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Using Performance-Based Approach in Building Energy Standards and Codes

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ABSTRACT

This paper investigates the nature and concept of performance-based approach in building design control with particular focus on building energy efficiency. The meaning of performance-based approach is explained and the current developments of performance-based building energy codes in some representative countries are described. Experience in these countries indicates that performance-based approach in building energy code is important for promoting innovation and new techniques in energy efficient building design. It can also help minimise the limitations of prescriptive criteria which are commonly found in current building control codes. The recent development in Hong Kong to establish a performance-based building energy code is explained to illustrate the practical considerations. The implication of performance concept to the future development of building energy codes in Mainland China is reviewed and discussed. It is found that performance-based codes often require higher level of skills from the designers or users and could be more complicated in the implementation and validation. In order to ensure their success and effectiveness, it is important to build up the institutional and human capacities in the local building industry.

Keywords: Building energy standard, building energy code, performance-based approach, Hong Kong, Mainland China.

1. INTRODUCTION

Building energy standards and codes have been developed and used in many countries to provide a degree of control over building design and to encourage awareness and innovation of energy conscious design in buildings (Janda and Busch, 1994; UN-ESCAP, 1999). This policy measure is taken by many governments as a means to enhance energy efficiency in the building sector, which typically accounts for 30-50% of the primary energy demand and half of the total electricity consumption. In recent years, there has been strong interest in the world to develop or revise building energy codes using a performance-based approach, with the aim to improve flexibility, clarity and effectiveness of the regulatory documents.

This paper investigates the nature and concept of performance-based approach in building design control with particular focus on building energy efficiency. The meaning of performance-based approach is explained and the current developments of performance-based building energy codes in some representative countries are described. The recent development in Hong Kong to establish a performance-based building energy code is explained to illustrate the practical considerations. The implication of performance concept to

the future development of building energy codes in Mainland China is reviewed and discussed.

2. BUILDING ENERGY STANDARDS AND CODES

Hui and Cheung (1998) reported that building energy codes can help raise concern and awareness of building energy conservation in the society and overcome the market barriers to energy efficient design in buildings. They can also encourage the development of energy efficient building products and form a basis for assessing building energy performance and developing energy efficiency policy.

Traditionally, building regulations and codes have been prescriptive and they specify for each building component the minimum requirements to satisfy the code, such as minimum insulation levels and equipment efficiencies. Prescriptive requirements are simple to use and follow, but they tend to limit development of new technologies and techniques. Prescriptive codes are not able to consider the interactions between the building systems and measures that would optimise the combined performance. This might serve as a barrier to innovation and make the regulation very restrictive. Therefore, alternative code compliance options are needed to encourage building designers to take a more integrated approach to the design of energy-efficient buildings.

Figure 1 shows the major elements and compliance paths for building energy codes. The major elements include building envelope, lighting, heating, ventilating and air-conditioning (HVAC), electrical power, lifts & escalators and service water heating. The basic/mandatory requirements are fundamental issues that must be satisfied in code compliance. The prescriptive requirements, system/component performance and energy budget/cost are the options available for meeting the criteria of the code. The system/component performance is a partial-performance path and it combines the consideration of several parameters and provides “trade-off” among them in the compliance process, such as the calculation of overall thermal transmission. It can provide more flexibility as compared with the rigid prescriptive requirements. The energy budget/cost method is a full-performance path and will offer the greatest flexibility to manipulate the design parameters since it considers in its evaluation the total energy consumption for the building as a whole.

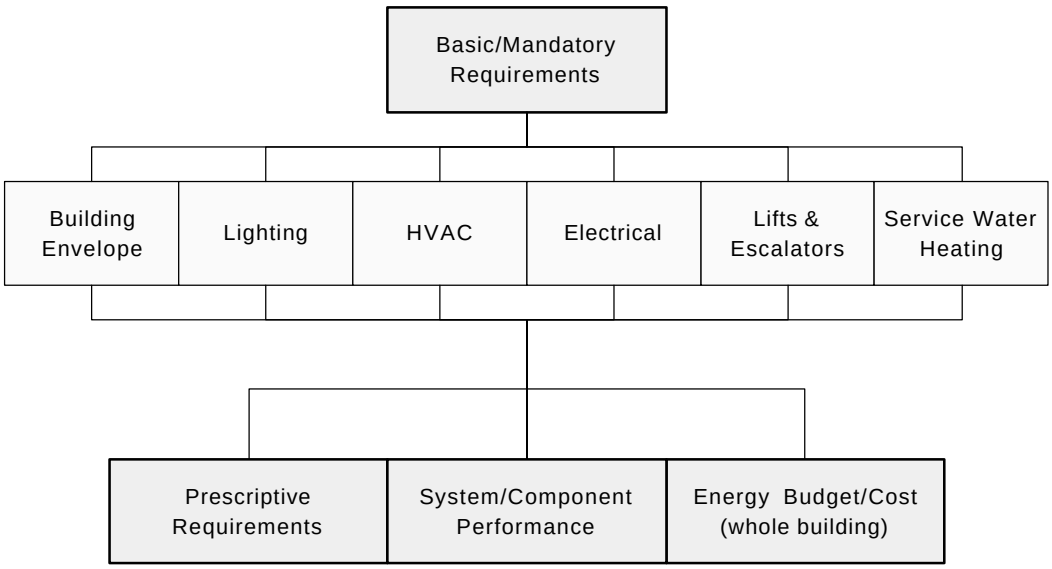

Figure 1. Major elements and compliance options for building energy codes

3. PERFORMANCE-BASED APPROACH

The term "Performance" is used throughout the world in a regulatory sense yet has many meanings depending on the country and its inherent building environment. Generally speaking, performance means "the objectively identifiable qualitative or quantitative characteristics of the building which help determine its aptitude to fulfil the different functions for which it was designed" (CIB, 1988). Performance approach is the practice of thinking and working in terms of ends rather than means. It is concerned with what a building or building product is required to do, and not with prescribing how it is to be constructed.

In recent years, there is a growing trend around the world to develop and introduce performance-based building codes, such as for fire safety and structural design. The trend towards the performance approach arises from the accelerating rate of change of building technologies, the availability of improved space-planning and design techniques and the higher expectations of the conditions to be provided by buildings (Follente, 2000).

Performance-based building codes state what must be achieved and are therefore by nature very broad and versatile. By the term "performance-based", it refers to the situation in which regulations are written in terms of the required outcome rather than by prescribing the process by which the specified outcome can be achieved. The adoption of this approach opens up the possibility of new and innovative solutions to the construction process. At the same time it provides a clear definition of the levels of health, safety, and other societal issues that a particular country has chosen to establish as a minimum for its own society.

Most performance-based regulatory frameworks are variations of what is known as the "Nordic Five Level System" (see Figure 2). In this system, Level 1 (Objectives) addresses the essential interests of the community at large and/or the needs of the user-consumer. Level 2 (Functional Statements) addresses one specific aspect of the building or a building element to achieve the stated goal. Level 3 (Performance Requirements) specifies the actual requirement to be satisfied. Levels 4 (Verification Methods) and 5 (Deemed-to-satisfy/Acceptable

Solutions) deal with the specifics of meeting the goal. The last two levels are sometimes combined because compliance to a given prescriptive solution (Level 5) is just one of several possible methods of verification (Level 4). Ideally, a performance-based code would also contain a commentary section, which helps clarify the interpretation and application of performance-based provisions. The commentary section explains the basis for each performance criterion and its evaluation or verification.

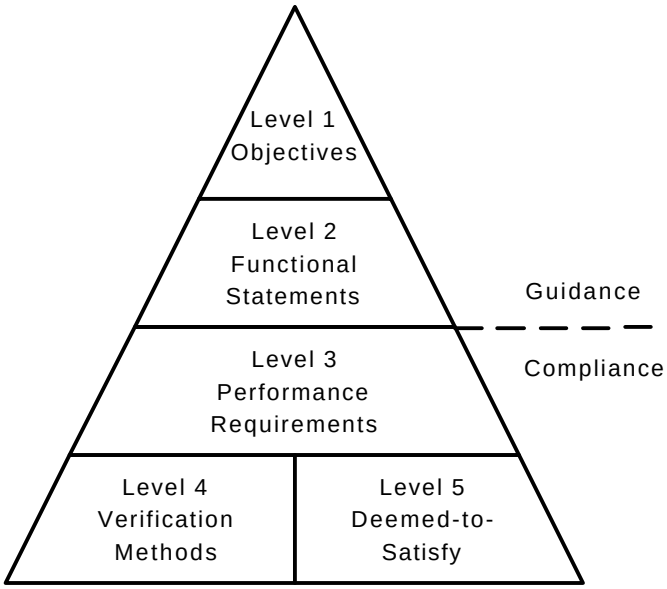

Figure 2. Performance-based hierarchy

4. PERFORMANCE-BASED BUILDING ENERGY CODE

A performance-based building energy code sets a maximum allowable energy consumption level without specification of the methods, materials, processes to be employed to achieve it. The onus will be on the designer to present a design solution together with appropriate predictive evidence of its energy behaviour. Compliance through the performance option will need to study and estimate the likely consumption levels based on the integrated performance of the elements concerned, such as building envelope, lighting and HVAC. But the actual number of areas to be included in the evaluation may vary depending on the purpose and scope of the assessment.

The performance criteria is based on calculating the energy consumption for the proposed building and ensuring that it does not exceed an energy budget or target. This approach allows flexibility in the design of the building and individual components, but it often requires the application of rigorous analysis and scientific method to demonstrate code compliance. The energy budget, expressed in kWh or MJ per square metre of conditioned floor area per year, is determined either from a fixed level set out by the policy maker or from a custom-made energy budget for a standardised building. When the later is being used, compliance is achieved if the annual energy consumption for the proposed building is less than the annual energy consumption for a similar building known as the “reference building”.

The reference building and the proposed building must have the same energy sources, geometry, floor area, exterior design conditions, occupancy, thermal data, etc. The reference building is designed with its envelope, building elements and energy-consuming systems conforming to the prescriptive requirements for the building elements. Figure 3 shows the compliance procedure for performance-based building energy code. The performance-based code allows greater design flexibility and can consider innovative features such as daylighting, passive solar heating, heat recovery, better zonal temperature control, thermal storage, off peak electrical energy, etc. (Briggs and Brambley, 1991).

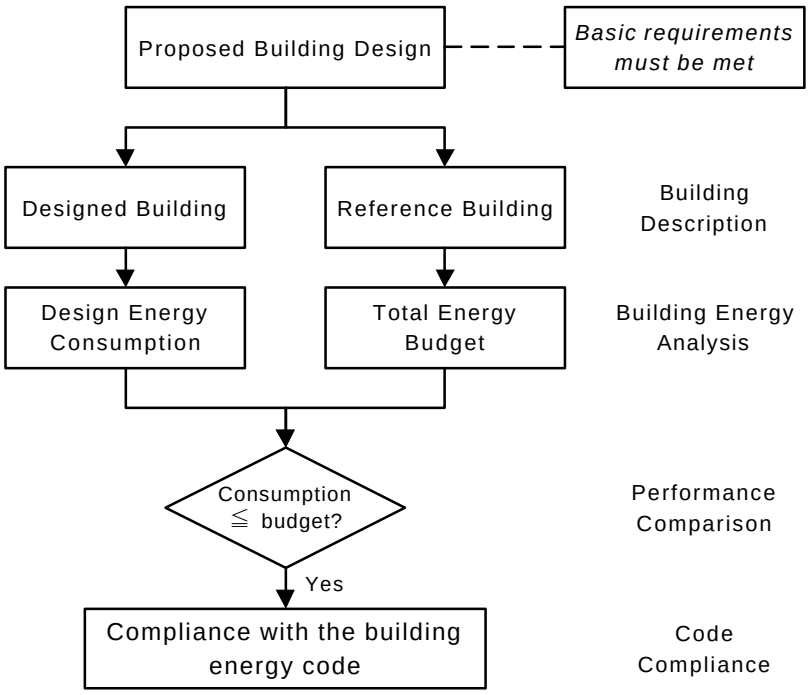

Figure 3. Compliance procedure for performance-based building energy code

5. EXPERIENCE IN OTHER COUNTRIES

The following countries have adopted the performance approach in their building codes and have used performance-based language for the energy efficiency requirement (the number in the bracket is the year when the performance requirement is first introduced).

- United Kingdom (1984)
- New Zealand (1992)
- Australia (1998)
- Canada (1995-2003)
- The Netherlands (1996)
- Sweden (1994)
- Norway (1998)
- USA – American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (1989, energy cost budget for whole building)
- USA – International Code Council (2001)

It is interesting to note that "performance" can be expressed in many ways in these countries. For instance, in Australia and United Kingdom, how the building is to perform is

described in qualitative terms in the building code; in New Zealand, USA and Canada, the performance is usually quantified. The performance requirements in the Building Code of Australia are deliberately written in a qualitative manner. Qualitative, meaning that they must have certain attributes or qualities to achieve a certain level of performance. An example of this is contained in the Victorian Appendix which states: "A building must have an adequate level of thermal performance to ensure efficient use of energy for internal heating and cooling". On the other hand, some countries like New Zealand have quantitative performance requirements (Isaacs, 1999). They specify a certain level or quantity that the performance of the building or element must achieve. For example the New Zealand's performance requirement states: "The building envelope shall be constructed to ensure that the building performance index shall not exceed 0.13 kWh". In this case, a quantitative measure has been applied to the performance requirement.

USA and Canada have been actively promoting building energy codes since the energy crisis in 1970s. The ASHRAE Standard 90 series is by far the most widely accepted reference model for designing building energy codes in North America and in the world (ASHRAE, 2001). In ASHRAE Standard 90.1 (both the 1989 and 1999/2001 versions), an energy cost budget method is being used to evaluate the whole building's energy performance. This is basically a method that compares annual energy costs of the proposed building to a similar prototype or reference building, using computer-based building energy simulation techniques. In Canada, a similar approach called building energy performance method is being used as an alternative to the prescriptive path for the major building elements. The calculations for this method of compliance must be carried out using software that conforms to specifications set out by the authority.

Some developing countries are trying to establish or revise their building energy codes using the performance approach. For example, Singapore is developing a building energy performance standard using energy analysis method. A Windows-based computer program, called Building Energy STandard (BEST), has been developed to facilitate the implementation of the energy budget method (Chou, 2001). Calculation by BEST is based on a cooling degree-day method, correlated with key parameters such as envelope thermal transfer value (ETTV) and part-load performance. The aim of BEST is to provide a user-friendly tool for people to do compliance checking and evaluate their building design.

In general, the trend in the world for modern building energy codes is to move towards a greater use of building energy simulation and modelling techniques to express building energy performance. Building energy codes need to be flexible to adapt to dynamic conditions such as technological advances. They also should increase incentives for industry to invest in development of more energy efficient technology. However, even in the case of the performance-based provisions, the prescription of a minimum required level is necessary. Most of the codes in use today have a mix of performance and prescriptive language; no code has been written strictly as a prescriptive or performance document. Building energy codes for residential buildings are often more prescriptive with their extensive use of tables and diagrams while the codes for commercial or non-residential buildings lean more to the performance side.

Most design briefs agreed between building owners/clients and designers are a mixture of prescriptive and performance specifications. The more performance-oriented the specification

is, the more freedom the designers have to provide alternative solutions or products. A lower-level specification is more prescriptive and constraining. But the higher the level of specification in terms of performance, the more difficult it is to find a universally acceptable method for the verification of performance.

6. CONSIDERATIONS IN HONG KONG

The existing building energy codes in Hong Kong are set out separately and contain energy efficiency requirements for each aspect of building design, including building envelope, lighting, air conditioning, electrical, and lift & escalator installations (Hui, 2000). In general, the requirements are prescriptive in nature in which the submission party is required to comply with all the requirements for each building component outlined in the codes. At present, Hong Kong is conducting a consultancy study to develop a performance-based building energy code based on a total energy budget approach. The aim is to provide an alternative path to the existing building energy codes and set out a sound foundation for establishing a set of comprehensive building energy codes. The important issues considered in the development of the performance-based code include:

- Pros and cons of performance approach and prescriptive approach.
- Data and information to benchmark building energy performance.
- Numerical method for building energy calculation and code compliance.
- Interface with the existing building energy codes.
- Implementation strategies, framework and timetable.

One major challenge here is to balance flexibility against complexity in the code and this requires careful consideration of the compliance process and the proficiency of the local building industry. Verification is an important component of the performance-based approach because it will be necessary to demonstrate that a particular building solution will meet a given performance criteria. In essence, the party responsible for developing the building solution is also responsible for demonstrating that this solution meets the performance requirement for its intended use. Verification can be demonstrated through a calculation procedure to show that the required performance will be achieved. Specifications for the calculation procedure and simulation tools or programs are necessary to avoid ambiguity (some overseas countries, like USA, Canada and New Zealand, have a number of software packages that are acceptable or may be used at the discretion of the authority). Also, modelling assumptions used during the calculation or simulation process need to be carefully scrutinized and documented for future checking.

Another key issue determining the effectiveness of the building energy code is the implementation and enforcement process. Implementation encompasses both startup activities to launch the code and ongoing activities to maintain an operation and improve it over time. These activities can include training; marketing, promotion, and advertising; staffing and institution building; field testing, enabling compliance; evaluation; revision and updates; and so on. They probably exerts more influence on how much energy is ultimately saved than the content of the code does.

It is generally believed that a mandatory approach is more effective and the legislation process is important for ensuring code compliance. However, considering the time needed for

going through the legislation process, the code in Hong Kong is suggested to be first put into use for a voluntary or trial implementation period to avoid the delay and lost of opportunity.

7. IMPLICATION TO MAINLAND CHINA

As one of the world's most rapidly developing economies, China has a large impact on the global energy market and environmental sustainability. Measures to improve energy efficiency in China's buildings are very important since the number of new buildings is growing rapidly and people are requesting better living standards. The development and enforcement of building energy codes that are technically feasible, economically justified and environmentally beneficial could have a tremendous impact in reducing China's runaway energy growth.

In the past decade, efforts have been made to develop building energy efficiency standards and codes for cold climate in northern part of China and for transition climate near the Yangtze River. Work has also begun on a "Hot-Summer/Warm-Winter" residential standard for southern China. Xu (2002) has described the current building energy codes in China and they include:

- Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone, JGJ 134-2001.
- Standard for Energy Efficiency Inspection of Heating Residential Buildings, JGJ 132-2001.
- Technical Code for Renovation of Existing Heating Residential Buildings, JGJ 129-2000.
- Energy Conservation Design Standard for New Heating Residential Buildings, JGJ 26-95.
- Energy Conservation Design Standard on Building Envelope and Air Conditioning for Tourist Hotels, GB 50189-93.

At present, some of these codes have adopted simple performance criteria in their requirements. For example, JGJ 134-2001 has specified the annual cooling and heating electricity consumption as a compliance option; JGJ 26-95 has used an index of heat loss of building and an index of coal consumption for heating as the criteria for energy efficient building design. However, the calculation procedures for the performance evaluation have not been clearly defined and the codes are still burdened with a significant amount of prescriptive criteria that make them in flexible to use. Except the fifth one in above (GB 50189-93), all the codes are focusing on residential buildings. There is an urgent need to develop codes for the commercial sector and for addressing the warmer climatic regions of the country (formulation of an energy efficiency code for commercial buildings has been started recently).

At the provincial level, some provinces and cities, like Shanghai, Jiangsu, Chongqing and Anhui, have set up or proposed their own building energy standards or codes, to tackle the problems peculiar to their local conditions. For instance, Shanghai has designed a building energy code on high-rise buildings as they had many of them appearing in the past decades; Chongqing has set up a code to deal with building energy efficiency in their climate (hot summer and cold winter).

Nevertheless, implementation and enforcement of the building energy codes still remains a difficult task to handle, since energy is subsidised by the government and heating is often considered as a social benefit provided by the work unit. Weak awareness and poor understanding of the benefits of energy efficiency have hindered the code implementation

process. In order to ensure success and effectiveness of the building energy codes, greater care must be taken to design and carry out the implementation activities. As performance-based codes often require higher level of skills from the designers or users and could be more complicated in the implementation and validation, it is important to build up the institutional and human capacities in the local building industry.

8. CONCLUSION

There is a growing trend around the world to develop and introduce performance-based building codes. Experience in other countries and the study in Hong Kong indicates that performance-based approach in building energy code is important for promoting innovation and new techniques in energy efficient building design. It can also help minimise the limitations of prescriptive criteria which are commonly found in current building control codes. Review of the current situation and future development of building energy codes in Mainland China shows clearly a need to evaluate and improve the performance concept in the existing and future code documents. As the performance-based codes often involve the application of detailed building energy analysis, higher level of skills will be required from the designers or users to demonstrate the code compliance. To ensure successful implementation and enforcement, it is important to build up the institutional and human capacities in the local building industry. It is hoped that through wider use of performance-based codes, more integrated and holistic approach to the design of energy-efficient buildings can be fostered to benefit the sustainability of buildings in the long run.

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運用性能爲本方法於建築節能標準及規範

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摘要： 本論文研究性能爲本方法在建築節能標準及規範的特性與概念。 闡釋性能爲本方法的意義，簡介一些具代表性的國家在發展性能爲本建築節能規範的情況。 根據這些國家之經驗指出，性能爲本方法對於推展創新建築節能技術和設計，尤其重要。 它也可以幫助減低建築節能規範常見的過於拘謹弊病。 通過介紹香港最近正在建立性能爲本建築節能規範的情況，展示其具體所需考慮之要點。檢討性能爲本之概念對日後中國內地推進建築節能規範的影響。 性能爲本之規範一般需要其使用者具備較高分析技巧，而且可能使到規範的施行和驗證會變得更複雜。 若要保證其成功及有效推行，必須在當地建築行業裡，建立起體制與人才各方面的能力。

關鍵詞：建築節能標準，建築節能規範，性能爲本方法，香港，中國內地。