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Overall Thermal Transfer Value (OTTV): How to Improve Its Control in Hong Kong

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Abstract
The overall thermal transfer value (OTTV) standard has been implemented in Hong Kong for more than two years. It is the right time to re-examine it and to find out ways to improve its control. The concept and brief history of the OTTV method are reviewed. The methodology for developing OTTV standards is explained and the OTTV standards in some developing countries are compared. Limitations of the OTTV standard in Hong Kong are discussed. The ways to enhance the standard are proposed. It is hoped that a more comprehensive building energy standard integrating all aspects of architectural and building services designs can be developed in the coming future.

Keywords
Overall thermal transfer value, building energy standard and building energy efficiency.

Introduction

Building energy standards or codes are becoming more and more important in energy efficiency policies [1]. These standards can help raise concern and awareness of building energy conservation, promote energy efficient designs in buildings, encourage the development of energy efficient building products, and form a basis for assessing building energy performance and developing energy efficiency programmes [2]. Many countries in the world are now developing or upgrading their building energy standards in order to achieve the energy efficiency goals.

In Hong Kong, the Government has implemented the building energy efficiency regulation in July 1995 [3]. The overall thermal transfer value (OTTV) method is used as a control measure for building envelope design in commercial buildings and hotels [4]. The controls on OTTV aim at reducing external heat gains through the building envelope and hence the electricity required for air-conditioning. After two years, the Government is about to review the OTTV legislation. It is the right time to re-examine the OTTV method, assess its limitations, and to find out ways to improve it for better energy efficiency and effectiveness.

OTTV Concept and Brief History

OTTV is an index for comparing the thermal performance of buildings. It is a measure of the average heat gain into a building through the building envelope [5] and consists of three major components: (a) conduction through opaque walls, (b) conduction through window glass, and

(c) solar radiation through window glass. The usual practice is to have two sets of OTTV -- one for the exterior walls and the other for the roof. The general form of OTTV equation for an external wall is:

$$
\begin{aligned}
OTTV_i &= \frac{Q_{wc} + Q_{gc} + Q_{sol}}{A_i} \\
&= \frac{(A_w \times U_w \times TD_{eq}) + (A_f \times U_f \times DT) + (A_f \times SC \times SF)}{A_i} \\
&= (1 - WWR) \times U_w \times TD_{eq} + WWR \times U_f \times DT + WWR \times SC \times SF \qquad (1)
\end{aligned}
$$

where $OTTV_i$ = overall thermal transfer value of the external wall (W/m^2)

Q_{wc} = heat conduction through opaque walls (W)
Q_{gc} = heat conduction through window glass (W)
Q_{sol} = solar radiation through window glass (W)
A_w = area of opaque wall (m^2)
U_w = U-value of opaque wall (W/m^2.K)
TD_{eq} = equivalent temperature difference (K)
A_f = area of fenestration (m^2)
U_f = U-value of fenestration (W/m^2.K)
DT = temperature difference between interior and exterior (K)
SC = shading coefficient of fenestration (dimensionless) = SC_{win} x SSF
SC_{win} = shading coefficient of window glass (dimensionless)
SSF = solar shade factor of external shading devices (dimensionless)
SF = solar factor of fenestration (W/m^2)
A_i = gross area of the walls (m^2) = $A_w + A_f$
WWR = window-to-wall ratio (gross wall area) = A_f / A_i

The OTTV of the whole exterior wall is given by the weighted average of the OTTVs of individual walls at different orientations, like this:

$$
= \frac{\sum (OTTV \times A)}{\sum} \qquad (2)
$$

where $OTTV_{wall}$ = OTTV of the whole exterior wall (W/m^2)

The approach for calculating the roof OTTV is similar to that for walls. The terms in the OTTV equations may vary in different OTTV standards and their characteristics depend on how the equations and coefficients are derived [6, 7]. Compared with thermal insulation standards in cold climates, OTTV is more suitable for application to buildings in hot climates because it accounts for the solar heat gain at the building envelope [8].

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) was the first body to propose the OTTV method [9, 10]. In Asia, Singapore was the first country to develop an OTTV standard [11]; her standard was based on the ASHRAE Standards 90-75 and 90-80A, but with some refinements to suit local climate and construction practices. In 1980s and early 1990s, some countries of the Association of Southeast Asian

Nations (ASEAN), including Indonesia, Malaysia, Philippines and Thailand, used Singapore's development as a reference model to develop their building energy standards [1, 12, 13, 14]. They have also made reference to the new generation of ASHRAE Standard 90 series [15]. At the same time, some countries in Central America, including Jamaica and Ivory Coast, also developed their building energy standards, using OTTV as a part of the requirements [1, 16]. It is believed that OTTV is a simple method suitable for developing countries.

The OTTV standard in Hong Kong was developed from a consultancy study in 1991 [17]. The control of OTTV is the first part of the Government's plan to establish a comprehensive set of energy codes [18]. Other energy codes on lighting systems, air-conditioning systems, electrical systems, lifts and escalators, and central control and monitoring systems are now being developed or planned to promote energy efficiency in other aspects of building design.

Methodology for Developing OTTV Standards

The experience of the ASEAN countries in developing energy standards is important for Hong Kong since they have similar climatic conditions and social structures. The ASEAN-USAID Building Energy Conservation Project (1982-92) is an essential research basis for supporting the standard development in the ASEAN countries [19]. Under the auspices of the United States, a systematic method has been established for developing building energy standards in developing countries. Figure 1 shows an overview of the development process which involves policy and analysis processes. A key focus of the project is the application of technical tools for analyzing and assessing building energy consumption.

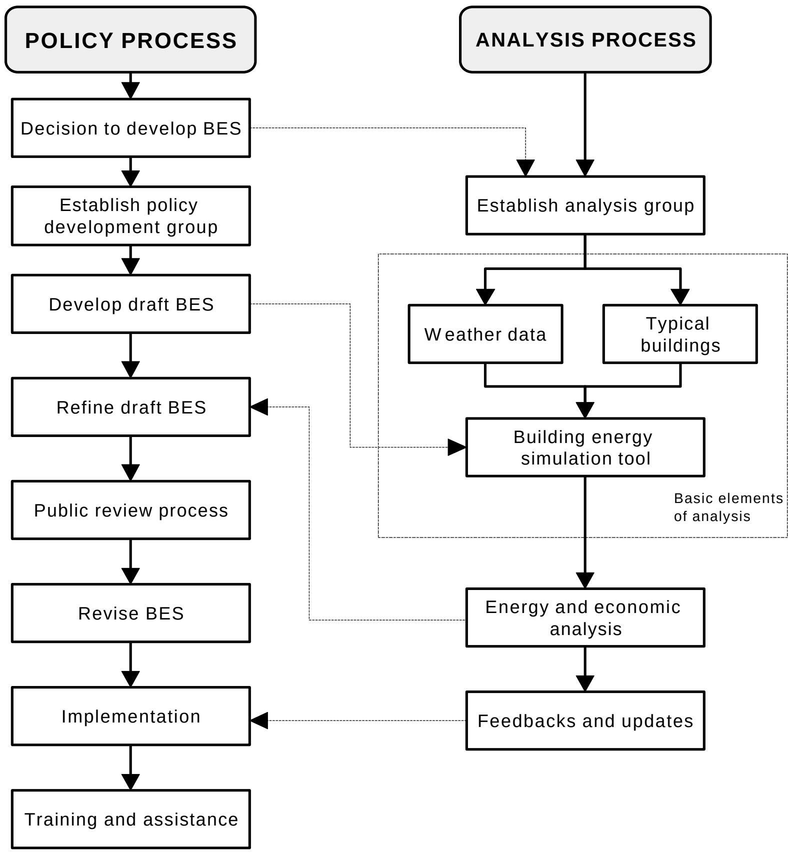

Figure 1 Overview of the development process of building energy standards (BES)

To develop the OTTV equations, building energy simulation methods and multiple regression techniques were used to study the energy performance in buildings and determine the form of equations. Figure 2 shows the general methodology for developing OTTV equations. Parametric analysis was carried out to examine the major design parameters of building envelope and formulate the coefficients of the OTTV equations [20, 21, 22]. The analysis process is quite complicated since it involves the use of detailed building energy simulation programs, such as DOE-2 [23]. The properties of the OTTV equations depend on the climatic data, the input assumptions of the simulation, and the way that the simulation results are interpreted. Therefore, comparison of them is not simple and straightforward.

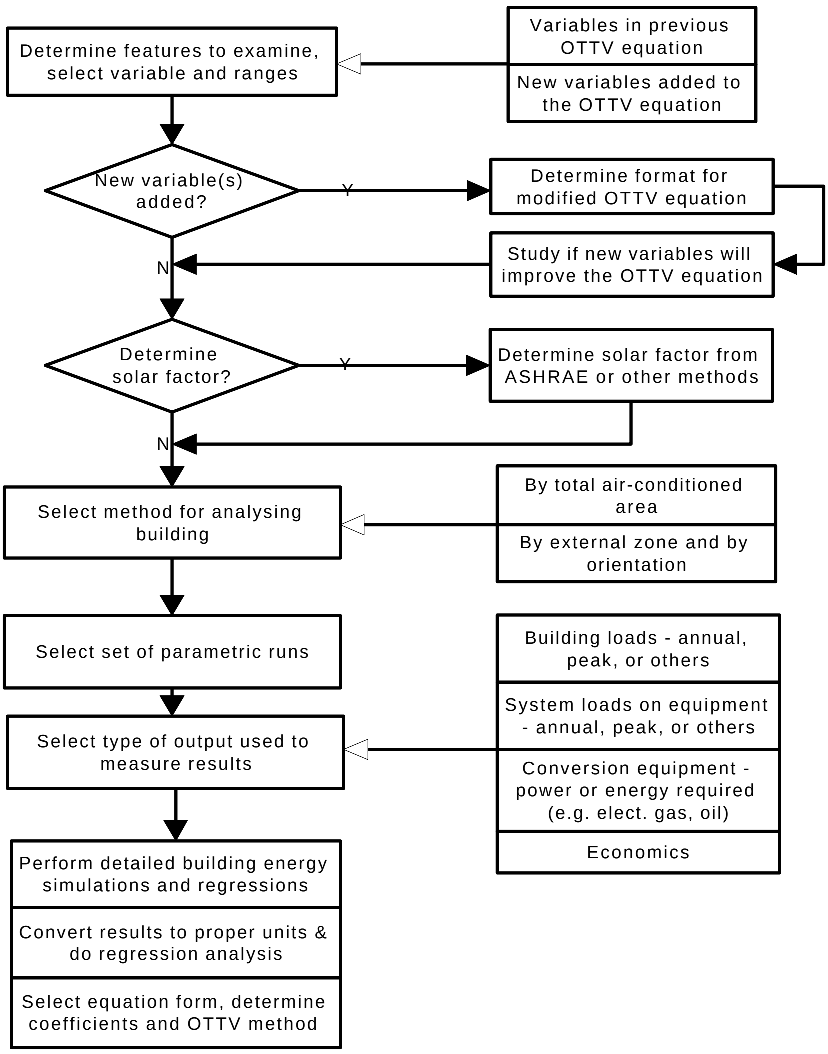

Figure 2 General methodology for developing OTTV equations

Comparison of OTTV Standards

Table 1 shows a comparison of the OTTV standards in Singapore, Malaysia, Thailand, Philippines, Jamaica and Hong Kong. It is interesting to see the similarities among them in the overall approach and limits. For example, the ‘ ’ number 45 W/m is used in Singapore, Malaysia and Thailand for the wall OTTV limit, although they are located at different

different sets of equations. Using a reference building envelope, Lam and Hui [2] have shown that as compared with other countries, the current OTTV limits in Hong Kong are moderate for tower (35 W/m^2) and are generous for podium (80 W/m^2).

Table 1 Comparison of OTTV standards

	Singapore	**Malaysia**	**Thailand**	**Philippines**	**Jamaica**	**Hong Kong**
Latitude (city)	1° 20' N Singapore	3° 7' N Kuala Lumpur	13° 41' N Bangkok	14° 35' N Manila	17° 56' N Kingston	22° 18' N Hong Kong
Year adopted	1979	1989	1992	1993	1992	1995
Status	Mandatory	Voluntary	Mandatory	Voluntary	Mandatory	Mandatory
OTTV limits for walls (W/m^2)	45	45	45	48	55.1 - 67.7	Tower: 35 Podium: 80
OTTV limits for roof (W/m^2)	45 (max. U-value if no skylights)	25 (max. U-value if no skylights)	25 (max. U-value if no skylights)	Max. U-value if no skylights	20	(average for walls and roof)
TD_{eq} for walls (K)	10 - 15	19.1 α	9 - 18	12.65 α (office) 5.4 α (hotel)	varies with α	1.4 - 7.5
TD_{eq} for roof (K)	16 - 24	16 - 24	12 - 32	---	varies with α	7.9 - 18.6
DT for walls (K)	5	neglected	5	3.35 (office) 1.10 (hotel)	varies by location	neglected
DT for roof (K)	5	neglected	5	---	varies by location	neglected
Average SF for walls (W/m^2)	130	194	160	161 (office) 142 (hotel) 151 (store)	372	160
Average SF for roof (W/m^2)	320	488	370	---	435	264
Consider exterior shading?	Yes	Yes	Yes	No	Yes	Yes
Daylighting credits?	No	Yes (10% or 20%)	N/A	Yes (10%)	Yes (7.5% or 30%)	No

Notes: 1. α = solar absorptivity.
2. Average SF for walls is calculated for the four principal directions (N, E, S, W).

Moreover, the relative importance of the components in OTTV may be studied from the heat gain values calculated using the coefficients TD_{eq}, DT and SF, respectively. It is found that the solar component is the most significant in the OTTV and may account for a portion from 44% (in the Singapore method) to 87% (in the Hong Kong method). A clear understanding of the climatic properties and local construction practices is important for assessing the OTTV standards and their implications to building design.

Limitations of the OTTV Standard in Hong Kong

The biggest limitation of the OTTV method is that it only deals with the building envelope and does not consider other aspects of building design (such as lighting and air-conditioning) and the coordination of building systems to optimize the combined performance. The use of

OTTV as the only control parameter is inadequate and cannot ensure energy is used efficiently in the building [8]. Before other energy codes are implemented, the effect of the OTTV standard on 'real' energy savings is questionable, although it helps to increase concern and awareness of energy efficiency matters.

The OTTV method has also been criticized for limiting design freedom in architecture and restricting innovations [24]. Although the OTTV approach has made code compliance simple for conventional building designs, it has tended to restrict designers from innovation and more challenging work. If alternative paths for code compliance are not provided, innovative designs that may exceed the OTTV limits but can achieve a higher overall efficiency will be excluded and discouraged. For example, designs employing daylighting to reduce energy consumption of electric lights will be restricted.

Evolution of the ASHRAE's energy standards has indicated that more flexible approaches are needed to encourage innovative energy efficient design in buildings. Many countries are now moving towards energy performance criteria which give designers greater flexibility [14, 15, 16, 20, 25]. To maintain its economic competitiveness in the international market, Hong Kong should not lag behind the current development [26].

Chow and Chan [21] have commented that the OTTV equations developed in Hong Kong are rather unclear and many influential parameters have not been studied thoroughly. Moreover, specific requirements on air leakage of the building envelope do not exist; the research basis of the Hong Kong OTTV standard is weak and verification and testing of the criteria are inadequate [27]. A lack of understanding of the method for developing the OTTV equations is also making designers not confident about the standard. Without reliable data and information obtained from research studies, upgrading of the standard is very difficult.

Other problematic areas are related to the implementation issues. At present, the code of practice for OTTV [4] only provides a manual approach to the OTTV calculations. The compliance and calculation procedure is often lengthy and time-consuming, so that checking of the results during submission and enforcement are not easy. The lack of a competent professional engineer to be responsible for the OTTV submission is also affecting the actual implementation. In addition, as there is no control measures for the design and operation of existing buildings which constitute a large portion of the energy consumption, the energy savings arisen from the OTTV standard are limited.

The Ways to Enhance the Standard

Alternative paths to code compliance. Different paths to the compliance process should be provided in the standard to allow innovation in architectural and building services designs [2]. Figure 3 shows the requirements and compliance of modern energy standards. The basic and prescriptive requirements which specify rigidly the minimum requirements for each building component such as insulation levels and equipment efficiencies, are effective for simple and conventional designs. The system performance requirements such as OTTV will provide additional flexibility, whereas a whole-building energy performance method will offer the greatest flexibility to manipulate the design parameters. Since the energy performance method (usually by simulation) is complicated and demanding, designers should select the path according to their project requirements and conditions. It is understandable that a comprehensive set of energy performance criteria will be complicated and difficult to enforce in developing countries. Therefore, it is advisable to have a long-term plan to gradually build up confidence and encourage taking up of the criteria.

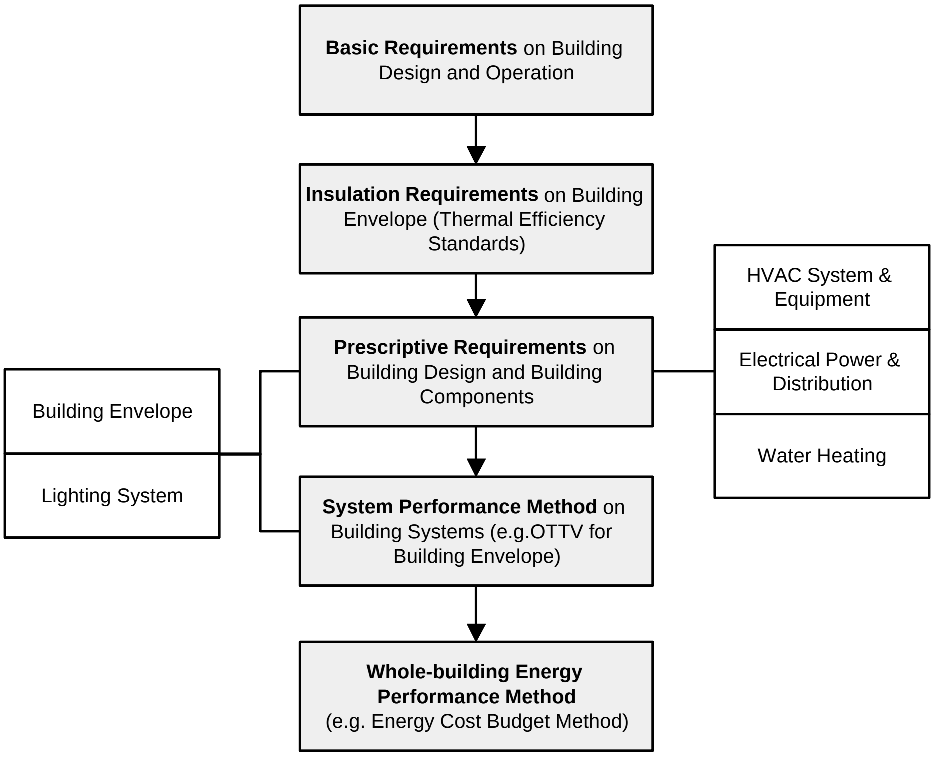

Figure 3 Requirements and compliance of modern energy standards

Towards a performance-based approach. A 'performance-based' approach sets a maximum allowable energy consumption level without specifying the methods, materials and processes to be employed to achieve it. It is concerned with what the building is required to do, rather than prescribing how it is to be constructed. This approach can also provide information for diagnosing and identifying areas for energy improvement [8]. With greater access to simulation tools, many countries now have a common goal to move towards performance-based energy codes. It is essential for Hong Kong to plan and prepare for that in order to catch up with the world-wide trend.

Integration of energy codes. The energy codes being developed and planned in Hong Kong (such as lighting and air-conditioning) are isolated and not well coordinated with the OTTV standard. To optimize the combined performance of the building systems, it is important to consider the interactions between them. Integration of building systems and cost-effective trade-offs in design should be facilitated to achieve higher energy efficiency in buildings.

Mandatory and voluntary requirements. Past experience showed that the question of the code being mandatory or voluntary is often a controversial issue that may take a long time to discuss and compromise. There is no hard and fast rule since the success of the standards depends not only on how it is designed and coded but also on how it is implemented and publicized. To avoid the delay in implementation, Hong Kong should adopt a mixture of mandatory codes and voluntary guidelines to cater for certain aspects of the building designs that cannot be well defined. From a market point of view, fiscal incentives and support for energy conservation programmes are often more effective than statutory measures.

Use of compliance software. Computer software can help to simplify and facilitate the compliance procedure and is particularly important for performance-based energy codes [26]. The current trend in the world is to develop a software program in the standard to provide a simple and flexible compliance tool for designers. For example, a new building energy standard software is now being developed in Singapore to upgrade the standard [28].

Research and development. The importance of research support to the development of building energy standards has been clearly demonstrated in the ASEAN countries [19]. Hong Kong should establish research projects and coordinate existing research activities in various institutions to support the standard development. Study of energy data and design practices will help to develop a set of criteria that is appropriate to the local conditions. By developing the experience and information, the standard can be extended to other types of buildings as well.

Education and training. Education and training are important to keep the designers and the public informed of the requirements and the technologies for building energy efficiency. Development of simulation techniques and skills among the design professionals will pave the way for more detailed energy simulation of building performance and a wider use of simulation tools in building design. Competent professional engineers responsible for the evaluation and checking process will ensure that the standard is properly enforced.

Standard update and information network. To keep the standard updated and to keep up with the development in the world, planned review and revision process are important. A mechanism should be designed to facilitate feedback and impact assessment which help to improve the standard. Information exchange with other countries should be promoted by setting up information network and communication. It is beneficial to discuss with other countries on the common interests about building energy standards.

Conclusion

To achieve sustainability and economic competitiveness, it is important for Hong Kong to promote energy efficiency in buildings and control building energy consumption. The OTTV standard is the first step towards this objective; the second step and so on are urgently needed. The success of the building energy standard depends on the will of the Government to persist with the policy, the back-up of research and development, and the co-operation of the professionals to accept any initial inconvenience. It is hoped that a more comprehensive building energy standard integrating all aspects of architectural and building services designs can be developed in the coming future.

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