FIRE SAFETY CONCERNS ON EXISTING SUPERTALL BUILDINGS AND PROPOSED UPGRADING IN HONG KONG

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(Received 28 January 2011; Accepted 27 June 2011)

ABSTRACT

Many supertall buildings of height over 300 m were constructed all over the world in the past decades. However, very few researches reported on fire safety for such supertall constructions. Several big post-flashover fires had occurred in tall buildings. Consequently, there are new challenges that fire safety provisions for existing supertall buildings are insufficient. For example, total evacuation took over 2 hours as experienced before without using elevators. Occupants do not like to stay at the refuge floors waiting for rescue after the quick collapse of World Trade Centre in 2001. There are difficulties in setting up firefighting ladders in downtown area as experienced in the Garley Building Fire.

Fire safety concerns in supertall buildings in Hong Kong were surveyed and reported in this paper. Upgrading works were proposed to enhance fire safety for existing supertall buildings. An effective fire detection system would satisfy better the life safety objective and response in firefighting. More reliable fire detection systems should be installed.

1. INTRODUCTION

Many supertall structures with different terms are found in the literature such as mega high-rise buildings [1], skyscrapers [2], super-high-rise buildings [3] and supertall buildings [4]. There is no internationally agreed height adopted for classifying supertall buildings yet. The value is above 150 m in Europe [5]. Buildings taller than 100 m [6] would be regarded as supertall buildings and additional requirements are specified for buildings over 250 m in China [7]. 250 m was adopted as the height to classify supertall building in the research community. Supertall buildings were referred to be those of height over 300 m by the Council on Tall Buildings and Urban Habitat [8].

In Hong Kong, high-rise buildings are defined [9] as buildings with the highest storey over 30 m above the exit at ground floor. No official definition was found for supertall buildings. In the existing codes, there are additional requirements for buildings with over 40 storeys. This value was then taken as the reference in classifying supertall buildings in many projects [10,11]. Taking minimum height of floor to floor as 3 m, the height of a 40-storey building would be at least 120 m. There are over 700 supertall buildings in Hong Kong classified in this way [12]. Besides environmental issues on affecting natural ventilation and disposing smoke to the neighbours, fire hazard in supertall buildings should be watched. Since the buildings are too close to one another, smoke generated in a fire would spill to the space between the buildings and stay there. The smoke exhaust of a supertall building could be next to the fresh air intakes of air-conditioning system for adjacent buildings.

Most of the supertall buildings are Grade A office [13] towers or luxury residential buildings. Grade A offices are the highest class offices with excellent management [13]. However, over 30% of the 700 supertall residential buildings are public housing estates. Quality of management should be watched as problems in the elevators systems had been reported frequently [14]. From a questionnaire survey on working evacuation strategy of supertall buildings [15], people are worrying about fire safety management.

Local fire codes are actively updated with new products, social needs, painful experiences learned from previous fire incidents [16] and other reasons. Inadequacies in the existing codes were discussed in tall buildings, deep subway stations and long tunnels. As it is difficult to upgrade hardware provisions, fire safety management should be enhanced [17]. Open kitchen design in small residential unit of supertall buildings is a good example [18]. In-depth study should be carried out for providing adequate fire safety provisions in supertall buildings. Fire codes can then be upgraded accordingly by specifying more fire safety provisions for supertall buildings.

2. PROBLEMS IDENTIFIED FROM FIRE STATISTICS

Fire statistics were published in the Fire Services Review (previously known as Annual Departmental Report) by the local Fire Services Department (FSD). The number of false alarm cases, the causes of fires, the kind of premises and the floor level that was on fire were released. A classification system was implemented in 1981. Data reported after that [19,20] were complied as shown from Figs. 1 to 4 for further study in this paper.

In Fig. 1, there is a general trend of increasing false alarm cases in the last three decades. The percentage of false alarm increased more than the total number of fire cases. It is obvious that the fire detection and alarm systems installed in existing constructions cannot distinguish false alarm. Reasons for the high false alarm rate were identified to be improper engineering designs, inadequate maintenance, environmental aspects and human activities.

The top three causes of fire were careless handling or disposal of cigarette ends, matches and candles, food stuff (stove overcooking) and general electrical faults. Over 90% for fire cases were due to those incidents as in Fig. 2. General electrical faults may not be strictly related to human activities. Over 80% of the fire cases were due to improper action of the occupants. These activities are commonly found in domestic buildings and public housing estates, matching with the fire cases classified according to the premises. Fire action plans must be enhanced.

About 80 % of the fire cases appear to occur in domestic buildings or housing estates as in Fig. 3. Residential buildings have a higher chance of fire outbreak. A possible reason is because the fire service installations (FSI) required for high rise residential buildings are not so tight as others in the local fire codes [9]. Occupants are expected to be familiar with the environment and more responsible to protect their own properties. High cost associated with installations and annual inspections on FSI might be another reason for not providing the systems in residential buildings. Therefore, fire safety in open kitchen design in small residential units in tall buildings with high fire load density of over 1400 MJm^{-2} as surveyed should be watched carefully. Additional requirement must be installed to enhance fire safety for such tall residential buildings with open kitchens.

More fires occurred at higher floors as shown in Fig. 4. However, the existing fire engines can only access up to 53 m [20]. Difficulties were found in setting up the fire ladder over 13 floors in the big Garley Building fire due to metal wires used for fixing up neon light panels in adjacent buildings [16]. People at the upper floors cannot rely on external rescue including helicopters which was demonstrated to be not effective in the big Garley Building fire [16]. High amount of air was driven to the upper burning floors by the helicopter to give a bigger fire as reported. Therefore, appropriate fire protection engineering systems should be provided for supertall buildings. More requirements such as providing more evacuation paths should be specified for taller building heights as proposed [10].

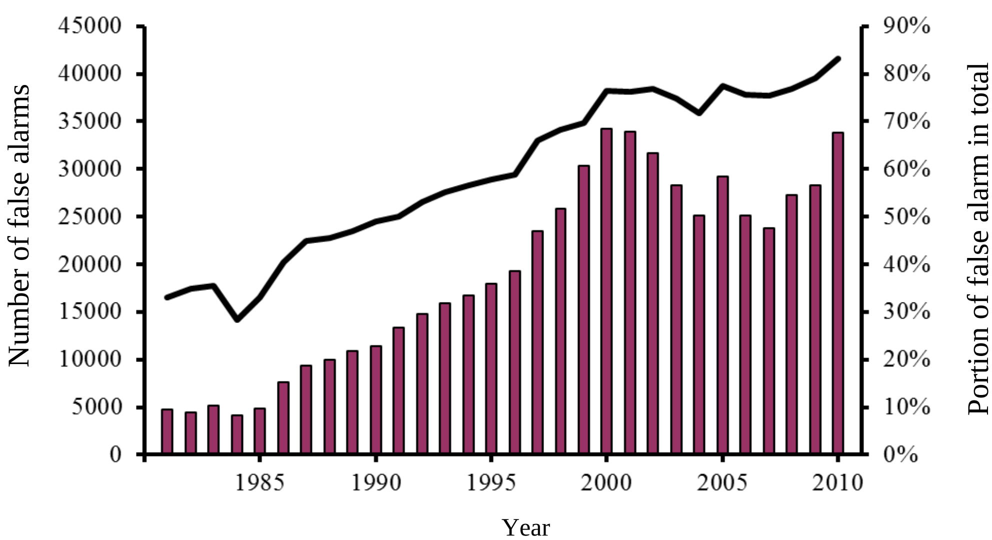
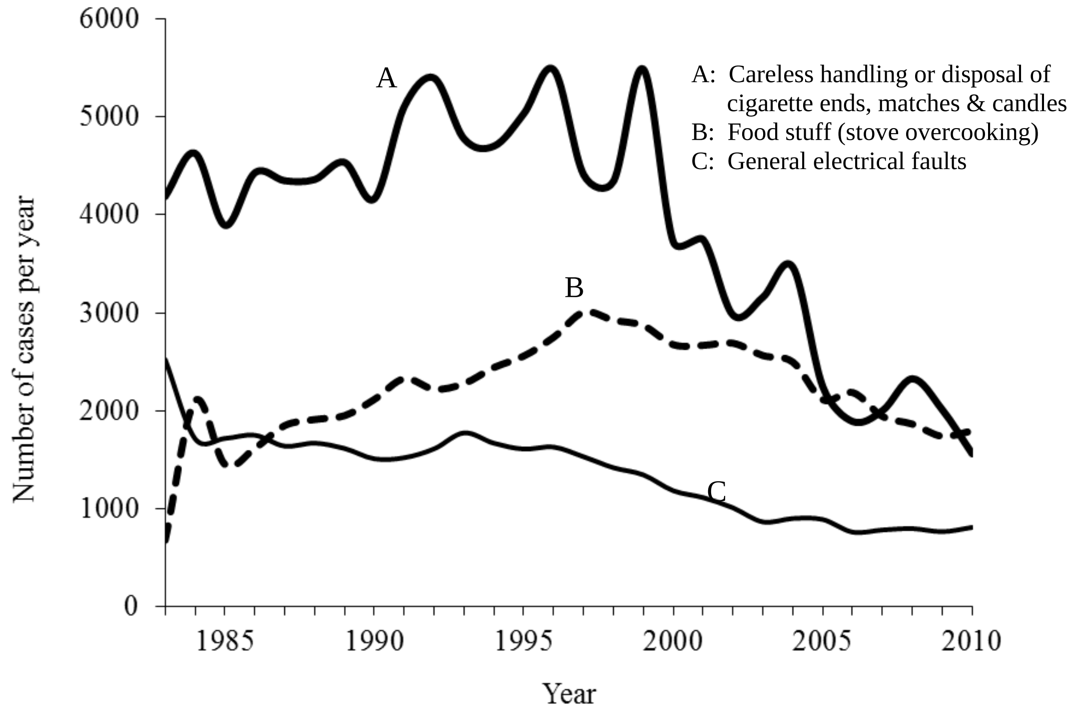
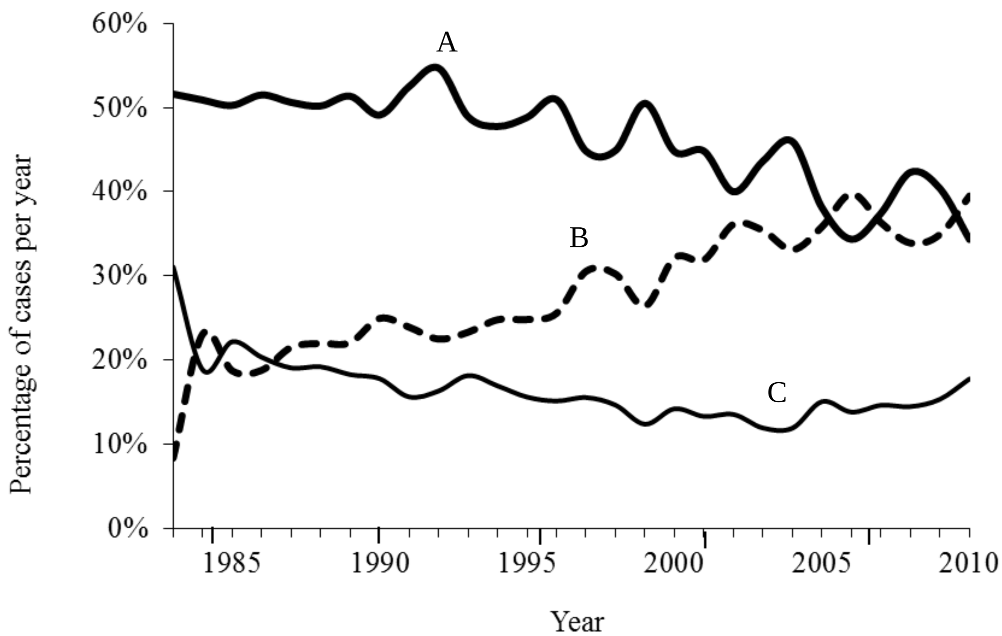


Fig. 1: Number of false alarms received by FSD

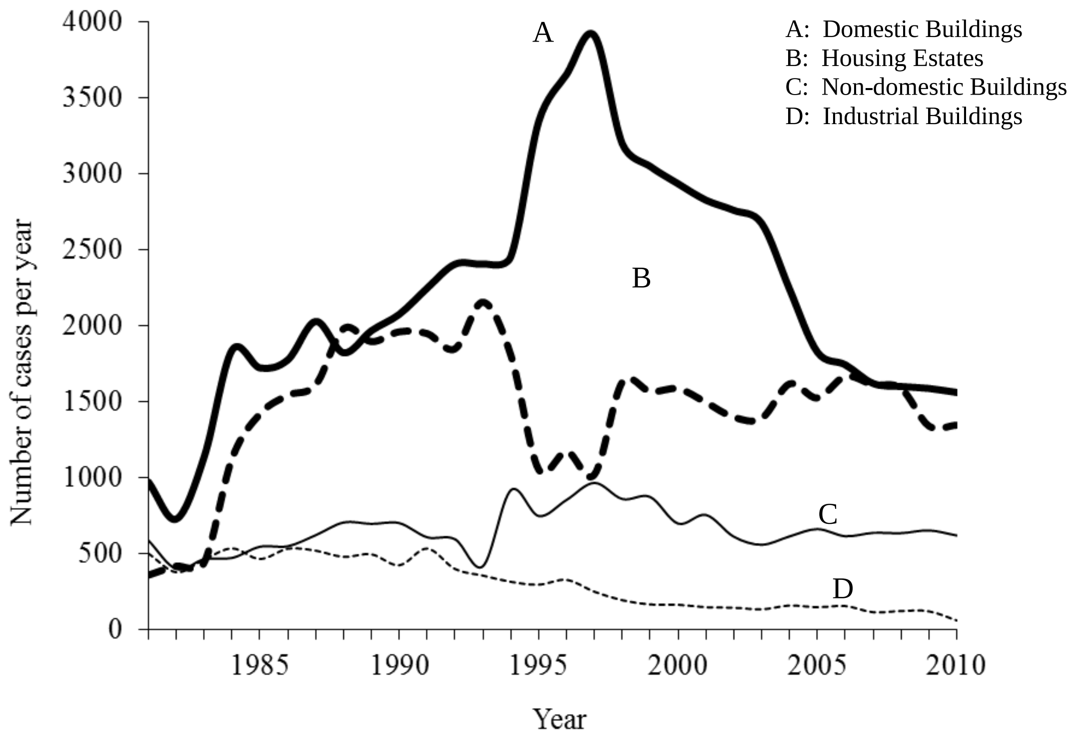


(a) Number of cases for different causes of fires

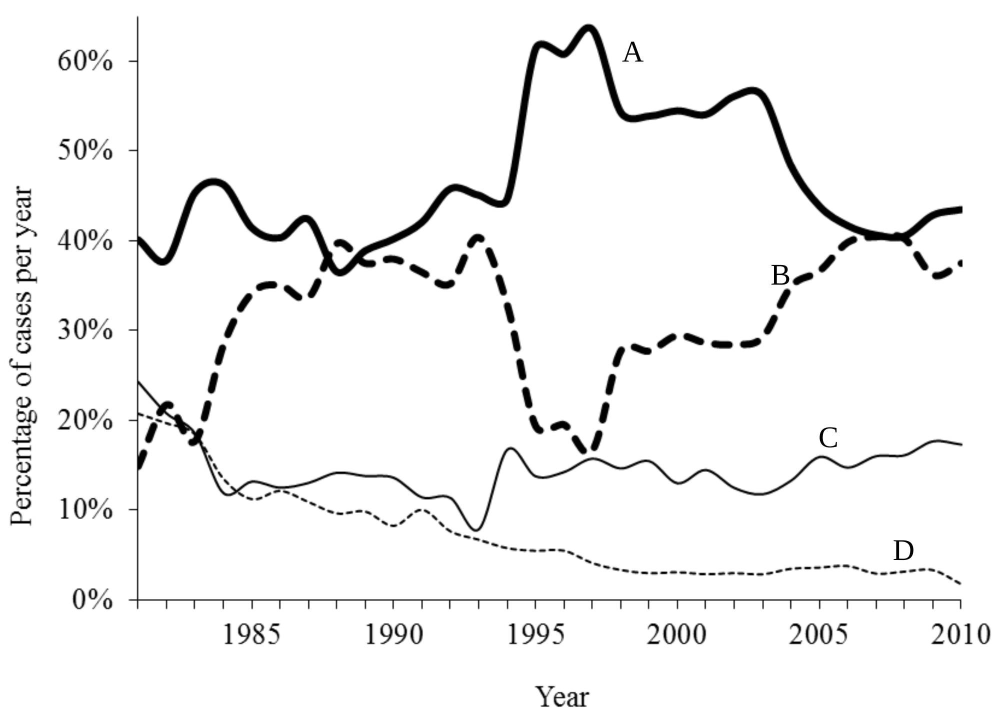


(b) Percentage of various premises

Fig. 2: Different causes of fires

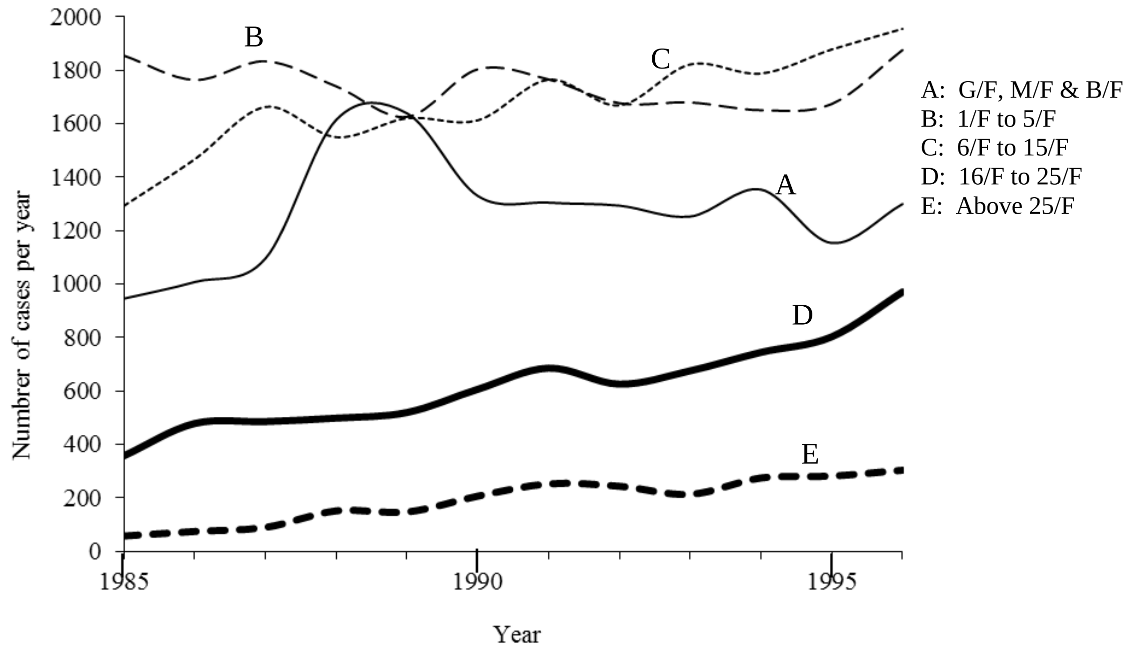


(a) Number of cases for various premises

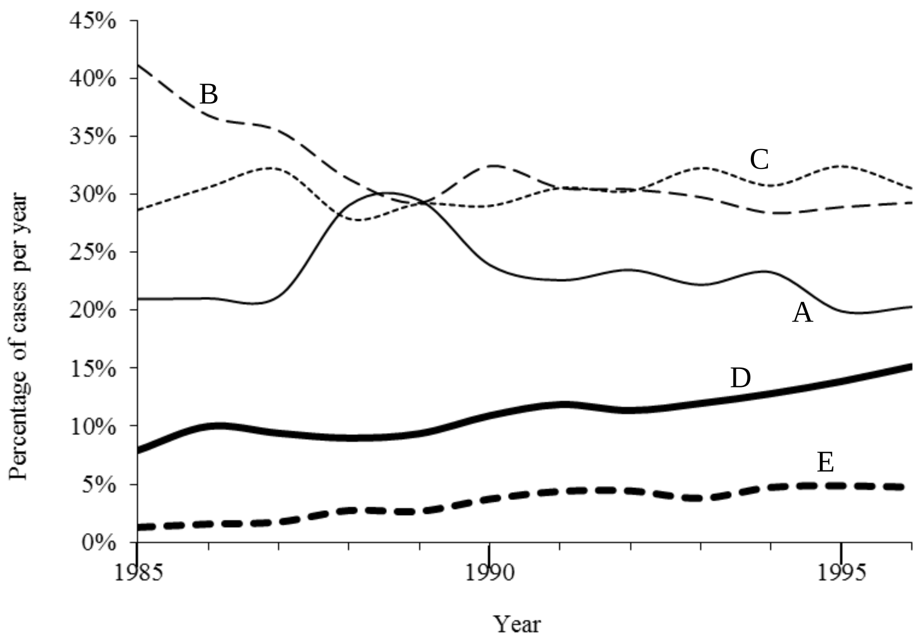


(b) Percentage of various premises

Fig. 3: Fire cases in various premises



(a) Number of cases at relative floor levels



(b) Percentage of cases at relative floor levels

Fig. 4: Fire cases at relative floor levels

3. ENGINEERING PROBLEMS IDENTIFIED IN EXISTING SUPERTALL BUILDINGS

At least three problems are identified in supertall buildings as surveyed.

- Pressure requirement for water system at higher floors

High pressure is experienced at the low level of a water system in a tall building due to gravity. Designs and equipments selected for fire hydrant and hose reel (FH/HR) system should be watched.

Schematic diagram of typical design for FH/HR system in a 150 m tall residential building is shown in Fig. 5. Local FSI codes [9] stated that the minimum pressure at any fire hydrant is 3.5 bar when discharging water with a flow rate of 900 l/s. The total pressure can be higher than 20 bar at the pump outlet without water flowing through. Note that the design working pressure for system components is 13.7 bar [21], or even down to 10 bar [22]. Such problem is also found in sprinkler systems. The fire pump and other components located at ground floor should be able to stand such high pressure or changes to appropriate hydraulic design.

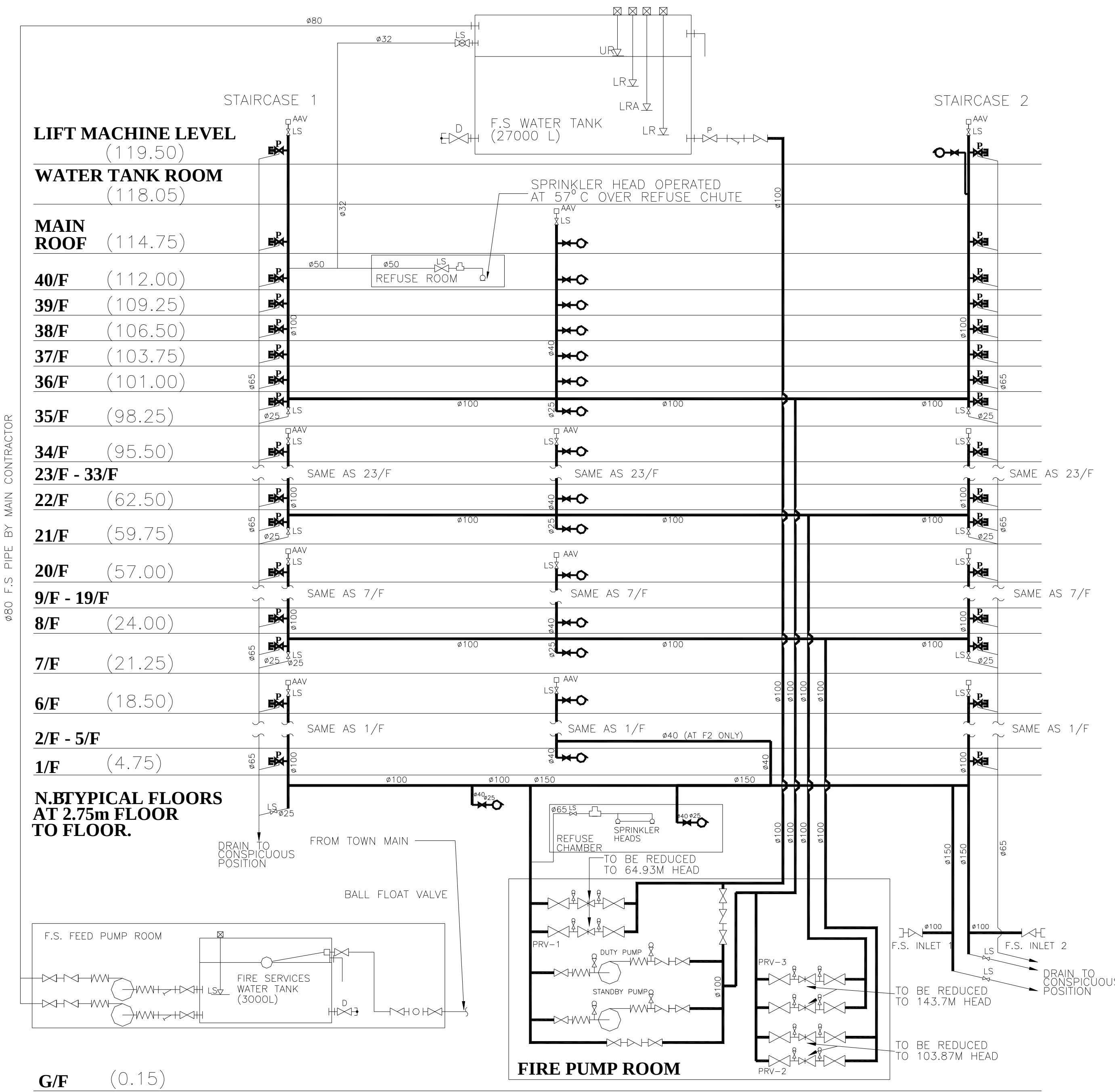


Fig. 5: Schematic diagram for fire hydrant / hose reel system of a supertall building

System components have to stand much higher working pressure in supertall buildings. The system would eventually deteriorate with a faster rate. As firefighting systems are always in "standby" mode, the defects due to high pressure cannot be easily identified during regular annual maintenance. Bursting the components in firefighting would lead to disaster.

- Stack effect for vertical shafts

Stack effect would affect performance of smoke management systems such as staircase pressurization system. As recorded by the Hong Kong Observatory between 1971 and 2000, the mean daily minimum and maximum monthly air temperature recorded were 14.1 ^{o}C in winter and 31.3 ^{o}C in summer [23]. The corresponding extreme temperatures are 0.0 ^{o}C and 36.1 ^{o}C [23]. Taking the tall residential building in Fig. 5 as an example, an enclosed shaft of height 135 m with indoor temperature 25 ^{o}C would give a mean stack pressure difference of mean 60 Pa in winter, and -32 Pa in summer. The extreme value can be up to 144 Pa in winter, and -56 Pa in summer. Staircase pressurization system must be designed to get the required pressure difference of 50 Pa [9].

- Strong wind at height

Besides the operation of traditional fire detection systems, high wind speed around higher floors of supertall buildings is hazardous [24]. The heat release rate for a residential flat at height in a supertall building with openable windows can be very high [25]. The water curtain discharged to protect refuge floor openings would be disturbed by the strong wind [26-28].

4. MANAGEMENT IN EXISTING SUPTERTALL BUILDINGS

Site surveys were carried out to understand the managment in existing supertall buildings. At least three problems are identified as the following. These problems are also found in other buildings. However, the consequence would be very serious in supertall buildings.

- Refuse bins in staircases

Most supertall buildings in Hong Kong are planned to be green and sustainable without refuse chute nor refuse chamber at each floor. Refuse bins were then put at the staircases as in Fig. 6a. The design width of the staircase was 1.1 m with effective width of 800 mm [29]. Putting in litter bin reduced the width less than 400 mm. If three recycle refuse bins were put in each floor of the staircases for environmental protection, the staircases would be blocked and affected emergency evacuation.

- Decoration of hose reel cabinets

Many occupants do not like to see the notice of hose reel and put on internal decorations at the wall surface as in Fig. 6b. It is difficult to locate the hose reel cabinets. Mirrors and marble finishes installed on the cover of the hose reel cabinets are very heavy. It is not easy for women and elderly to open the cover before the firemen arrive.

- Blocking of fire service inlets

Fire services inlets installed at "prominent" locations were obstructed outside the coffee shop at the ground floor of a supertall building as in Fig. 6c. The seating area was extended to cover the "free space" in front of the fire services inlets. The space is the "unloading area" for the fire brigade in fighting fire. Those tables and chairs would affect firefighting.

5. PROBLEMS ON FIRE ENGINEERING APPROACH

Performance-based design, or known as fire engineering approach (FEA) in Hong Kong has to be applied for supertall buildings having difficulties to comply with the prescriptive codes [30]. As raised by Chow in an open lecture recently [18], the available safe evacuation times (ASET) are commonly calculated with very small fire scenarios. The required safe evacuation times (RSET) were estimated without studying local human behaviour. It is difficult to keep people evacuating orderly in the Far East as clearly demonstrated in the Lan Kwai Fong incidence [31]. In most FEA reports, only several small fire scenarios were considered to give a long ASET. Excluding human behaviour gets a shorter RSET. A set of scenarios matching with real big post-flashover fire as experienced many times in Hong Kong, Shanghai and Shenyang should be illustrated in FEA reports. Values of the shortest ASET and the longest RSET for the worst scenarios must be submitted for the authority to consider. Higher cost of fire protection in a building per person than the insurance cost of a person cannot be an excuse.

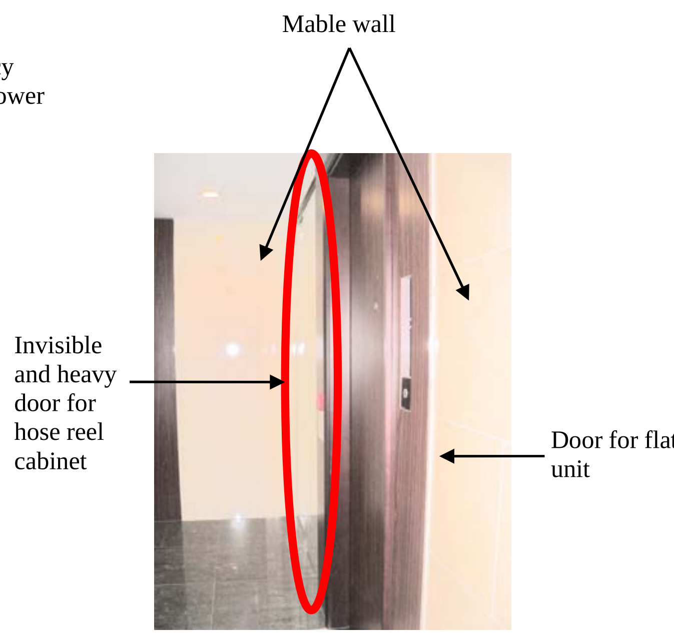
Interaction with other fire safety provisions imposed by the prescriptive codes are not considered. It is assumed that provisions determined by FEA could work well and equivalent to prescriptive designs. Apart from the problems described in the last section, the inadequacy of the existing prescriptive codes would even deeply jeopardize the expected results deduced from FEA when the prescriptive solutions are broken down.

Interactions between FSI must be studied rigorously. A typical example is the interaction between sprinkler spray and natural smoke extraction system [32]. Consequences can be very serious for deep underground crowded spaces.

Human behavior like understanding on fire safety issues and response to fire alarms [15] should be watched while adopting overseas fire standards in Hong Kong. Codes practicing in overseas with their assumptions, such as UK and USA, cannot be applied directly in the Far East without justifications. Differences in interpretations, education and social awareness on fire safety are all different. Studies and assumptions made by other countries cannot be directly interpreted as applicable and suitable for elsewhere.

Overseas recommendations [33] should be demonstrated to work under local conditions before implementation. Long ASET determined from engineering calculations are only applicable with thermal effect only. Only carbon monoxide is included in smoke toxicity assessment.

(a) Garbage bin at the evacuation and firefighting staircase



(b) Decoration for hose reel cabinet

(c) Blocking fire services inlets

Fig. 6: Problems identified in supertall building

6. FIRE DETECTION SYSTEM

Although effective fire detection can alert the occupants to evacuate before the fire develops, high false alarm rate as discussed above would give adverse effect. Many problems for fire detection systems are found in supertall buildings [24]. Examples are decoration and poor fire safety management in blocking staircases or fire service inlets.

Effective fire detection has the advantage of minimizing property loss, reducing water damage and shortening the disruption to normal operation. Further, high false alarm rate of fire detection systems can be eliminated. Fire detection systems should not be only used as a complementary system to cover places without automatic fixed installations such as sprinkler systems in commercial buildings. Fire detection systems should be installed in most area of domestic buildings [9], not only in the plant rooms in supertall buildings.

Smoke detector is very effective in detecting smouldering fire. A prompt fire alarm can alert the well-trained occupants or management to take appropriate fire action plans. The fire can then be put out easily before the fire develops and even before activating the sprinkler system. The fire growth rate is limited by early suppressing actions. The ASET can be extended to allow longer evacuating time for occupants. The firemen can extinguish the fire more effectively. If the fire is very small and that the people can put it out by themselves, evacuation is not necessary. A heat detector has a fast response than sprinklers to gain the above advantages.

7. UPGRADING FIRE SAFETY FOR EXISTING SUPERTALL BUILDINGS

Very few research work was reported on fire safety provisions in supertall buildings. Professionals are not aware of the differences between applying the existing codes to normal tall buildings and to supertall buildings. There are many new constructions in the last two decades with similar features. Typical FSI designs are extended and expanded to cover the taller systems. Economic tsunami has led to cut budget and tight schedule. There are no sufficient resources nor time for reviewing the design with adequate research studies.

After the handover of the supertall buildings to the end-users and the management, many renovation and fitting out works might be carried out to suit their usage and daily operation. There might even be serious illegal refurbishment [36]. Such alternations and decoration works would introduce more problems. Note that such designs are for aesthetics, convenience in operation and full utilization of the premises. Fire hazards can be very different from those assumptions.

Table 1: Related international standards on fire detectors

Types of detectors	**Australian Standard**	**British Standard**	**International Standard**
Point-type heat detectors	AS 7240.5–2004	BS EN 54–5:2001	ISO 7240–5:2003
Carbon monoxide fire detectors using electro-chemical cells	AS 7240.6–2004	--	ISO 7240–6:2006
Point type smoke detectors using scattered light, transmitted light or ionization	AS 7240.7–2004	BS EN 54–7:2001	ISO 7240–7:2003
Carbon monoxide fire detectors using an electro-chemical cell in combination with a heat sensor	AS 7240.8–2007	BS ISO 7240–8:2007	ISO 7240–8:2007
Point type flame detectors	AS 7240.10–2007	BS EN 54–10:2001	ISO 7240–10:2007
Line type smoke detectors using an transmitted optical beam	AS 7240.12–2007	BS EN 54–12:2002	ISO 7240–12:2006
Multisensor fire detectors	AS 7240.15–2004	BS ISO 7240–15:2004	ISO 7240–15:2004
Aspirating smoke detectors	NA	BS EN 54–20:2006	ISO 7240–22:2004

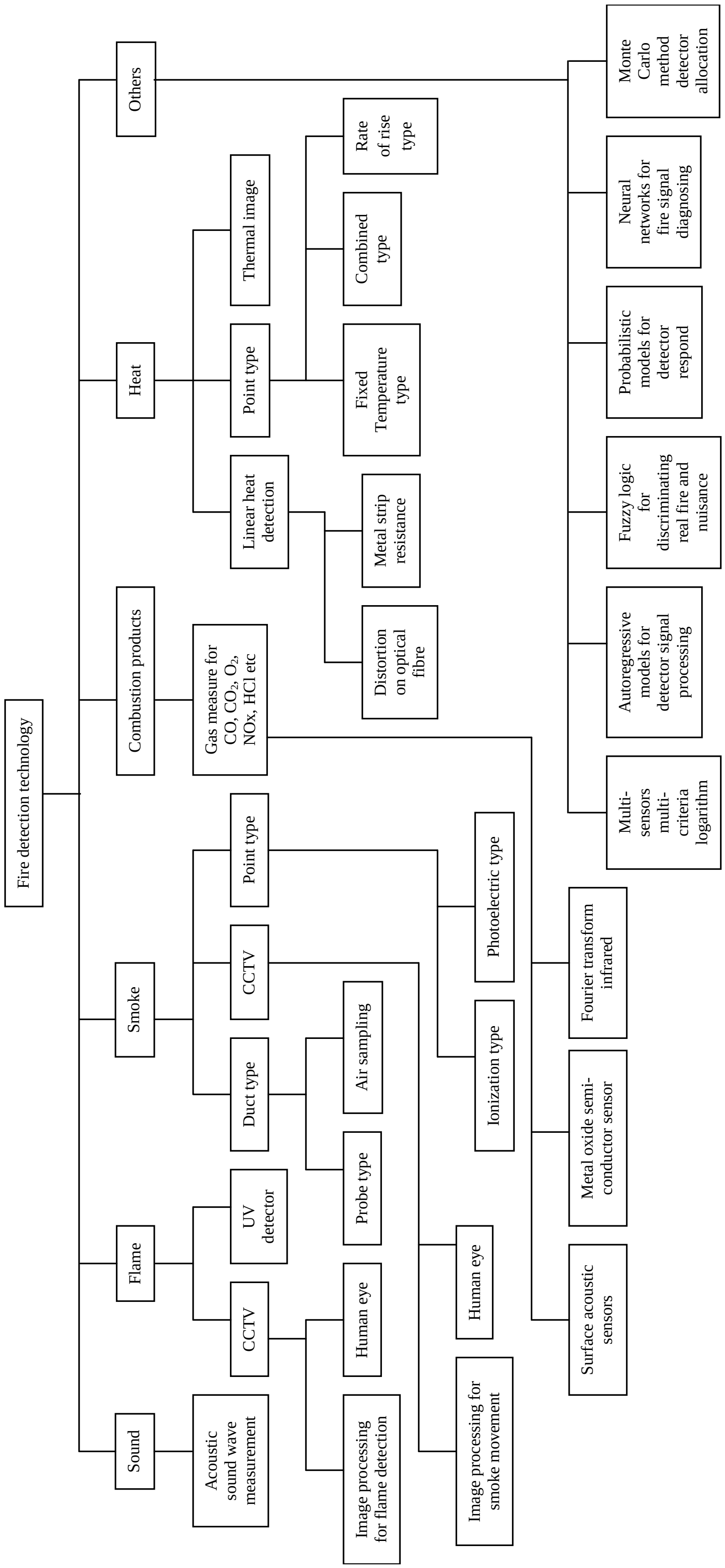


Fig. 7: Summary of fire detection technologies [23]

Problems discussed above are difficult to solve for existing supetall buildings. Some can be improved easily by replacing the valves or components with proper pressure ratings. Changing the decorations for the ease of locating the fire safety equipment would be very useful. Establishing correct fire safety attitudes of the management and occupants is essential. Adding reliable fire detection system is the most essential one.

Wind effect in units with openable windows should be watched. Monitoring devices installed at the louvres and openings would control the air flow across the compartment. Sufficient air flow can be provided for ventilation by adding variable dampers at the openings. Video detection system is worthwhile to consider [24].

8. CONCLUSION

There are lots of supertall buildings erected locally without any specified fire safety provisions by the government nor engineering assessment to tackle the problems determined in the site surveys. Simply extending the applications of current codes requirements would lead to many design, installation and management faults. Improving the quality of engineering designs and fire safety management in supertall buildings are essential. New developments should be supported by adequate local research data. Fire detection system should be installed in most public areas with proper fire alarm system and that could enhance the fire safety level in existing supertall buildings

ACKNOWLEDGEMENT

This project is supported by the Croucher Foundation with title "Active Fire Protection in Supertall Buildings" and account number 5-ZH46.

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