

FIRE SAFETY DESIGN FOR HERITAGE BUILDINGS IN HONG KONG

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ABSTRACT

Due to historic background of the Hong Kong Special Administration Region, the types of historic buildings are varied including traditional Chinese ancestral halls, Western styled residences and functional buildings (e.g. Police Stations). To-date's prescriptive codes for fire safety provisions would inevitably present challenges to alterations or renovations of historical buildings, where impact to historic fabric, appearance and aesthetics should be minimized and at the same time fire safety level with respect to life must not be compromised. The use of alternative approach or performance-based approach to fire safety design as allowed under the local codes is then the only means to address both fire safety concerns and preservations of historical elements. Fire safety management is an importance aspect to mitigate the potential fire risks.

This paper outline the characteristics of historic buildings in Hong Kong and gives an overview on the approach to deal with fire safety design in historical buildings including design objectives, legislative environment, administrative aspects and technical aspects. Typical building elements in historical buildings in Hong Kong that rise fire safety problems are listed. The problems and difficulties encountered in fire safety design are discussed. The application of fire safety engineering to a real historic building project is also described.

KEYWORDS: Historic buildings, Hong Kong practice, Fire safety design problems

INTRODUCTION

Hong Kong, the Hong Kong Special Administrative Region (SAR) of the People's Republic of China (PRC) since 1997, consisting of Hong Kong Island, Kowloon Peninsula (its northern side New Territories connects to the PRC), Lantau Island and a number of small outlying islands centered around the Victoria harbour, is a densely populated modern city geographically located in southern China. Hong Kong had been a British colony for more than 130 years till 1997. Prior to the arrival of the British in the Nineteenth Century, Hong Kong was a small fishing community in the South China Sea. Following the first Opium War with China in the Nineteenth Century, Hong Kong Island became a British colony (ceded to Britain) since 1842. After the second Opium War, the Kowloon Peninsula south of Boundary Street and Stonecutter's Island were then ceded to Britain since 1860. In 1898, the New Territories including Lantau Island were then leased by Britain from China for 99 years. On 1 July 1997, Hong Kong was handed over to the mainland China and became a special administrative region with continuous economic growth.

The concern of preservation of historical buildings/ monuments in the Hong Kong SAR has been increasingly raised in recent years. Due to the historic background of the Hong Kong SAR with mixed cultures of the East and West, the types of historic buildings are varied ranging from elegant traditional Chinese ancestral halls, Chinese temples to Western styled residences and functional buildings (e.g. military facilities). The Antiquities and Monuments Ordinance (Cap. 53)¹, enacted in 1976, which is administered by Secretary of Home Affairs (Antiquities and Monuments Office of Leisure and Cultural Services Department), is to preserve and protect the objects of historical, archaeological and palaeontological interest. Under the Antiquities and Monuments Ordinance, the Antiquities Authority may, after the consulting process through the Antiquities Advisory Board with the approval from the Chief Executive and the publication of the notice in government gazette, declare a place/building to be protected that alteration should be prevented or proposed alteration should have

imposed conditions. In January 2007, there are a total of 496 graded historic buildings and 81 declared monuments.

Apart from continued preservation, maintenance, extensive repairs and restoration for some historic features which are remaining their original usage (e.g. temples, traditional ancestral halls for tourists, buildings in university), it is not uncommon that some historic buildings will be renovated to alter their original uses for other usages coping with the societal needs, with their building appearances being preserved for aesthetic purpose. Examples include the conversion of Western styled residence to museum (e.g. Kom Tong Hall to Dr. Sun Yat-sen museum)², the adoption of historic military buildings to suit the complexities of modern exhibition in museum complex (e.g. Hong Kong Heritage Discovery Centre) or holiday village (e.g. Lei Yue Mun Park and Holiday Village). Nature of fire safety design necessary for these historic heritage buildings depends on the types of buildings, ultimate usages, cultural significance of the building and purpose restoration.

As the prescriptive building fire safety codes³⁻⁶ have not anticipated application to historic buildings, conflict between the authentic way of the preservation of historic buildings and the application of to-date specified fire safety design requirements is expected, which presents inevitable challenges and friction for the alteration/ renovation works. The use of alternative approach or performance-based approach to fire safety design as allowed under the local codes³⁻⁶, will then be the only means to address both fire safety concerns and preservations of historical elements for renovation of historic buildings.

CHARACTERISTICS OF HISTORIC BUILDINGS IN HONG KONG

There are a total of 496 graded historic buildings (Grade I, II and III) and 81 declared monuments in Hong Kong on January 2007 as announced by the Antiquities Authority. They are of varied historic building types ranging from elegant traditional Chinese ancestral halls and Western residences to function buildings such as military facilities. Their historic significance also varies depending on the architectural styles, building materials, the cultural and social belief and its history. Generally, the types of historic building can be categorized as in Table 1 below.

In terms of purposes or uses of these historic buildings, they can be classified into the following four main aspects:

- i. Remain its original use with regular repairing and restoration (e.g. temples, monasteries, university buildings, schools, some government buildings)
- ii. Remain its original outlook and convert to museum, tourist attraction or recreation facilities (e.g. Chinese village and ancestral halls, some former government buildings and former railway stations)
- iii. Remain its original outlook and convert to commercial uses such as hotel, shops or restaurant (which occurs in some former government buildings)
- iv. Abandon or leave it as what it is.

As items ii and iii involve rehabilitation and adaptive reuse of existing building, practical difficulties in dealing with fire safety design arise and approach to resolve such concern will be discussed in the following sections.

TABLE 1. Types of historic building

Type	Architectural Style	Typical Characters
1. Temples, Monasteries	Traditional Chinese	Open in nature, wooden construction involved, single storey, high ceiling for natural lighting and ventilation.
2. Chinese villages, residence compound	Small house in village	A group of small dwellings with brick work construction or else.
3. Chinese ancestral halls	Traditional Chinese	Open in nature, wooden and/or brick work construction, single storey, high ceiling for natural lighting and ventilation.
4. Former or old government buildings, e.g. - Police station - Post office - British troops facilities - Supreme court - Marine police station - Quarters - Prison compound	European	Relatively large construction with multi-storey (usually up to 3 storey), stone/ granite structure, hardwood slabs, non-enclosed wooden staircases, timber framed glass windows, window open to verandah that facilitate nature ventilation.
5. Specific Buildings in University	European	Relatively large construction with multi-storey (usually up to 3 storey), stone/ granite structure, hardwood slabs, non-enclosed wooden staircases, timber framed glass windows, windows open to verandah that facilitate nature ventilation.
6. Former railway station	Hybrid	Single storey and open in nature
7. Western Schools	European	Relatively large construction with multi-storey, stone/ granite structure, hardwood and brick construction, non-enclosed staircases, timber framed glass windows, windows open to verandah that facilitate nature ventilation.
8. Western Residences	European	Relatively large construction with multi-storey (usually up to 3 storey), stone/ granite structure, hardwood slabs, non-enclosed wooden staircases, timber framed glass windows, windows open to verandah that facilitate nature ventilation.

DESIGN PROCESS AND APPROACHES

Objectives for Fire Safety Design

The current international perspective on fire safety objectives specifically includes the protection of life, the contents of a building, the building fabric and minimization of environmental threat ^{7,8}. These objectives for fire safety design in building are widely recognized within the context of performance-based design approach ⁹⁻¹¹, which are usually focusing and applying on new buildings design. On the objective of protection of building fabric, historic buildings will need to put more emphasis in preservation of historical building features from loss by fire. Also, during the design and construction of the fire safety system within such buildings, specific care is needed for the preservation of original quality and character of the historical features ⁹ according to the respective historic significance. In short, the objectives for life safety and historic preservation are the basic goals for the design of fire protection systems ¹². To implement the fire safety design for a historic building by achieving these two basic goals, it depends on the how the fire regulatory environment set for the design of fire

protection measures in building and whether there is specific building fire safety code/ standard/ guides for historic building.

The current building fire safety codes³⁻⁵ for Hong Kong are prescriptive in nature which allow the use of Alternative Approach to fire safety design for special and complex buildings. Hence, only general functional objectives for the provision of respective fire protection measures have been stated but not the high level fire safety objectives as described above. They are listed in Table 2 below. As expected, the general functional objectives as stated in these codes³⁻⁵ are based on new construction, not anticipated application on historic buildings. Even for the application of alteration or renovation on existing buildings, full compliance to the prescriptive specifications is expected.

TABLE 2. Fire safety objectives in Hong Kong Building Fire Safety Codes

Code	Objectives Stated
Means of Escape ³	<ul style="list-style-type: none"> • To announce provisions for the protection of buildings from the effects of fire by providing adequate means of escape in the event of fire and other emergencies. • Others: preventing the outbreak of fire, inhibiting the spread of fire, abating fire hazards, fire suppression, preventing loss of property and assisting in firefighting and rescue.
Fire Resisting Construction ⁴	<ul style="list-style-type: none"> • To announce provisions for the protection of buildings from the effects of fire by inhibiting the spread of fire and ensuring the integrity of the structural elements of buildings. • Others: preventing the outbreak of fire, abating fire hazards, fire suppression, preventing loss of property, providing means of escape and assisting in firefighting and rescue.
Means of Access ⁵	<ul style="list-style-type: none"> • To achieve the objective of assisting in firefighting and in saving life of people in buildings by ensuring adequate access for firefighting personnel in the event of fire and other emergencies. • Others: preventing the outbreak of fire, limiting the spread of fire, abating fire hazards, fire suppression, prevention of loss of property, providing means of escape.

Building Fire Safety Legislations and Codes

Unlike most new buildings, the historic building inevitably pose unique problems for fire protection due to its visual record of architectural or historic significance¹³ that significant alteration or modification might destroy the goal of preservation of historic elements. Once an existing building is declared as a historic building, the Antiquities Authority (i.e. the Secretary for Home Affairs) under the Antiquities and Monuments Ordinance¹ is then responsible to prevent alterations, or to impose conditions upon any proposed alterations as needed and to cope with the diverse problems of restoring old structures, in order to protect the historic building, where necessary, technical assistance from relevant concerned bodies (e.g. Architectural Services Department who is responsible for the design, construction and maintenance of government buildings) will be sought.

In addition to Antiquities and Monuments control, alterations and changes of use of a particular historic building is also subject to the Building Ordinance and Regulations. The fire safety legislations with respect to fire safety design and building management applied to a particular historic building currently has no different from that of any existing building subject to alteration/ renovation or a new building. The passive fire protection measures shall follow Building (Planning) Regulations¹⁴ which prescribes the planning requirements for the provision of staircases, fire escapes and access for firefighting and rescue. Detailed requirements are prescribed in Codes of Practice for the Provision of Means of Escape³ and Means of Access for Firefighting and Rescue⁵. Building (Construction) Regulations¹⁵ prescribes the requirements of building construction/structural design, use of materials and the general requirements of fire resisting construction to inhibit fire spread and

maintain stability. Detailed technical requirements are specified in Code of Practice for Fire Resisting Construction ⁴. On active fire protection measures, it shall follow the requirements laid down in Codes of Practice for Fire Service Installations ⁶. Besides, building ductwork systems in particular of fire safety purposes shall follow requirements as in Building (Ventilation Systems) Regulations ¹⁶. With respect to building management, presently there is no mandatory requirement to impose fire safety management ^{17,18} and is relied on the available guidance document ¹⁹ to be carried out by the building management professionals.

As historic buildings may be used as hotels, university, shops, museums or temples, some of the uses require to follow the relevant addition fire safety design requirements should such use demands a license for business operation. Examples include hotel usage shall follow the Hotel and Guesthouse Accommodation Ordinance ²⁰ and the respective detailed fire safety specifications ²¹ and; restaurant usage shall follow Public Health and Municipal Services Ordinance ²² and the respective detailed fire safety specifications ²³.

Administrative Aspects

As mentioned above, the fire safety legislations and codes applied to new buildings or existing buildings subject to alteration are also applied to historic buildings. As a result, the historic character of a building may unavoidably be destroyed by rigid application of fire safety regulation. Of course, life safety is the non-compromised objective to be achieved in the process of building fire safety design, which is well recognized by the official and building design professionals. Under the prescriptive regulatory environment, the adoption of alternative approach to fire safety design as recognized under the local codes ³⁻⁵ is the only way to develop creative or engineering solutions to meet the life safety objectives with minimum or limited compromise of the historic or architectural significant of the historic building. It is then relied on the building official to determine and agree the level of acceptable equivalency to a specific code requirement or the level of fire safety in respect to the tenable condition, through the submission of fire strategy report.

The application of fire safety engineering to new buildings or existing buildings ²⁴ has been successfully carried out in Hong Kong for more than 10 years. However, the application to historic buildings is still rare due to the relative less number of historic building projects as compared to typical new building projects. Hence, the design to achieve the life safety objective and the historic preservation objective will highly depend on the design proposal from the fire safety engineers with the agreement of the official. There is no apparent difference in considering the fire safety solutions for historic buildings in respect to different levels of historic significance (Graded I, II, III or declared Monument), in order to exhibit the goal of historic preservation.

Technical Design/ Assessment Aspects

Watts ¹² has pointed out that there are generally three ways to deal with fire safety design in historic buildings. They are adopting prescriptive requirements, fire indexing or hazard ranking and performance-based evaluation. The ways of adopting prescriptive requirements (by identifying alternatives to code provisions, setting way to achieve equivalency to code provisions, or modifying code provisions with compensatory measures) and performance-based evaluation (by setting performance criteria and fire scenarios, engineering/ fire modeling assessment and documentation of assessment) are the two options as in NFPA 914 ²⁵, a code specifically for historic buildings. Besides, fire researchers in different geographical locations have proposed various fire indexing or fire hazard ranking methods using multi-attribute decision analysis and scoring process to grade and assessment the level of fire safety for existing buildings as well as historic building. Examples include Watt's fire risk indexing for historic buildings ¹³ and NFPA 101A fire safety evaluation system ²⁶ in US; Chow's fire safety ranking system ^{27,28} and Lo's fire safety assessment system ²⁹ for existing buildings in Hong Kong and; Copping's protocol for an integrated life and property fire safety assessment procedure for historic buildings in UK ³⁰. Fire safety management is another key measure to improve fire safety along with either way of technical approach ^{17,18,31}.

In Hong Kong, the industry practice to deal with fire safety design in historic building, taking the codes³⁻⁵ allowed alternative approach, is a hybrid of adoption of prescriptive requirements and performance-based evaluation depending on the identified building elements that have deviated from the prescriptive requirements. One example, which will adopt prescriptive requirement, is that escape staircase (original staircase is open to the interior within any doors) is required to be enclosed by fire rated construction. Compensatory measures or alternatives to achieve equivalency will then be proposed including newly built lobby with doors (provided there is sufficient space) and fire rated drop curtain to maintain integrity of the vertical shaft in case of fire. In most cases, the adoption of prescriptive requirements is the prioritized means unless it is technically infeasible due to site condition or vulnerability of historic significance. The other example which will utilize the performance-based evaluation approach is that should the width of exit be deficient from that of code provision, then evacuation performance will need to be evaluated to assess the offered level of fire safety.

FIRE SAFETY DESIGN ISSUES

For rehabilitation and adaptive reuse of historic building, practical difficulties in dealing with fire safety design arise and solutions to meet both life safety objective and historic preservation objective need to be developed. The initial step is to identify the deviations of the original building elements as compared to the current codes³⁻⁶ provisions. Though the historic buildings are varied in a wide range of past uses with different architectural styles, typical building elements that have deviated from the present codes are listed below:

- *Staircase of deficit width.* Usually, there are difficulties in enlarging the staircase due to limitation of space and modification of existing staircase may destroy its original quality should such staircase be an item for preservation of historic character.
- *No lobby to staircase.* Commonly, staircases in older building were aimed for amenity and circulation purpose and the importance being protected as a means of escape in case of fire was not recognised.
- *Insufficient number of exits.* Existing rooms inside a building will be converted to suit current use (e.g. shop unit), hence, it is common that the original number of doors may not be sufficient as per current code³ provision.
- *Unenclosed staircase.* It is not easy to add vertical shaft to enclose an existing unenclosed staircase due to its regular shape, unlike to-date's escape staircase. Mostly, staircase is a historic character.
- *Verandah as escape route with deadend situation.* The normal circulation route of the verandah will also serve as part of the escape route and very often windows are open onto the verandah. Fire safety concern arises when deadend situation occurs, where occupants need to pass through windows open to the fire room.
- *Wooden staircase.* It is commonly found in Western styled building and its combustible as well as unenclosed nature is not appropriate to form an escape path.
- *Wooden structure/ construction.* The current regulation¹⁵ does not allow the use of combustible material as a building structure.
- *Smoke extraction for fire compartments of space volume exceeding 7000 m³; but less than 28000 m³; and the fire load density is likely to exceed 1135 MJ/m².* As the fire rating of partitions and slabs, sometimes they are made of hardwood, is unknown, then the entire building or a multiple part of the

building may form one big fire compartment as required under the current code ⁴. Then smoke extraction will be required as per fire services installation code ⁶ and space for the accommodation of fan and duct is a concern.

- *Sprinkler system.* In Hong Kong, sprinkler system is a mandatory provision to almost all types of building usage except residential buildings ⁶. Additional space for the accommodation tank and pump facilities, which will impose extra structural load, is a concern.

The solutions to deal with the above listed elements vary on a case-by-case basis depending on the technical flexibility to modify the original building elements and how significance of the historic elements. In general, the standard of means of escape provisions which is a prime means for life safety shall need to satisfy the current standard, at least in terms of equivalency by having alternative or compensatory measures (e.g. automatic drop fire curtain to enclose the escape staircase, extra new escape staircase). Another current fire safety design elements shall not be compromised, they are sprinkler provision and non-combustible building structure. For other existing building elements, performance evaluation may be applied to verify their offered level of fire safety for the decision of acceptance or not.

APPLICATION OF FIRE SAFETY ENGINEERING ON PROJECT

Description of the Historic Building

A former government functional building compound (European Style), which is currently under renovation, constructed in 1884 will be converted to a hotel development with guest rooms, food and beverage (F&B) services and retails. The building compound is a declared monument (having the highest historic significance than that of Graded historic buildings) including the Main Building, the Stable Block and the Signal Tower. There are over 50 items identified as preserved features (e.g. wooden staircases, railing along the corridors, cell units, doors, windows). The Main Building comprises 3-storey (G/F, 2/F and 3/F) of rectangular shape with an open courtyard at the center of the building. There are four existing staircases located at the four corners which are connected to the balcony corridor (verandah) open onto the open courtyard. The balcony corridors connect to individual rooms which will be adapted reuse. The rehabilitated usages of the building include: G/F – F&B areas, retail and open courtyard, 2/F – F&B areas and guestrooms and 3/F – guestrooms.

Fire Safety Designs by Adoption of Prescriptive Requirements

The renovation project is taking the approach that fire safety provisions for life safety must not be compromised. Should there be any unavoidable modification needed for life safety, the original construction will be demolished with its appearance being resumed by new construction. Therefore, sometimes, the preservation of historic character is through retaining of appearance rather than restoration of original construction. Besides, the adoption of prescriptive requirements for fire safety design is normally non-achievable without any alternative or compensatory measures being added to meet the equivalency of code provisions. Sprinkler system is a mandatory provision

The four staircases at each corner of the building will be used as escape staircases, hence, their protection to against ingress of smoke and fire must be provided. These staircases originally have no lobby on each floor. New lobby with doors will be provided as there are sufficient spaces to accommodate such new provision. Also, these staircases originally have no fire separation from G/F, where current code ⁴ requires escape staircase to be continued to open air and fire separation from the rest of usages of the G/F. Alternative measures are proposed to achieve such requirement, which is by the use of automatic drop fire curtain on the G/F with actuation by fire detector, together with a 800mm downstand to prevent ingress of smoke to the staircase prior to the operation of fire curtain.

Two of the existing staircases which are originally made of wood, is proposed to transform to steel structure staircases with wood being remained as surface finishes for retaining its historic character. The wooden finishes will be treated fire retardant to retard rate of flame spread and ignitability. On this design element, if rigidly applying prescriptive requirement, it won't be feasible because that the current code⁴ does not allow the presence of combustible items within escape staircase. It has been recognized by the official that fire safety of an escape staircase shall rely proper fire safety management to prevent fire occurs inside. If a fire occurs within an escape staircase which is free of combustible, it can't serve the escape purpose either.

In addition, the structure of the building will be modified (i.e. use steelwork as structure instead of wood) to suit the current code⁴ requirements with hardwood slabs as surface finishing.

Fire Safety Designs by Performance Evaluation

Very often, fire safety designs in historic building cannot avoid performance evaluation due to the complicated existing conditions and historic preservation. Or should an alternative measure or compensatory measure be proposed for a fire safety design element through adoption of prescriptive requirement, the achieved performance (or code equivalency) will also need to be verified by carrying out fire and/or evacuation modeling(s).

In this project, evacuation time analysis is carried out to verify the performance of escape provision in respect to the code deviation of number of exit and width of individual exit. Three of the four staircases are of deficient individual width (two of them are 1035 mm and one is 973 mm) as compared to the current code³ requirement (minimum width of exit is 1050 mm). However, the total width provided by the four existing staircases is 4158mm, which is wider than that of the minimum code requirement of 3000 mm (based on the largest population on 2/F of 338 persons) by 38%. Evacuation software STEPS³² is used to simulate the evacuation times for both the proposed design and a notional code-compliant design. The proposed design is based on the existing staircases arrangement that is four staircases one at each corner with a total width of 4158 mm. The notional code-complaint design is based on the minimum code requirement that is three number of escape staircases each of 1050 mm with a total width of 3150 mm. The subsequent matter of longer travel distance is resolved by the introduction of protected corridor within the notional code-compliant design. The simulation result shows that time required for evacuees on 2/F (largest population) to enter the protected escape staircase/ corridor for the proposed design and the notional code-compliant design is 1.5 mins and 2.3 mins, respectively. The proposed design is provided an evacuation time 35% less than the notional-code compliant design because of the shorter queuing time by one more number of exits and the greater total width as well. Therefore, the proposed design in respect of the number of exit and width of individual exit is found in favor to the minimum code provision and is acceptable.

CONCLUSIONS

It is recognized that historic buildings pose unique fire safety problems. Direct or rigid application of prescriptive codes requirements is infeasible to meet both life safety objective and historic preservation objective as prescriptive codes have not anticipated the application to historic buildings. Performance-based design approach or alternative fire safety engineering approach is then only means to deal with the problems and difficulties in fire safety design with life safety objective not being compromised and significant historic character being protected.

The application of fire safety engineering on historic buildings is relatively less as compared to the application on typical new buildings or renovations in existing buildings. The objective of historic preservation is an added objective for historic building project. This paper gives an overview of fire safety design for historic buildings in Hong Kong in which, the characteristic of historic buildings, legislative environment, practical problems, approach to deal with the problems are discussed. The

application of fire safety engineering to a real historic building project is also described. With thorough understanding of the overall picture for fire safety design in historic buildings, fire safety engineers and architects can develop better design solutions in the future.

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