PERFORMANCE-BASED FIRE SAFETY DESIGN IN HONG KONG

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ABSTRACT

Presently, performance-based or fire engineering approach is normally treated as a way to seek for exemption for commercial projects by producing engineering justification report, unless for large, complex and special projects such as railway lines or airport which would be treated as an alterative way to achieve fire safety by formulating fire safety strategy report. This paper gives a brief overview on the two (prescriptive-based and performance-based) approaches to achieve fire safety, current legislative control of fire safety measures in buildings and the performance-based applications in Hong Kong. The basic performance-based design framework, which most overseas countries have adopted as the initial step for the development of engineering performance-based fire code, is described with illustrative example. Finally, the issues and challenges in the process of developing engineering performance-based fire code in the situation of Hong Kong are highlighted.

1. INTRODUCTION

Hong Kong (now the Hong Kong Special Administrative Region HKSAR), a densely populated city, has a reputation of the rapid construction of quality buildings and infrastructure facilities. Traditionally, the control of fire safety measures in buildings has mainly been achieved through a framework of prescriptive rules. In the past 20 years, architectural features in Hong Kong have changed rapidly along with the expansion of the construction industry [1]. Thus in the last decade, performance-based fire engineering approach [2] has been adopted for complex and large buildings (e.g. Hong Kong International Airport, railway stations, train tunnels and atria), which contain novel architectural features raising challenges to the traditional fire safety design. In 1995/96, the Buildings Department code of practices [3-5] officially permitted the principle of adopting an "alternative approach" to the traditional prescriptive approach to achieve fire safety in buildings. A Practice Note for Authorized Persons and Registered Engineers (PNAP) No. 204 "Guide to Fire Engineering Approach" [6] was issued in 1998 to provide submission guidelines for the practitioners. In the same year, Fire Safety Committee (FSC), an advisory/assessment panel has been formed within the Buildings Department to evaluate the fire engineering strategy on case basis. Hong Kong is now going to develop an engineering performance-based fire code, which has been undertaken by a consultant currently [7]. This paper aims to provide a brief outline for the current applications of performance-based fire safety design, an overview of the basic set-up of a performance-based design framework and the issue and a highlight on issues and challenges that would be faced in the process of developing engineering performance-based fire code in Hong Kong.

2. APPROACHES TO ACHIEVE FIRE SAFETY DESIGN IN BUILDINGS

Prescriptive codes are straightforward for practitioners to follow and to provide efficient/guaranteed accepted design solution, easy for a third party to check, and relatively easy for authorities to enforce. Recently, building fire safety codes in many countries over the world (e.g. Australia [8,9], New Zealand [10,11], UK [12], Sweden [13], US [14]) have changed from solely prescriptive to including performance/functional requirements after developing for almost two decades [15]. This global movement is mainly due to the shortcomings (e.g. inflexible solution) of the prescriptive codes; the advances made in fire sciences and engineering; the need for codes to use engineering principles within the context of regulations to satisfy the clear fire safety goal; global harmonization of regulation systems and allowing flexibility/cost-efficiency in design [16].

A prescriptive approach describes an acceptable solution while a performance approach describes the required performance. The difference between these two approaches is illustrated by an example as follows. A prescriptive code would specify the minimum separation distance between unprotected openings in two buildings, which the buildings are adjacent to each other. Whereas, a performance-based fire code might state that the unprotected openings of the building should be of sufficient distance apart from an unprotected opening in the adjoining building to prevent fire spread to the adjoining building. In this case, the separation distance could be designed by engineering principles with considerations of the sizes of the unprotected opening, fire severity of the room, radiation effect, etc. Therefore, if it can be demonstrated that a separation distance, which is

not necessarily the prescribed limiting value, would achieve the functional objective of preventing fire spread to the adjoining building, such design distance would be accepted under a performance-based fire code.

3. LEGISLATIVE CONTROL OF FIRE SAFETY MEASURES IN BUILDINGS

Building Ordinance (BO) [17], which enforced by the Building Authority (BA), is to ensure that minimum safety and health standards are maintained in the design, construction, use and safety maintenance of buildings. Matters involving fire safety of new and existing private buildings come under the jurisdiction of the BA as well. Under the BO [17], any person (or building owner) who intends to carry out building works should appoint an Authorized Person (AP) who may be architects, engineers or surveyors, Registered Structural Engineers (RSE) to submit proposals to the BA for approval and the building works should be executed by the Registered Contractor (RC).

In general, the requirements for fire safety measures within buildings are governed through BO [17] and Fire Services Ordinance (FSO) [18]. Basic requirements for the provision of staircases, fire escapes and access for firefighting and rescue are prescribed in Building (Planning) Regulations [19], subsidiary legislation F of the BO [17]. Detailed requirements such as travel distance, staircase width and occupant factors are prescribed in Codes of Practice for the Provision of Means of Escape (MoE) [3] and Means of Access for Firefighting and Rescue (MoA) [4] issued by the Buildings Department. The Building (Construction) Regulations [20], subsidiary legislation B of the BO [17] prescribes the requirements on building construction/structural design and construction materials, which include the general requirements of fire resisting construction such as inhibit fire spread and maintain stability. Specific requirements such as fire resisting periods and compartment size limits are prescribed in Code of Practice for Fire Resisting Construction (FRC) [5] issued by the Buildings Department.

The BO has offered power to the Director of Fire Services to issue certificates for buildings endorsing that the fire service installations and equipment as indicated in the submitted building plan and subsequently erected systems satisfy the requirements laid down in Codes of Practice for Fire Service Installations (FSI) [21] issued and enforced by Director of Fire Services (in Fire Services Department, FSD). Under FSO [22], FSD has empowered to execute any offences on fire safety management such as causing obstruction and locking of escape, as well as maintenance of fire services installation.

4. CURRENT APPLICATION OF PERFORMANCE-BASED DESIGN

In Hong Kong, the current application of performance-based or fire engineering design can generally be classified into two categories. One is the application on railway lines projects and the other is for commercial building projects. Different methods, approaches and submission procedure have been utilized for the two categories of application.

4.1 Railway Projects

When there is a new line of railway system comprising several numbers of passenger stations, depot and train tunnel, the railway corporation will seek agreement from the BD and FSD at the early stage that a fire engineering approach would be adopted for the concerned railway line, given the reason that the local codes [3-5,21] have not sufficiently covered the requirements for special, complex and large development such as railway system. A fire safety strategy report outlining the principles of fire safety design in various aspects will then be submitted to the Safety and Security Coordinating Committee (SSCC), a group of government officers from different authorities (e.g. FSD, BD, Highways Department) for wetting. The fire safety strategy report describes and formulates the design criteria/principles for fire compartment, escape route, evacuation time calculation, place of safety, fire fighting equipment, and smoke control etc. Once approved, this document will be regarded as a "code" in a case/project basis for the designer to follow. The detailed requirements set out in the strategy report would have a mixed nature of both prescriptive approach and performance-based approach. For example, fire-resisting period is prescribed to be 4 hour for underground design, which is consistent to that in FRC code [5], where smoke control and escape distance design are performance-based. The detailed design package in the form of drawings, which demonstrates the compliance with the approved fire safety strategy, will need to submit to the SSCC for approval.

4.2 Commercial Projects

When dealing with commercial projects, performance-based design will usually be applied for one or two specific fire safety design elements if there are difficulties in fully complying with the prescribed requirement [6,23]. One example is

that the provision of smoke extraction system for allowing compartment volume in excess of the 28,000 m^3 code limit [5] in big atria such that fire shutter lines can be omitted. In this case, a fire engineering report will need to be formulated, according to the procedure as in [6], including clear identification of the non-compliant (better to use the term "alternative") design element and engineering justifications by using fundamental fire engineering principles and modeling for submission to the BD along with the general building plan submission. If a performance-based design solution solely regards to active fire protection system (e.g. use of long flow sprinkler instead of conventional ceiling sprinkler), the alterative design proposal in the form of an explanatory letter or fire engineering report shall directly be submitted to FSD for assessment and seeking approval. If an alterative design proposal is concerned with any passive fire protection system (e.g. compartment size, fire resisting rating) or both active and passive provisions, then the submission shall be run through the BD assessment process by referring to the FSC. The FSC, chaired by an Assistant Director in BD, has members from BD internally (chief building surveyor and structural engineer), externally from FSD and other non-governmental members from industry and academy. Though there is no formal engineering performance-based fire code in Hong Kong, the current building design submission system has a way to deal with any alterative or performance-based design solutions prepared by the practitioners.

4.3 Assessment Approach

Presently, local fire professionals will adopt the technical methodology used overseas to demonstrate an "equivalent" level of safety when comparing with a notional code-compliant solution given the fact that science and technology is not country-dependent but careful citation and wise evaluations to suit local situation are necessary. Common overseas references include BS ISO/TR 13387-1999 [24], SFPE Handbook [25] and guidelines [26], Australian and New Zealand Guidelines [9,11], NFPA code e.g. 95B for smoke control design [27], etc. When using a performance-based design approach, it should be clearly understood what the term "equivalency" stands for. Is it always present for every engineering case? The use of "equivalent level of safety" is one evaluation approach or performance/ acceptance criteria set for assessing the fire safety level achieved by an alternative solution, which is compared with the safety level of that achieved by a notional code-compliant solution. It can be regarded as a comparison method. There are other evaluation approaches, which are assessed against the deterministic acceptable criteria by using time-line analysis and the probabilistic acceptable criteria by using risk methodology [Ref. 24 Part 1,9]. Both of them are important techniques, which can be used to assess the "equivalency" for a particular solution. Selection of appropriate evaluation approach would require knowledge of fire engineering principles. Note that sometimes blindly asking for an "equivalent" level of safety by setting an unrealistic notional code-compliant solution will be meaningless. Instead a direct comparison against acceptable life safety/tenability parameters of smoke layer height, radiation level, gas temperature, visibility with significant safety margin may be more appropriate.

5. WORLDWIDE ADOPTED PER-FORMANCE-BASED DESIGN FRAMEWORK

The current application of fire engineering approach design by demonstration of the level of safety not below that of a total code-compliant solution [6] is considered only a start-up for allowing performance-based fire safety design via the "alternative" way in the absence of a well established performance-based design framework and code regime. Many of the countries that have decided to pursue the development and promulgation of performance-based building regulations have used the Nordic Five Level structure [28] with variation in the degree of detail at particular levels, and in the distribution of the material between mandatory and non-mandatory documents [15]. In this structure, Level 1 Goal addresses the essential interests of the community at large and/or the needs of the user-consumer. Level 2 Functional Requirement addresses one specific aspect of the building or a building element to achieve the stated goal. Level 3 Operative or Performance Requirement specifies the actual requirement to be satisfied. Level 4 Verification Methods and Level 5 Examples of Acceptable Solutions deal with the specifics of meeting the goal. The last two are sometimes combined because compliance to a given prescriptive solution (Level 5) is just one of several possible methods of verification (Level 4) as illustrated in Fig. 1.

In Fig. 1, Level 1, 2 and 3 are the objective statements of different levels. They are goal(s), functional requirement(s) and qualitative performance requirement(s), which should be clearly defined. Society and policy goals embody statements regarding acceptable performance of buildings in terms of health, safety, welfare, amenity, mission and/or others. Fire protection generally has (but not limited to) four goals, which complement each other: i) to provide life safety (for occupants, public and fire fighters); ii) to protect property and heritage including structural

protection, equipment, and content; iii) to provide for continuity of operations and iv) to limit the environmental impact of fire and fire protection measures. Functional requirement is the building or building element specific qualitative requirements and operative requirement is the actual requirements, in terms of performance criteria or expanded functional description.

Verification is an important component of the performance-based approach because it will be necessary to demonstrate that a particular material or building solution will meet a given performance criteria. Verification can be through i) actual testing, ii) calculation by using appropriate computational procedure or mathematical model to show that the requirement performance will be achieved, iii) a combination of testing and calculation. The prescriptive and performance-based solutions are intended to produce the same in-service performance, as specified in the performance criteria. It is obvious that to properly implement the performance concept, acceptable performance evaluation tools and methods are essential.

The Nordic five-level hierarchy is usually the first step to consider the performance-based design conceptual framework. Among countries, the differences of particular levels will depend greatly on the rigidity of mandatory/non-mandatory regulatory regime, the advancement of fire engineering technology and the degree of acceptance of the non-absolute solution. Recently, the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) has developed an eight-level hierarchy structure [28] with the inclusion of levels for performance or risk group, performance or risk level, and performance or risk criteria to illustrate how factors such as levels of tolerable building performance or risk and importance to the community are reflected in goals, functional requirements and operative requirements.

6. ISSUES AND CHALLENGES

In the situation of Hong Kong, some points are considered important for the building controllers, regulators, practitioners, fire researchers, product manufacturers, investors and owners in the industry, to clearly understand such that a smooth movement from a solely prescriptive based regulatory regime to a regime with the inclusion of performance-based design framework can be sought. Fig. 2 illustrates the relationship between regulators, fire researchers and practitioners/developers and their contributions in implementing engineering performance-based fire code.

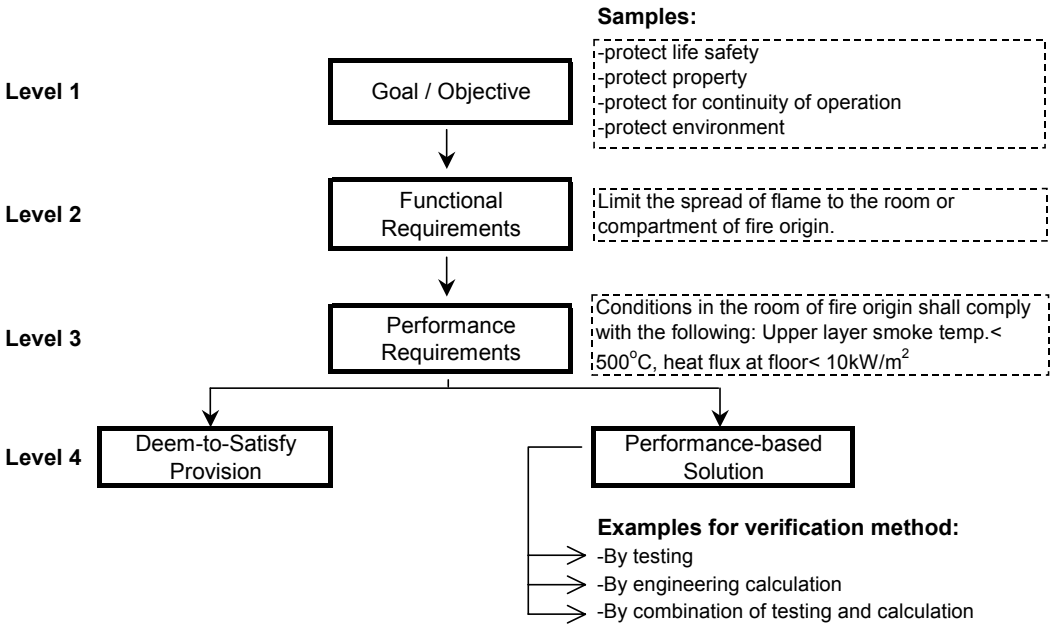

Fig. 1: The general four-level regulatory framework [29]

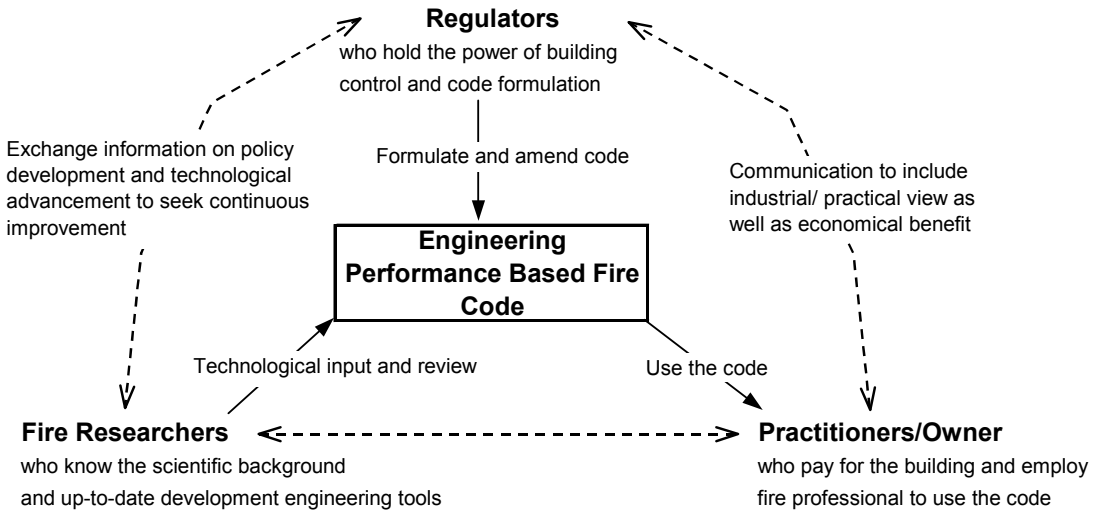

Fig. 2: Contributions to the development of engineering performance-based fire code

6.1 High Technology Fire Safety Design

Performance based fire safety design has distinct difference from that of traditional prescriptive-based design, which is regarded as a shift from low technology design approach by ticking the "yes" or "no" box for checking of the compliance with high technology design approach by verifying the performance level against the objective and acceptance criteria set such that appropriate evaluation method and engineering tools [30] should be selected. Undoubtedly, it should be treated as a separate engineering discipline in which the one who performs the performance-based design and the one who is responsible for wetting the submitted design should be qualified or trained to have specific knowledge on fire engineering principles, even with the local fire engineering guide or code of practice. It is because the shift is from code/rule-based design to knowledge-based design.

6.2 Degree to Adopt the Performance-Based Fire Safety Design

Idea of the degree of acceptance for the performance-based fire safety design should be clearly identified, whether it should be applied for a specific building design elements on a case basis or applied for every building design elements. The former one is similar to that of the current application on commercial projects, which usually one or two alternative design elements are performance-based with the majority design being prescriptive-based. The latter one would somehow similar to the current application on railway lines such that the majority or all of the fire safety design elements are performance-based. Though performance-based design approach has advantages over traditional prescriptive approach, prescriptive rules as Deem-To-Satisfy solutions, which are familiarized by the designers/approving officers are considered worth to remain to achieve efficient design solutions and minimize the impact to the industry especially at the present stage that there are very limited qualified fire professionals for designing and checking the performance-based design. As long as the industry and the authorities have realized the possible ways/approaches to achieve a fire safety design solution, appropriate ways can be established on a project basis with early agreement between the owners and authorities. Of course, a total performance-based project design would require significant resources on designing and checking.

6.3 Continuous and Long-term Process

As mentioned earlier, performance-based approach is a knowledge-based approach, which successful implementation will depend on the presence of continuous and long-term support for fundamental research to produce design data and regular review to cope with the ever-changing technological and societal environment. Most overseas countries have collaborated code writing organization (ICC/NFPA in US) or other research institute (e.g. British Standard Institute in UK), who will be responsible for monitoring the established technical guidebook. Hong Kong is a city and seems very costly to run independent research institute or organization. But it should find a way out for providing continuous code monitoring process.

6.4 Jurisdictions

Currently, the BD has control over the passive fire protection system in buildings and the FSD has

control over the active fire protection system as well as fire safety management. When applying prescriptive approach design by ticking the 'yes' or 'no' box of checking compliance, there is no apparent problem for the split of jurisdiction among passive and active fire protection system. When pursuing a performance-based approached design, the provided fire safety design elements (no matter passive or active) should be considered as a whole for assessing its overall performance level. The present FSC, which has power to make single decision, for assessing the submitted alterative design proposal in one goal is on the right track. However, in long-term, even not every approving officer will be trained (better to acquire a Master degree) to qualified fire professionals, at least a specialist group could be formed for technical support to the whole office. Whether the FSC be remained its function for assessing every project is an issue for re-think. One suggestion is for the FSC to act as a high level assessing body when facing critical or complex problems.

6.5 Distinction between "Alterative" and "Wavier"

Presently, performance-based or fire engineering approach is treated as a way to seek for exemption. Indeed appropriate application or utilization of performance-based approach can compensate for the inflexibility of the prescriptive-based design framework. By referring to the performance-based model in Fig. 1, performance-based design solution is an alterative to a Deem-To-Satisfy solution. The original aim to seek for alterative solution should not be intended to omit some prescriptive requirements or design elements for cost saving. Actually, it should be regarded as to design a fire protection system appropriately and to the objective, instead of strictly following the rules without thinking of applicability, safety performance, necessity, appropriateness, efficiency, economical benefit and so on. One example is the use of atrium based fire suppression system instead of conventional ceiling for high ceiling atrium.

7. CONCLUDING REMARKS

Hong Kong is in the process of developing engineering performance-based fire code. The first thought for the reason of such need is to fill-up the missing part on the current application. That is to set-up structured and organized procedure in design, submission, assessment as well as documentation; to produce appropriate technical guidance including clear objectives, functional requirements, performance requirements/criteria and verification methods. However, with the presence of engineering performance-based fire code, should the current picture and scale of the application of performance-based fire safety design be remained the same or be expected to have significant change? This would relate to the degree of adoption for the performance-based application in the future, it is high time to consider this carefully taking into account the availability of trained/educated professionals, the amount of resources that the authorities and industry can afford and the future way to deal with the long-term development.

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Q & A

Q1: Will the developers get benefits from using the performance-based codes? Hong Kong designers are usually forced to do the design following the requirements of clients due to the tight budget. They only need to include all minimum provisions to satisfy the authority. What will be the change?

Tsui: Different from the prescriptive framework, it is important to follow the goal in the performance-based approach. It might be the provision of a safe and health place, to minimize the interruption to business operation or any requirements from the client. Hong Kong developers always focus on cost-effectiveness. However, the first priority should be to provide a safe and healthy environment and they should consider the goals as a whole. It is necessary to persuade the clients to accept this concept. Sometimes, we need to have more systems and in other cases, some provisions might be reduced. The degree of adoption for performance-based design means we can use this approach on a case-by-case basis and to fill up the gap and shortcomings of the prescriptive requirements. This is one of the applications of the performance-based design.