

For a new highrise commercial building, the likely type, number and behaviour patterns of occupants are important parameters to determine the number of staircase. Different occupancies [3-5] are classified according to the usable floor area per person $A_{per}$. This is an important factor used to predict the number of occupants using a storey as intended. Values of $A_{per}$ vary from 0.5 $m^2$/person for assembly halls to 30 $m^2$/person for warehouses, godowns and storage areas. Buildings more than 6 storeys or more than 17 m in height require not less than 2 exit routes (staircases). For a non-domestic building or a composite building exceeding 15 storeys in height above the lowest ground storeys, where two or more exit staircases are required, people using one staircase should be able to gain access to at least one of the other staircases at any time without having to pass through other person's private premises. The width and the number of staircase are calculated by the capacity of the room or storey. The minimum requirements of exit routes [4] are shown in Table 2.

At least two access staircases are required for all highrise buildings. There should be one fireman's lift constructed within 60 m from any part of an arbitrary level [3]. Specifications of fireman's lift are addressed in the local regulations [1,3]. The fireman's lift aims to protect the passengers from the effects of fire and smoke by keeping the lift doors automatically closed until operated to open from the inside. At least one fireman's lift is required for buildings having two or more lifts.

Buildings are divided into different areas by structural elements so as to confine fire and smoke [5] to ensure the integrity of the structural elements, and to limit the number of people exposed to a fire. Fire compartments are classified according to their volume. The maximum allowed compartment volume is 28,000 $m^3$ for spaces above ground and 7,000 $m^3$ for underground spaces. The compartment volume can be bigger if an equivalent safety level is demonstrated. Internal parts of the building for different uses or with different occupancies must be separated. Escape staircases and lift wells are considered as separate compartments.

The Fire Resistance Period (FRP) is the period of time which any element of construction, wall, door, fire shutter or other component of a building is capable of resisting the action of fire when tested in accordance with BS 476: Parts 20 to 24: 1987 or as specified in tables A to F in the Code of Practice for Fire Resisting Construction [5].

Structural elements are designed for a specified Fire Resistance Period (FRP) [5]. A minimum FRP of one hour is specified for the elements for domestic buildings, hotel bedrooms and office buildings; a 2 hour FRP is specified for all industrial buildings and warehouses. The FRP of compartment floors and walls, however, is not less than 4 hours. Basement storeys are considered to pose special risks for escape and extinguishment, so an FRP of 4 hours is specified. Further, the level of fire protection accorded to the structural elements depends on the needs for escape and extinguishment. For example, a lift well must be separated from the rest of the building by walls and floors having an FRP of 2 hours. A door provided at a lift landing to give access to the car of lift and any other door to a lift well wall must have an FRP of 1 hour with regard to integrity and to insulation.

Floor openings tend to create vertical or horizontal drafts which permit the spread of fire and smoke. A barrier around such openings serves to stop heated air and smoke properly. Any internal unprotected opening in the floors within a compartment, e.g. those for escalators, circulation staircases or walkways in an atrium, a vertical barrier of 450 mm must surround the opening. The

barrier must be constructed to have an FRP of not less than 1 hour.

Three parts related to building structure are considered in the consultation paper [14] for improving fire safety in old highrise buildings. They are the means of escape [4]; means of access [3] and fire resisting construction [5]:

- *Means of escape:*

- to improve staircases in terms of their width and number;
- to strengthen the protection walls of exit routes and staircases;
- to improve access arrangements to staircases;
- to construct fire doors.

- *Means of access:*

- to provide or improve firemen's lifts;
- to strengthen protection of lift well for firemen's lifts.

- *Fire resisting construction:*

- to provide or strengthen the fire resisting construction of building elements, i.e. beams, columns, walls and slabs;
- to strengthen separation of different compartments in a building;
- to strengthen fire protection of basements.

## 4. REQUIREMENTS ON FIRE SAFETY MEASURES

Sufficient number of hydrants and hose reels must be provided within 30 m from any part of a new highrise building. An actuating point with audio warning device must be installed at each hose reel. The actuating point includes facilities for starting the fire pump and sound the audio warning devices. Any installed ventilation or air conditioning control system should stop all mechanically induced air movement within a designated fire compartment in the current codes of practice [1] for new buildings. Sprinkler systems, if required (such as hotels), must cover all parts of buildings including staircases and common corridors. A fire alarm is sounded upon actuation of a sprinkler head.

Artificial lighting with horizontal illuminance at floor level higher than 30 lux should be provided in the exit routes. An emergency lighting system which can give a minimum horizontal illuminance at floor level of 2 lux [4] is required as a back-up system.

The following are suggested to improve the fire safety measures for old non-residential (commercial) buildings [14]:

- Fire hydrant / hose reel systems to supply water for fire fighting;
- Emergency lighting to facilitate the evacuation in the event of a power failure;
- Automatic cut-off devices for mechanical ventilation systems to limit the spread of smoke through the ventilation system;
- A manual fire alarm system to alert occupants of the building in the event of fire;
- An automatic sprinkler system to control the spread of fire and sound the fire alarm.

## 5. HIGHRISE BUILDINGS IN THE MAINLAND

Prescriptive regulations, recommendations and suggestions for fire safety in highrise buildings are included in the Codes of China [16-18]. Highrise buildings in China are those residential buildings with more than 10 storeys; or those public buildings exceeding 24 m above ground level. For a building exceeding 250 m above ground level, fire safety measures will be individually considered by the Authority [19]. Otherwise, they are further classified into two types according to its usage, fire hazards, means of escape and assisting in firefighting and rescue [16-19]. A summary is shown in Table 1 and the key points are:

- Type 1 Buildings:

  Type 1 buildings include all residential buildings having not less than 19 storeys and all public or commercial buildings exceeding 50 m. Type 1 highrise buildings also include hospitals, high-class hotels, commercial buildings with the area of each floor exceeding 1,000 $m^2$, commercial-residential composite buildings with the area of each floor exceeding 1,500 $m^2$, major utility buildings (e.g. major broadcasting tower, major electricity distribution centre), libraries storing more than 1 million books, and others classified as important buildings (e.g. key science and research centres).

- Type 2 Buildings:

  All highrise buildings other than type 1 highrise buildings are type 2 highrise buildings.

**Table 1: Classification of highrise buildings**

<table>
<tr><td>Hong Kong [1]</td><td colspan="2">China Mainland [16,17]</td></tr>
<tr><td rowspan="3">A building of which the floor of the uppermost storey exceeds 30 m above the point of staircase discharge at ground floor level.</td><td colspan="2">• Residential buildings having 10 storeys or more.<br>• Public buildings exceeding 24 m above ground level.</td></tr>
<tr><td>Type 1</td><td>Type 2</td></tr>
<tr><td>• High class residential buildings.<br>• Residential buildings having at least 19 storeys.<br>• Hospitals, high-class hotels.<br>• Public or commercial buildings exceeding 50 m.<br>• Commercial buildings which each floor area exceeds 1,000 $m^2$.<br>• Commercial-residential composite buildings which each floor area exceeds 1,500 $m^2$.<br>• Major utilities buildings.<br>• Big libraries (more than one million books).<br>• Important buildings.</td><td>• Residential buildings having 10-18 storeys.<br>• Commercial buildings, commercial-residential composite buildings other than type 1 highrise buildings.<br>• Small utilities buildings.<br>• Hotels, offices, institutional buildings not exceeding 50 m.</td></tr>
</table>

## 6. FIRE RESISTING CONSTRUCTION IN THE MAINLAND

Two grades (grade 1 and grade 2) of fire resisting construction were addressed in the fire code of China [13-15]. Type 1 highrise buildings require the grade 1 fire resistance and type 2 highrise buildings must meet the minimum requirements of the grade 2 fire resisting ability. All basements must meet the requirements of the grade 1 fire resisting ability. Fire resistance period requirements for fire resisting walls, load bearing walls, staircases, lift wells, compartment walls of domestic, non-load bearing external walls, walls of escape route are the same for both grades. For structural elements other than those listed in above, grade 1 has a longer fire resistance period than the grade 2 as shown in Table 2.

All structural elements must be made of non-combustible materials. But for grade 2 hanging roof, materials difficult to ignite or treated with fire retardants are allowed.

A 2 hour FRP is required for almost all structural elements. There are a few exceptions where an FRP of 1 hour is allowed. A 4 hour FRP is required for those structural elements of special hazard areas (such as electrical installations and dangerous goods store). Non-combustible constructions are required. A comparison of the FRP requirements for different elements in China and Hong Kong is listed in Table 3.

## 7. COMPARTMENTATION IN THE MAINLAND

Floor area is an important factor in compartmentation [17-20]. The maximum compartment area is 1,000 $m^2$ for type 1 highrise buildings; 1,500 $m^2$ for type 2 highrise buildings; and 500 $m^2$ for underground spaces. The maximum allowed fire compartment area can be doubled if an automatic sprinkler system is provided. A 50% allowance to the compartment area would be allowed for commercial buildings (type 1). For shopping areas and exhibition areas, a larger compartment area of 4,000 $m^2$ for above ground spaces; and 2,000 $m^2$ for underground space is allowed if automatic sprinkler system and automatic fire alarm system are provided. Finishing in these areas must be made of non-combustible materials, materials difficult to ignite or treated with fire retardants. Lift shafts and services ducts (e.g. cable ducts, pipe ducts, air ducts and refuse chutes) are considered as separated compartments.

There must be at least 2 exits in every fire compartment of a highrise building except the following where only a single staircase is provided:

- Type 2 highrise domestic buildings of less than 8 units, and floor area at each level not exceeding 650 $m^2$ (fireman's lift and smoke protected staircase must be provided).

- Unit-type of domestic buildings (a staircase leading to roof must be provided; and every 2 units above level 10 must be linked by a balcony).

**Table 2: Requirements of escape routes**

| Capacity of room or storey | Minimum number of exit doors (from room) or exit routes (from storey) | Minimum total width/mm | | Minimum width/mm | |
|---|---|---|---|---|---|
| | | exit doors | exit routes | exit door | exit routes |
| 4 - 30 | 1 | | | 750 | 1050 |
| 31 - 200 | 2 | 1750 | 2100 | 850 | 1050 |
| 201 - 300 | 2 | 2500 | 2500 | 1050 | 1050 |
| 301 - 500 | 2 | 3000 | 3000 | 1050 | 1050 |
| 501 - 750 | 3 | 4500 | 4500 | 1200 | 1200 |
| 751 - 1000 | 4 | 6000 | 6000 | 1200 | 1200 |
| 1001 - 1250 | 5 | 7500 | 7500 | 1350 | 1350 |
| 1251 - 1500 | 6 | 9000 | 9000 | 1350 | 1350 |
| over 1500 | 7 or higher as required by the Authority | to be calculated at the rate of 300 mm per 50 persons | | 1500 | 1500 |

**Table 3: Fire resisting periods (FRP)**

| Constructions | Hong Kong* [5] | Mainland China [16] | |
|---|---|---|---|
| | | First Class | Second Class |
| Fire resisting wall | 1,2,4 | 3 | 3 |
| Load bearing wall, compartment walls of domestic staircase, liftwell | 2,4<br>2 | 2 | 2 |
| Non-load bearing external walls of escape route | 2 | 1 | 1 |
| Separation wall between rooms | 2 | 0.75 | 0.5 |
| Columns | 1,2,4 | 3 | 2.5 |
| Beams | 1,2,4 | 2 | 1.5 |
| Floor slab, escaped staircase, roof, support | 1,2,4 | 1.5 | 1 |
| Hanging roof | - | 0.25 | 0.25** |

* FRP depends on the intended function of the buildings.
** Materials which are difficult to ignite or treated with fire retardants.

- The adjacent 2 compartments except underground spaces connected with the fire door, and the total area of these 2 compartments less than 140% of the maximun allowed area.

## 8. FIRE SAFETY MEASURES IN THE MAINLAND

Fire hydrant with water supply system must be provided for all highrise buildings. Smoke extraction system is required for internal corridor exceeding 20 m long, atrium, basement and room exceeding 100 $m^2$ in type 1 buildings and type 2 buildings exceeding 32 m. Fire and smoke protection measures for ventilating and air-conditioning system are required [18]. A fire control centre is required for the highrise buildings with fire automatic alarm system. The centre must have the function of stopping the ventilating and air-conditioning system during an adjustable time delay up to 30 seconds. Sounding an alarm upon actuation of sprinkler system is only recommended, not a mandatory requirement [20].

Emergency lighting must be provided in every part of an exit system including staircase, smoke lobbies, fireman's lift lobbies and refuge areas. The horizontal illuminance at floor level must be higher than 0.5 lux.

Smoke protected staircase must be provided for type 1 highrise buildings, type 2 highrise buildings (except, unit-type and balcony-corridor type domestic buildings) exceeding 32 m above ground, tower type domestic buildings, unit type domestic buildings exceeding 18 storeys, and balcony-corridor type domestic buildings exceeding 11 storeys. The protected staircase must be constructed with a smoke lobby with area not less than 6 $m^2$ for public buildings and 4.5 $m^2$ for domestic buildings. Fire doors must be of 0.9 hour

FRP. The staircase must lead to the area outside the building. Openings except fire rated doors and windows are not allowed in the staircase. Services pipeworks in the staircase are not recommended.

Fireman's lift must be provided for type 1 highrise buildings, tower type domestic buildings, unit-type or balcony-corridor type domestic buildings exceeding 11 storeys, and type 2 highrise buildings exceeding 32 m. The number of fireman's lift is determined by the floor area at each level. One fireman's lift is expected to serve an area of 1,500 $m^2$. However, no more than 3 fireman's lifts are required. There are no prescriptive requirements on the exact location of the lifts, but recommended to be located in different fire compartments. The lift lobby adjacent to external wall is recommended, so the windows at the external wall would be used as smoke vents. At the ground floor, an exit from the lift lobby directly to outside buildings or a routeway less than 30 m to outside buildings is required. Smoke lobby is required and the door of the lobby must be at least of 0.9 hour FRP. The FRP for the lift well must be over 2 hours.

## 9. BRIEF COMPARISON BETWEEN THE MAINLAND AND THE SAR

Fire codes in the Mainland and in Hong Kong are briefly compared. A summary is shown in Table 4. The following are the key points:

- On the classification of highrise buildings, there are 2 well-defined types with specified fire safety in the Mainland [16-19]. In contrast, local highrise buildings are classified according to their intented usage for determining the fire safety provisions [1]. The critical height for a building classified as highrise is 24 m for the Mainland but 30 m for the SAR.

- FRP requirements of construction elements are defined according to the classified buildings types [17] in the Mainland. But an FRP of 2 hours is the basic requirement for construction elements in Hong Kong [5]. The values of FRP might be different and are to be specified individually for special cases.

- Building compartments are specified in terms of floor area in the Mainland [17-19], but space volume in Hong Kong [1]. In both places, separation of usage is applied for different compartments.

- The required number of staircases is determined by the number of fire compartments in the Mainland [17-19]. The number of persons in a floor is used to determine the required number of exit routes (staircases) in Hong Kong.

- The required number of fireman's lifts are determined by the floor area of a storey and a maximum of 3 are required in the Mainland [17-19]. But the exact location of the lifts are not specified, only suggestions were made in the codes. In Hong Kong, only one fireman's lift is required in buildings having 2 lifts [3]. The maximum travel distance between any position in a building and the lift is specified to be 60 m.

- In Hong Kong, air-conditioning and mechanical ventilation systems of the fire compartment must be shut down in coordinate operations of the smoke control system [1]. Similar requirements are found in the new edition of the code for Mainland [18].

## 10. CONCLUSIONS

Fire safety codes for new buildings in Hong Kong and those expected for old highrise non-residential buildings are reviewed. Comparison with the fire regulations in Mainland China was made. All these are useful in understanding the present situation on fire regulations for fire safety in old highrise buildings.

In addition to providing advanced fire safety measures, modifying the fire response of building structures in old highrise buildings are suggested [14]. Basically, the fire resistance period of structural elements, compartment walls and doors of staircases are referred. Staircases are recommended to be modified by changing their widths and numbers.

However, it is very difficult to carry out modification works in old highrise buildings. Space allocation brings problem. The normal building operation will be disturbed and there are environmental impact. Accidents might be happened while carrying out those works as most of the construction works were not performed properly. A possible explanation is that there are no 'registered construction workers'. The big fire occurred while replacing the lifts two years ago was an obvious example [3,13]. Perhaps, licenses should be issued to those workers having training on the awareness of safety and environmental protections.

**Table 4: Comparison between fire safety codes in HKSAR and Mainland**

| | Hong Kong [1,3-5] | Mainland China [16-20] |
|---|---|---|
| Definition of highrise buildings | Height ≥ 30 m | Residential ≥ 10 storeys.<br>Public buildings ≥ 24 m.<br>Further classified into 2 types as in Table 1. |
| Fire safety measures (provisional requirements) | Depends on the usage of buildings. | Depends on the highrise building type. |
| FRP | Depends on the function in the building. | Depends on the construction elements of the type of the highrise building. |
| Compartmentation | Defined by volume. | Defined by area. |
| Staircases/exits/route numbers | Depends on the number of occupants in a storey. | Depends on the number of fire compartment. |
| Fireman's lift | 1 if more than 1 lift installed.<br>≤ 60 m from any point of the floor. | Depends on the floor area.<br>No prescribed requirements on the location. |
| Control on HVAC systems in the fire compartment | Shut down in case of fire. | Shut down in case of fire during an adjustable time delay up to 30 seconds. |

Further, improving building structures as listed in above [14] might not give a safe environment when the building is under fire. Preliminary points of concern are:

- Smoke management aspects should be considered. Smoke can spread rapidly through vertical shafts to various levels of a building, this should be studied in detail. Smoke doors are very useful and now required by the Buildings Department. This is demonstrated to be effective in preventing smoke spreading as demonstrated in an accidental fire [21].

- Fire behaviour of materials has to be considered. Results measured from advanced fire tests on building materials and products such as the cone calorimeter [22] and the room-corner fire tests [23] should be referred. These tests give information on burning materials including heat release rate, flame spread, and their contributions to flashover.

- Implementing engineering performance-based fire codes in Hong Kong [e.g. 24-27] is another solution for dealing with different buildings such as atria [28]. For example, operating a sprinkler system will give high quantity of steam. The system should not be installed without a careful planning in evacuation.

- Full-scale burning tests should be carried out when necessary. A PolyU/USTC atrium was constructed [29] where performing experimental studies is possible.

- Fire safety management should be seriously considered [26,30]. Again, issuing license to 'hazard control officers' of a building or a group of buildings is a solution. At the present moment, building management staff are only very keen in 'locking up' cars for illegal parking. It is doubtful whether there are any fire safety training provided at all!

This paper is only a preliminary report on the project. The conclusion is that well-planned studies on fire safety aspect for highrise buildings [15] must be carried out before implementing regulations. That application [15] for research grants was unsuccessful because of the low rating on safety at that time. Fortunately, small funding was granted from the Polytechnic University in stimulating the study.

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