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# SUSTAINABLE BUILDING TECHNOLOGIES FOR HOT AND HUMID CLIMATES

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Sustainable building is an abstract and broad concept encompassing many issues and thinking, with the aim to minimise adverse environmental impacts and promote resources eco-efficiency. In order to apply and achieve sustainable building in hot and humid climates, efforts must be put into understanding the local climate, and integrating appropriate building technologies into the architectural and urban designs.

This research paper explains the basic concepts of sustainable building, describes the principles of building climatic design for hot and humid climates, and discusses the important considerations for sustainable building technologies. With reference to the conditions in Hong Kong and Hangzhou, the key factors affecting the development of sustainable buildings are analysed and the strategies to promote sustainable building practices and effective technologies are examined. As many cities in China will continue to expand and grow, the building and construction sector has major impacts on the sustainable development of our society. It is hoped that by mutually exchanging ideas across disciplines and cities, a better understanding of the long-term sustainability goals in building design could be developed, and more opportunities for joint efforts and close cooperation would be created.

## 1. Introduction

Buildings are significant users of energy and materials in a society [1] and they have a large impact on the natural environment and resources [2]. As the built environment continues to expand, the rate of resource depletion this involves is not sustainable. There is an urgent need to promote and enhance sustainable practices in the built environment [3]. This is especially important for developing countries with fast economic growth and building developments.

Sustainable building is an abstract and broad concept encompassing many issues and thinking. At present, there are many schools of thought on sustainable building or green building. Among the relevant literature, it is believed that cradle-to-cradle design will enable an ecologically intelligent approach to architecture [4] and life-cycle thinking is a key to the sustainable construction concept [5].

This research paper explains the basic concepts of sustainable building, describes the principles of building climatic design for hot and humid climates, and discusses the important considerations for sustainable building technologies in such climates. With reference to the conditions in Hong Kong and Hangzhou, the key factors affecting the development of sustainable buildings are analysed and the strategies to promote sustainable building practices and effective technologies are examined.

As many cities in China will continue to expand and grow, the building and construction sector has major impacts on the sustainable development of our society. It is hoped that by exchanging ideas across disciplines and cities, a better understanding of the long-term sustainability goals in building design could be developed, and more opportunities for joint efforts and close cooperation would be created.

## 2. Sustainable Building Concepts

According to Hasegawa [6], sustainable buildings can be defined as "those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting." The action of sustainable buildings may be defined as building practices which strive for integral quality (including economic, social and environmental performance) in a broad way. Thus, the rational use of natural resources and appropriate management of the building stock will contribute to saving scarce resources, reducing energy consumption, and improving environmental quality.

### 2.1. *Basic Considerations*

Sustainable design involves considering the whole life of buildings, taking environmental quality, functional quality and future values into account. It can also be considered as the thoughtful integration of architecture with building services and structural engineering resources. In addition to express concern for the traditional aesthetics of massing, orientation, proportion scale, texture, shadow and light, the building design team needs to be concerned with long-term costs and environmental impacts.

Successful sustainable design requires an integrated approach since building systems and operational practices are dependent on sitting, solar access and light penetration, architectural design, and product specification [2]. This approach to design examines how a building interacts with its systems, activities and surrounding environment.

### 2.2. *Design Objectives*

Hasegawa [6] has identified five major objectives for sustainable buildings as follows:

- Resource efficiency
- Energy efficiency
- Pollution prevention
- Harmonisation with environment
- Integrated and systemic approaches

To achieve these, sustainable buildings must be energy and resource efficient (including greenhouse gas emissions reduction), non-wasteful and non-polluting, highly flexible and adaptable for long-term functionality. They should also be easy to operate and maintain, and are supportive of the productivity and well being of the occupants (including good indoor air quality and noise abatement).

To put the objectives into practice and assess the building performance, the following categories of criteria are often used [3].

- Sustainable site
- Energy efficiency and renewable energy
- Water conservation
- Materials and waste management
- Indoor environmental quality

### 2.3. *Building Life Cycle*

Sustainable building emphasizes a "whole system" perspective and considers the construction process and first costs, toward the life of a building and the longer term interest of the owners and occupants. Figure 1 shows the concept of building life cycle and the four major aspects of sustainable construction, namely, energy, water, waste and materials [7].

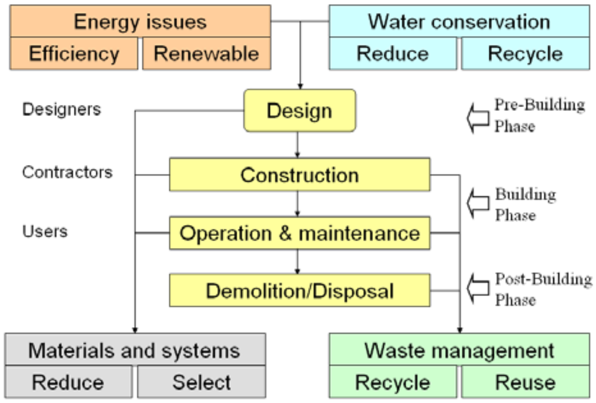


Figure 1. Building life cycle and sustainable construction

Sustainable design takes into account the energy and environmental performance of the building during its complete life cycle, including site selection, construction, operations and maintenance, renovations, demolition and replacement. It requires the joint efforts of building designers, contractors and end-users.

## 3. Principles of Climatic Design

In the past human history, climate considerations are very important in building and urban design [8]. However, with the emerging of modern architecture and building services systems, the process of climatic design is often overlooked [9].

The basic philosophy of climate responsive design lies upon the evaluation of climatic influence and the optimisation of building environmental performance [10]. In other words, we are trying to minimise the resource consumption and environmental impact through cooperation with external climate.

To establish a systematic approach to this, two important areas shall be examined:

- Outdoor climate
- Indoor climate

### 3.1. *Outdoor Climate*

Sustainable design of buildings and building services systems requires careful consideration of local climatic conditions and characteristics [11]. Without good information and understanding of the local climate, it is not possible to ensure optimal building design and efficient building services operation.

To achieve energy efficiency and sustainability in buildings, it is essential for Hong Kong and the cities in mainland China to establish accurate and detailed climatic data [12]. The quality of climatic data and information will determine the effectiveness of building design strategies and the accuracy of design load and energy calculations.

Table 1 shows a comparison of climatic design conditions in Hong Kong and Hangzhou. It can be seen that both cities are hot and humid in the summer, but Hangzhou is about 3.3 °C hotter. In the winter, Hangzhou is much cooler than Hong Kong. As passive cooling by induced natural ventilation can be most effective in hot and humid climates [13], the information about wind speed and prevailing wind direction will give designers some hints on optimizing the ventilation.

Table 1. Climatic design conditions in Hong Kong and Hangzhou (Data source: ASHRAE [14])

| | Hong Kong | Hangzhou |
|---|---|---|
| Latitude | 22.32° N | 30.23° N |
| Longitude | 114.17° E | 120.17° E |
| Cooling design DB/MCWB (1%) | 31.6 °C/26.5 °C | 34.9 °C/26.9 °C |
| Heating design DB (99%) | 10.6 °C | -1.1 °C |
| Wind speed<br>MCWS (summer)<br>MCWS (winter) | <br>3.1 m/s<br>2.2 m/s | <br>3.5 m/s<br>1.7 m/s |
| Wind direction<br>PCWD (summer)<br>PCWD (winter) | <br>270<br>30 | <br>180<br>340 |

Notes:

1. Weather stations: Hong Kong = King's Park, Tsimshatsui; Hangzhou = Jian Qiao.
2. Abbreviations:
   DB = Dry bulb temperature
   MCWB = Mean coincident wet bulb temperature
   MCWS = Mean coincident wind speed
   PCWD = Prevailing coincident wind direction
   (0 = North, 90 = East)

Figure 2 shows the monthly design temperatures in Hong Kong and Hangzhou. From this graph, we can study the monthly design dry bulb (DB) and mean coincident web bulb temperatures (MCWB). The monthly summaries are useful when building designers consider the seasonal variations in outdoor weather against the building use patterns and occupancy. In particular, these values can be used for determining air-conditioning loads during periods of maximum solar radiation [14].

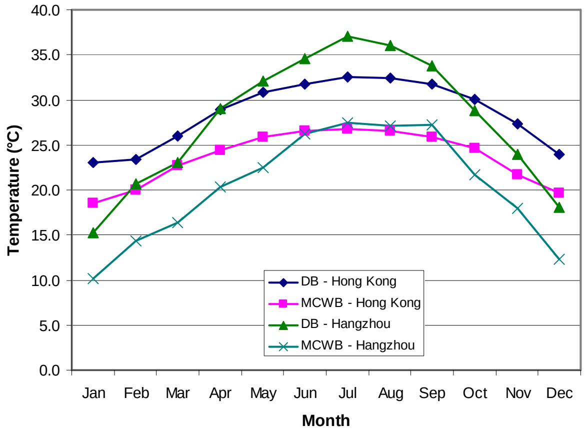


Figure 2. Monthly design temperatures in Hong Kong and Hangzhou (Data source: ASHRAE [14])

### 3.2. *Indoor Climate*

Indoor climate focuses on those physical environmental conditions created inside built environments that provide for a comfortable and healthful experience, and that improve human performance and promote work productivity. Typical indoor environmental conditions include temperature, relative humidity, ventilation and visual conditions.

A sustainable ways to achieve comfort in buildings is called "bioclimatic design". It refers to the design of buildings and spaces based on local climate, aimed at providing thermal and visual comfort by making use of solar energy and other environmental sources in the natural energy flows [8, 10]. Basic elements of bioclimatic design are passive solar systems which are incorporated onto buildings and utlilise environmental sources (such as sun, air, wind, vegetation, water, soil, sky) for cooling, heating and lighting the building [13]. Usually, at the early design stage, some simple decisions on bioclimatic design can help save energy usage later on.

Figure 3 shows a comfort zone diagram which is often used to analyse the thermal conditions of indoor environment [15]. If the outdoor weather conditions of Hong Kong and Hangzhou are plotted onto this diagram, it can be found that in most of the time, the climatic conditions is falling outside the comfort zones.

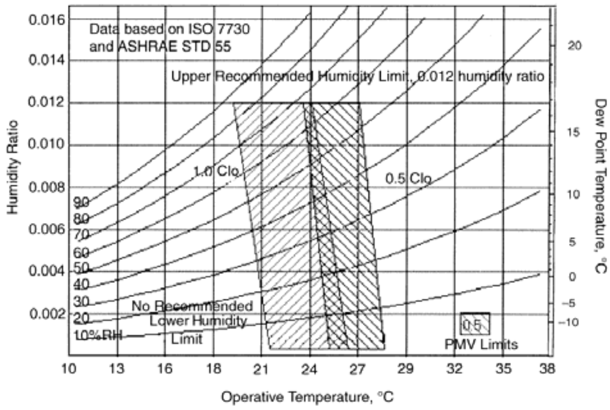

Figure 3. ASHRAE thermal comfort zone (ASHRAE [15])

Nicol [16] pointed out that the current international standard for indoor climate (ISO7730 based on Fanger's predicted mean vote equations) does not adequately describe comfortable conditions in hot and humid climates. Thus, adaptive thermal comfort models were developed in order to address the implications of air movement and humidity in the hot-humid tropics. Also, a variable indoor temperature standard will help save energy by encouraging the use of naturally ventilated buildings.

## 4. Sustainable Building Services

Sustainable building approach enables building owners and managers to reduce energy consumption, improve the work environment, and reduce the environmental impacts of building operations. To ensure this goal, building services systems have an important role to play since the building environmental performance is directly affected by the building services systems.

### 4.1. *System Design Strategy*

It is important for the design team to re-examine basic engineering principles in order to develop appropriate system design in support of a sustainable building. Techniques such as natural ventilation, thermal-mass storage, radiant cooling and passive solar control are applications of basic thermodynamic principles. The designers must help drive innovation and be an expert in understanding the technical characteristics and performance of architectural components, construction practices and maintenance/operational practices in terms of energy use, environmental impact and indoor air quality.

Bunn [17] pointed out that sustainable building services in developing countries must find best-fit technologies. He argues that ostensibly energy efficient solutions will not perform as intended unless they are appropriate for the climate, are well detailed, installed and commissioned, and are of a level of complexity that can be understood by building managers and users. Some energy saving technologies are simply switched off because they are too complex to manage.

### 4.2. *Energy Optimisation and Modelling*

Energy use in a building is a function of building services, the general design and the interaction of people with the building [18]. Figure 4 shows the key factors influencing energy consumption in buildings.

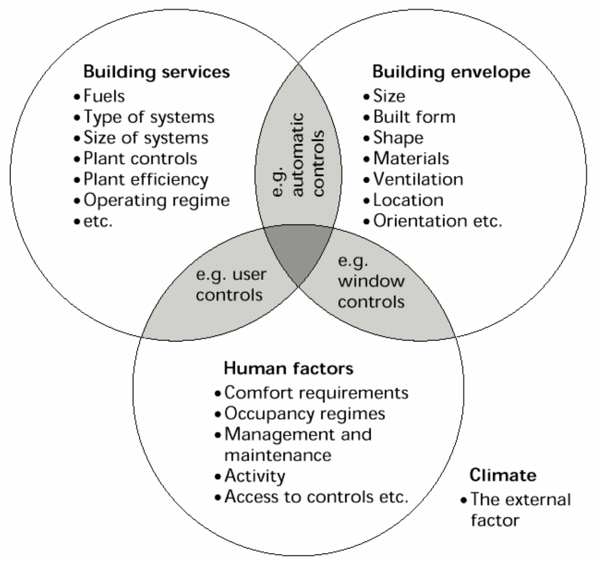

Figure 4. Key factors influencing energy consumption in buildings (CIBSE [18])

As a significant portion of sustainable building criteria are energy-related, the energy issues are usually a critical factor in determining the building performance. Whole-building design methods that integrate passive solar, energy efficiency, and other renewable energy technologies can be used to reduce building energy consumption. By optimising the building's standard components (site, windows, walls, floors, and air-conditioning systems) building owners can substantially reduce energy use without increasing construction costs.

Here, computer modelling is a very useful tool in optimising design of building services systems and the building shell. Building energy simulation can be used to investigate in advance the ways in which costs and energy consumption can be reduced [19]. It could also enable the designer to evaluate the impact of the architectural configuration on energy performance and indoor air quality. To achieve sustainable design, designers should make use of energy analysis tools, as well as financial analysis techniques, to determine the optimal configurations of architectural and engineering components, while meeting the typical budget, schedule and aesthetic requirements.

### 4.3. *HVAC and Indoor Environmental Quality*

Hui [7] indicated that for hot and humid climates, the heating, ventilation and air conditioning (HVAC) system is often the most important area to consider for green buildings. Although HVAC systems offer many opportunities for recovery and re-use of thermal energy, the preferred solution is to use less energy in the first place. This is achievable by more energy efficient buildings, systems and equipment and through improved operating and maintenance procedures. Moreover, attention should be paid to the thermal characteristics of building and strategies for minimising internal loads, examining in detail the opportunities for natural ventilation and daylighting, and exploring ways to reduce the energy requirements of HVAC.

In addition to improving energy efficiency and environmentally sound operations, high performance sustainable design also seeks to provide an indoor environment that enhances the productivity of the occupants. Current research information suggests that good indoor environmental quality increases alertness and improves performance, while reducing illnesses and absenteeism [3]. Sustainable design can thus provide significant life-cycle cost savings and productivity gains in addition to energy and resource savings.

## 5. Hong Kong Situation

Hong Kong’s environmental problems are similar to most developed communities [20]. Rapid population growth, plus a high degree of commercial activities, creates pollution and environmental degradation.

### 5.1. *High Building Density*

With a limited supply of habitable land and extremely dense urban conditions, the building development in Hong Kong often faces significant spatial constraints. Economic and social imperatives dictate that the city must become highly concentrated, making it necessary to increase the density to accommodate the people, reduce the cost of public services, and achieve social cohensiveness. High-rise, high-density buildings represent the major urban settings in Hong Kong and form an important background for sustainability challenges.

Designing sustainable buildings in a complex and dense urban environment like Hong Kong requires special care to the planning of urban structure, coordination of energy systems, integration of architectural elements, and utilisation of spaces [1]. Simply making individual building green is too narrow a concept. It is important to consider other factors such as urban planning and transport strategy, and how they will interact and influence the results.

### 5.2. *Important Factors*

Sustainable building in Hong Kong must consider a range of factors which frame the current building development and city lifestyle. For example, because of the important element of land value, property developers usually demand a fast-track development and are more concerned with selling or letting their properties quickly than on long-term benefits. Short investment horizons and rapid economic changes in society also lead to concerns about initial costs and indifference to running costs and life-cycle penalties.

At present, the Hong Kong government is developing some practical means to integrate sustainable development considerations into decision-making [20]. In doing so, some competitive advantage might be gained for creating more ecologically sound development projects.

## 6. Conclusions

A sustainable building should mean a quality building that is efficient, elegant and easy to maintain, considering the efficient use of resources throughout the building life cycle and ensuring high productivity and well-being of the occupants. The use of technology is an important step toward more sustainable building. In order to apply and achieve sustainable building in hot and humid climates, efforts must be put into understanding the local climate, and integrating appropriate building technologies into the architectural and urban designs.

Although the momentum for sustainable building is growing in Hong Kong, more efforts and creative ideas are needed to remove the barriers and provide effective solutions to meet the local requirements in an intelligent way.

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