THE DEVELOPMENT OF PERFORMANCE-BASED FIRE SAFETY ENGINEERING DESIGN IN HONG KONG AND JAPAN

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ABSTRACT

Traditionally, buildings are designed in accordance with prescriptive building and fire codes. However, the prescriptive rules may often prescribe the requirements with insufficient commentary and no flexibility to be used for unusual and innovative building design, especially for complex and huge building structures. Recently, rapid increase in population in many cities in Asia has fostered the construction of many large and complex buildings. The demand for alternative approach, in which designers may not simply follow the prescriptive requirements, for designing buildings of complex setting is increasing. Using alternative approach, designers are required to evaluate the fire safety performance of the building and that the fire safety level of the building can be demonstrated. In the circumstance, the introduction of *performance-based fire codes* in the building control regime is evolving. Japan may be considered as the first country in the Asia-Pacific region to adopt performance-based fire engineering design in buildings. The Japan Building Standard Law, established in 1950, prescribed the requirements for designing buildings. Since 1983, it has been developed to include performance-based approach and a major revision, which included full performance-based approach, was published in 1998. Similarly, the 1955 Hong Kong Buildings Ordinance prescribed the building and fire safety design, and in the fire codes published by the Hong Kong Building Authority in 1995/1996 had explicitly permitted the use of fire engineering approach as an alternative to prescriptive design. The purpose of this article is to provide some highlights of the Japanese legislation and to compare the codes' development in Hong Kong.

1. INTRODUCTION

Based on the United Nation population projections, it is noted that by December, 2006, the world will be predominantly urban. Some 3.5 billion people are packed into cities covering only about 1% of the Earth's 13,391 million hectares of land surface. The current rapid urbanization, which leads to the construction of super high-rise complex buildings, is a phenomenon in China and many Asian countries. However, building designers have perceived that the requirements prescribed in building and fire codes may be stated with limited commentary and with little flexibility for designing large and complex buildings. Moreover, prescriptive requirements, which control individual fire safety attributes, may not secure holistically the safety of complex buildings. Using alternative approach, designers are required to evaluate the fire safety performance of the building and that the fire safety level of the building can be demonstrated. In the circumstance, the introduction of *performance-based fire codes* in the building control regime is evolving. This article briefly discusses the development of fire safety control in Japan with a brief comparison to the Hong Kong situations.

2. THE HONG KONG BUILDING CONTROL

All building works in Hong Kong should have prior approval given by the Building Authority[1]. Under the Buildings Ordinance [1], every person, such as a developer, for whom building works are to be carried out, should appoint an Authorized Person (AP)[2] as the project coordinator. The AP will be entirely responsible for submission of building plans, supervision of the building works and to ensure that the works are in compliance with the Buildings Ordinance [1]. A chart showing the building control mechanism in Hong Kong is given in Fig. 1.

[1] The Director of Buildings Department is nominated as the Building Authority under the Hong Kong Buildings Ordinance.
[2] Building professionals such as architects, structural engineers and building related surveyors have to be examined and enrolled in the Government's Authorized Persons Register before they can practice as AP.

Fire safety is one of the major safety issues that should be considered by the Hong Kong Building Authority. In general, the fire safety issue is controlled under two separate legislations, namely the Buildings Ordinance (BO) and the Fire Services Ordinance (FSO). However, before the approval of every building plan, the approval of FSI at building design stage is also through the BO in that such building plan should be endorsed with a certificate issue under the FSO by the Director of Fire Services.

The prescriptive requirements of fire safety are given in the Codes of Practice on: (a) means of escape [2]; (b) fire resisting construction [3]; and (c) means of access for fire fighting and rescue [4] issued by the Hong Kong Buildings Department as well as the code of practice on minimum fire services installation and Equipment and Inspections [5] issued by the Hong Kong Fire Services Department. The building designers should design the fire protection measures in buildings in accordance with the prescriptive codes. Alternative fire safety design is also explicitly permitted in the codes. Fire engineering approach is considered as the means to demonstrate the fire safety design in buildings is satisfactory [6].

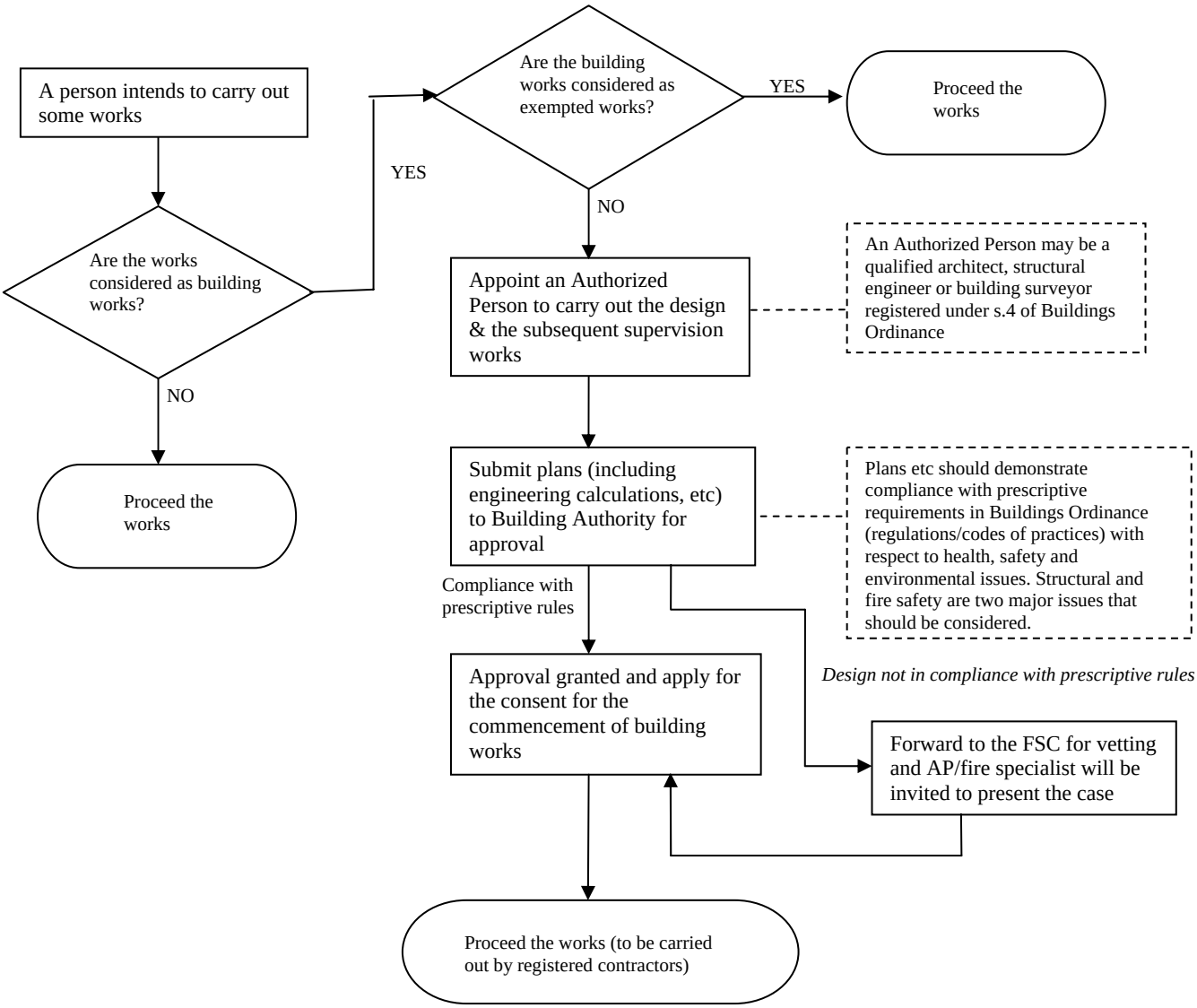

Fig. 1: Building control mechanism in Hong Kong

The building and fire codes mentioned above and the practice note [7] provide preliminary framework of what should be considered in the fire safety engineering study. However, the Hong Kong Government has yet neither published guidance to explain the rationale behind each prescriptive requirement nor engineering guide to illustrate the acceptable evaluation methods. When fire safety engineering design is adopted for a project, a fire engineering specialist will normally be appointed. The specialist will assist the AP to identify the non-compliance items and establish an alternative design. A fire safety engineering report will be produced to justify the fire safety level of the alternative design by computation or experimental evaluation methods. The report in associate with general building plans will be submitted by the AP to the Building Authority. The building officials in the Building Authority will preliminary vet the proposal and if they believe the general approach given in the fire safety engineering report is acceptable, they will refer the case to the Fire Safety Committee (FSC) which is established as a consultation committee for the Building Authority. Normally, it comprises four senior building officials, two fire officials and two non-official members from the industry and academic institutions. The AP and fire specialist will be invited to attend the meeting to defend their case. Fig. 2 briefly shows the checking procedures for fire safety engineering reports in the Hong Kong Building Authority.

3. THE JAPAN'S CONTROL

In Japan, the Ministry of Construction is responsible for the administration of the building laws. The Building Standard Law (BSL), which applies to all buildings throughout Japan, and related Enforcement Order, Ministry Order, and Notifications are the statutory document for governing the design and construction of buildings in Japan. The BSL is basically divided into 3 parts:

(a) general provisions;
(b) building codes; and
(c) zoning codes

The general provisions stipulate the administrative provisions such as the means to demonstrate compliance with the requirements, etc. The building codes stipulate structural safety, fire safety and hygienic requirements. The zoning codes stipulate land-use planning requirements such as the building height-bulk-shape control, restriction in fire protection districts and others. Table 1 shows the building regulatory system and Table 2 summarizes the development of BSL in the past decades.

4. DEVELOPMENT OF PERFORMANCE APPROACH

In 1988, the Japan government committed an exercise in studying the development of the building regulations and led to the publication of a four-volume Manual of Practice [7]. The Article 38 of the BSL has empowered the approval of alternative building designs which are equivalent to the prescriptive requirements stipulated in the law. This approach has the limitation in that the building designer should demonstrate equivalency on a paragraph-by-paragraph basis in accordance with the provisions set out in the Manual of Practice. In order to further develop the engineering approach, the Japanese Ministry of Construction (now the Ministry of Land, Infrastructure and Transport - MLIT) had committed another study in 1993. The project is called '*Sogo Gijutsu Kaihatsu Project*' (SOPRO), which means Comprehensive Project for Technical Development. The Building Research Institute of the Ministry of Construction in associate with the Japanese relevant industry was responsible for the project. The project had been completed in 1998 and the performance-based track of the building law has been implemented in 2001 [7].

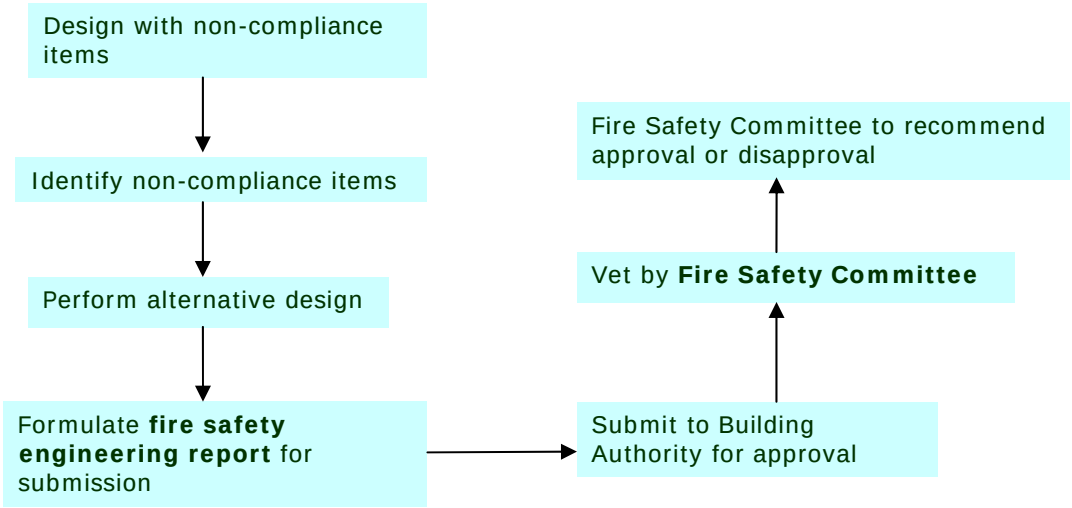

Fig. 2: Vetting procedures for fire safety engineering design in Hong Kong

Table 1: Building regulatory system

Hierarchy	To specify	Examples
Law	Performance requirements: - fire safety - structural safety - etc.	Fire resisting performance: A building must be able to withstand heat during a normal fire until the fire is over.
Enforcement Order	Performance criteria	Fire resisting performance criteria for each principal building part such as posts and beams
Ministry Order/ Notifications	Verification methods	Fire resisting design – adopting methods for predicting fire properties and confirming the capacity of principal building parts can maintain their stability under fire
	By specifications	The prescribed design

Table 2: Brief description of the development of Building Standard Law

	Development	Remarks
The Law (regulations)	Building Standard Law (BSL) ➢ 1950 BSL ➢ 1988 Publication of 4 volumes: Comprehensive Fireproof Building Design Methods as the manual of practice for building fire performance evaluation (implemented under Article 38 of BSL) [1] ➢ 1993 The Japanese Ministry of Construction [2] commenced a new 5-year project: SOPRO – 'Sogo Gijutsu Kaihatsu Project' (Comprehensive Project for Technical Development) ➢ 1998 Major revision to BSL (introducing the performance requirements – a full performance-based approach) [3] ➢ 2002 revision to BSL	The Law stipulates the objective and functional performance requirements of buildings (The objective of the BSL is to protect lives and property from disasters and protect health by ensuring environmental sanitation) The BSL comprises 3 parts: ➢ General provisions ➢ Building codes ➢ Zoning codes

[1] In 1988 the Building Standard Law of Japan (the Japanese national building regulations) was revised to add an equivalency clause (Article 38). This equivalency was to be established by conducting a detailed fire safety engineering analysis. The methods to be used for the analysis were documented in a four-volume handbook that represented the first published fire engineering code of practice.
[2] Now the Ministry of Land, Infrastructure and Transport.
[3] The 1998 Building Standard Law (Major Revision) effected on May 1999.

The scope of the project included [9,10]:

a) The use of standards issued by the International Organization for Standards (ISO) to replace the local (Japanese) fire test methods;

b) The development of new performance-based design guidelines in that the overall equivalent level of safety to the current prescriptive system is considered;

c) The improvement of the testing methods, including new technical inventions and etc;

d) The promotion of international collaboration/ co-ordination.

Table 3 summarizes the administrative context of the BSL.

Table 3: Administrative context of Building Standard Law

Item	Administration	Remarks
Supporting document	BSL supported by: ➢ Enforcement Order ➢ Ministry Order ➢ Notifications	Quantitative (technical) performance criteria and deem-to-satisfy (prescriptive) provisions are provided in the: ➢ Enforcement Order ➢ Ministry Order ➢ Notifications
The organization to establish the codes	On the basis of the recommendation of the MLIT, various committees have been established at the National Land Development Technology Research Center. The aim of the committee is to work on the design method and publish the research results[1].	The Comprehensive Fireproof Building Design Method Compilation Committee was responsible for publishing the Fireproof Building Design Method[2] (published by the Japan Architectural Center) Four Volumes [8]: i) Comprehensive fireproof design method ii) Design methods to prevent fire from spreading iii) Evacuation safety design method iv) Fire resistant design method
Approval/ Inspection	Interim inspection Final inspection	Inspection to be performed by local government agencies or private construction inspection firms/organizations. To control the private construction inspection firms (a qualification system and standards have been established within the 1998 revised BSL).
Building design approaches	THREE options: ➢ Follow the prescriptive requirements – deem-to-satisfy design ➢ Follow the provided verification methods stipulated in the published 'Comprehensive Fireproof Building Design Method' ➢ Performance approach – building designers are required to prove that the construction methods or materials satisfy the performance-based provisions in the BSL	For performance approach – a designated (recognized) *Performance Evaluation Body* will conduct tests and evaluate the results. Performance Evaluation Body – designated organization under BSL by the MLIT to implement evaluation and approval (e.g. Building Center of Japan).

[1] The Ministry of Construction (later MLIT) carried out its development of Fireproof Building Design Methods for 5 years starting in 1982 as one of its Comprehensive Technological Development Projects.

[2] A notable limitation of the Article 38 approach was that equivalent Fire Safety Engineering techniques, as set out in the Manual of Practice, had to demonstrate equivalency on a paragraph-by-paragraph basis. This, of course, is restrictive, since ideally a performance-based design should only need to demonstrate equivalent overall safety for the entire structure.

5. COMPARISON

The performance approach has been developed for more than a decade in Japan. Whereas in Hong Kong, the government has committed to develop a performance-based guide for fire engineering design since the beginning of the 21st century. We can note that the building fire safety engineering approach in Japan has gradually changed from *equivalent basis* to fully performance-based. In Hong Kong, the fire engineering designs are a mix of equivalent basis and fully performance-based approach. A summary given in Table 4 shows the comparison of various items between Japan [7-9] and Hong Kong.

Table 4: A brief comparison

	Japan	Hong Kong
The organization to establish the codes	On the basis of the recommendation of the MLIT, various committees have been established at the National Land Development Technology Research Center. 4-volume design manual has been published.	The Buildings Department is responsible for the establishment of fire safety control requirements. A private consultant firm has been appointed to draft the fire safety engineering design manual and etc.
Approval/ Inspection	Inspection to be performed by local government agencies or private construction inspection firms/organizations. To control the private construction inspection firms (a qualification system and standards have been established within the 1998 revised BSL).	The Authorized Persons, Registered Structural Engineers, Registered Contractors have been responsible under the Buildings Ordinance to supervise the construction works. The Buildings Department and Fire Services Department are also responsible for the vetting and inspections.
Building design approaches	THREE options: ➢ Follow the prescriptive requirements – deem-to-satisfy design ➢ Follow the provided verification methods stipulated in the published 'Comprehensive Fireproof Building Design Method' ➢ Performance approach – building designers are required to prove that the construction methods or materials satisfy the performance-based provisions in the BSL	Building design can follow the prescriptive requirements. Alternative approach is allowed provided that the design can be demonstrated to be equivalent to the prescriptive performance.
	For performance approach – a designated (recognized) *Performance Evaluation Body* will conduct tests and evaluate the results. Performance Evaluation Body – designated organization under BSL by the MLIT to implement evaluation and approval (e.g. Building Center of Japan).	Building approval will normally be granted by the Buildings Department in consultation with the Fire Services Department and other government departments. The building fire safety engineering design will be considered by the Fire Safety Committee – a government formed body.

A so-called FSC has been established in the Hong Kong Building Authority to assist the building officials to vet the fire safety engineering reports. The committee comprises senior and experienced building and fire officials, and independent experts from the industry and academic institutions are also invited to serve for the committee. Every application will be carefully reviewed and the quality of the reports can be assured. However, the time required for a report vetted by the committee may be very long, in particular the committee is normally held biweekly. This implies that the FSC may merely handle limited volume of cases and the waiting time may form an 'obstruction' for the development of performance-based fire safety engineering design. Moreover, about ¾ of the members in the committee are government officials, this may imply that government's concerns may be greatly reflected in the committee's decision. Technically, Hong Kong does not have a government research institute and the parameters selected for formulating the engineering reports may not be justified by local scientific data. On the other hand, in Japan, *Performance Evaluation Bodies* are organizations designated under BSL by the MLIT to implement evaluation and approval, such as the Building Center of Japan. The experience and specialism of such organizations can handle the evaluation of the performance approach effectively. Furthermore, extensive research activities have been supported, such as in the Building research Institute of Japan, and other government or semi-government organizations. If sufficient bodies can be designated, this may be a more efficient approach than a central government committee to handle the evaluation of fire safety

engineering cases. Nevertheless, the roles of the vetting bodies should be carefully managed to avoid 'conflict of interest'.

6. CONCLUDING REMARKS

The Japanese Ministry of Construction (Now the MLIT) has, since the end of 80 s, supported the development of the building codes. Full performance-based approach has been advocated in the recent BSL revisions. The government through the Building Research Institute has participated in codes' development. In Hong Kong, fire safety codes are also developed since the 90 s. However, the investment in the fire safety research to support the development of the fire codes may still need improvements. As there is no government building research establishment, the Hong Kong Government has committed a consultancy service to draft the fire engineering design guide and fire codes reform. The consultancy service has not been completed and the society is still pending to ascertain if the results can be comparable to that produced by extensive research studies, such as that reported by the researchers in Hong Kong [11-13].

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