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Climatic Data for Sustainable Building Design in Hong Kong

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ABSTRACT

Sustainable design of buildings and building services systems requires careful consideration of local climatic conditions and characteristics. Without good information and understanding of the local climate, it is not possible to study and achieve optimal building design and efficient building services operation. At present, the building designers, managers and researchers in Hong Kong often find it difficult to identify reliable and accurate weather data and information. Although some meteorological data and design conditions exist, they are not always applied correctly and well understood by the users, because of the data complexity and the abstraction of sustainable design concept.

This paper will present the major findings of a research which aims to study and develop the important climatic data in Hong Kong for sustainable building design. By analysing the long-term weather data over the past 114 years and examining the practical issues of building design, useful climatic information and patterns are identified. In addition, the key results from other relevant local and overseas research studies are evaluated so as to assess the present needs and future development of building climatic design. It is hope that the research information will enable people to better understand the local climate and to build up the resources for assessing important issues of energy and environmental design.

Keywords: Climatic data, weather information, sustainable building, Hong Kong

1. INTRODUCTION

Sustainable practices in building design and operation are becoming more and more important in the world (Langston and Ding, 2001). However, to achieve them is not straightforward because of the abstraction of sustainable design concept and the complexity of many influencing issues. One of the most important factors affecting sustainable design of buildings and building services systems is the consideration of local climatic conditions and characteristics. Without good information and understanding of the local climate, it is not possible to study and achieve optimal building design and efficient building services operation (Givoni, 1998; Hui and Cheung, 1997a).

Too often the climatic factors are taken for granted in modern building development because they are not of immediate interest and concern to building developers, owners, designers or builders. Even though some people try to search for appropriate building climatic conditions in Hong Kong, they often find it difficult to identify reliable and accurate weather data and information. Although some meteorological data and design conditions exist, such as (HKO, 1993-2004) and (ASHRAE, 2005a, 2001a & 1997a), they are not always applied correctly and well understood by the users. There is a need to develop the climatic data and information which are essential to sustainable building design (Lam and Hui, 1995). It is also important to encourage building designers, managers and researchers to critically assess the weather data they are currently using, if the best design strategy for sustainable building is to be obtained.

This paper will present the major findings of a research which aims to study and develop the important climatic data in Hong Kong for sustainable building design. A long-term weather database has been developed based on the raw meteorological data and related information provided by the Hong Kong Observatory. By analysing the weather data over the past 114 years in Hong Kong and examining the practical issues of building design, useful climatic information and patterns are identified in the study. In addition, the key results from other relevant local and overseas research studies are evaluated so as to assess the present needs and future development of building climatic design. It is hope that the research findings and information will enable people to better understand the trends of local climate and to build up the resources for assessing important issues of energy and environmental design.

2. CLIMATE AND SUSTAINABLE BUILDING

In the past human history, climate considerations are very important in building and urban design (Givoni, 1998). Although the scientific measurement and recording of meteorological data and climatic conditions were possible only when the technical instruments were invented a few hundreds years ago, ancient people understood and realised the significance of climate responsive design that would harmonise with the nature (Gut, 1993; Hyde, 2000). Buildings were considered as "climate modifiers" which could take advantage of local weather to enhance their architectural integrity and environmental quality (Torrance, 1991).

With the emerging of modern architecture and building services systems, the process of climatic design is usually overlooked. Nowadays, building development and construction are often planned and implemented with little concern for long-term sustainability and harmony with natural climatic forces. At the same time, the growing world population and its environmental impact have presented common concerns and challenges to the present and future generations. To address these issues, some building designers and researchers try to revisit and rediscover the principles of sustainable building through the study of climate responsive architecture and energy efficient buildings (Krishan, et al., 2001; Olgyay, 1963).

Nevertheless, to define clearly the concept of sustainable design and its relationship with climatic factors is not a simple task. The basic thinking lies upon the evaluation of climatic influence and the optimisation of building environmental performance. In other words, we are trying to minimise the resource consumption and environmental impact through cooperation with external climate. In practice, this will require a careful assessment of local climatic conditions and a thorough understanding of sustainable design principles (Langston and Ding, 2001). These principles are summarised as follows.

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

From the architectural point of view, it implies wider and better use of passive design, natural ventilation and daylighting. From the engineering and environmental perspectives, this leads to a systematic and critical evaluation of building's life cycle performance, including thermal design, ventilation, energy and resources use. If the project considers impacts beyond its normal boundary, then the issues of off-site renewable energy (such as solar and wind) and embodied energy would become a concern too. No matter what sustainable design issues we are looking at, an element of climate is always required.

3. CLIMATIC DESIGN INFORMATION

Depending on the requirements of a particular building design task, various types of weather data and information will be required (Pike, 1994). In general, the weather parameters directly related to the ambient air such as air temperature, humidity, wind conditions and solar data are needed for studying the climate characteristics. These meteorological data are presented in different formats and various levels of details. The data complexity and formats sometimes may prevent designers from grasping the key attributes of climatic design. Therefore, relevant guidelines and standards are being established in recent years to help them identify the essential information and compare the climatic design implications.

3.1 Sources of Data

Table 1 shows the sources of climatic data that are commonly used by building designers and researchers. The information includes outdoor design conditions for thermal and HVAC (heating, ventilating and air conditioning) design, solar and illuminance data, as well as hourly data files for building energy analysis and simulation. Statistical summaries and seasonal variations are often provided to indicate the key climate concept.

Table 1: Sources of climatic design data for building design

Sources of Data	References
ASHRAE Handbook Fundamentals (2005, 2001 & 1997 versions), Chapter 28, 27 & 26 – Climatic Design Information	(ASHRAE, 2005a, 2001a & 1997a)
ASHRAE International Weather for Energy Calculations (IWEC) (CD-ROM) ASHRAE Weather Year for Energy Calculations 2 (WYEC2) (CD-ROM)	(ASHRAE, 2001b) (ASHRAE, 1997b)
CIBSE Guide A: Environmental Design Addendum to CIBSE Guide A - for Hong Kong	(CIBSE, 1999) (CIBSE, 2005)
CIBSE Guide J: Weather, Solar and Illuminance Data (CD-ROM) and CIBSE/Met Office weather data sets (hourly data, test reference year, design summer year)	(CIBSE, 2001)
Engineering Weather Data (printed or CD-ROM)	(Kjelgaard, 2001)
METEONORM Global Meteorological Database for Solar Energy and Applied Meteorology (www.meteotest.ch)	---
Weather data files (hourly) provided by building energy software, such as: - DOE-2 (http://doe2.com/) - EnergyPlus (http://www.energyplus.gov) - TRNSYS (http://sel.me.wisc.edu/trnsys/)	---

Notes: ASHRAE = American Society of Heating, Refrigerating and Air-conditioning Engineers
CIBSE = Chartered Institution of Building Services Engineers

It is worthwhile to mention that in the 2005 version of *ASHRAE Handbook Fundamentals* (ASHRAE, 2005a, 2001a & 1997a) the weather information has been organised into a more systematic way than before (see the list below) and a large weather database has been developed to show the design conditions of different HVAC applications for many international locations. This indicates a growing demand for the information worldwide and the need to consider/select appropriate conditions for specific purposes.

- A1 Climatic design conditions
    - A1.1 Station information
    - A1.2 Annual heating and humidification design conditions
    - A1.3 Annual cooling, dehumidification, and enthalpy design conditions
    - A1.4 Extreme annual design conditions
- A2 Monthly climatic design conditions

A separate ASHRAE Standard 169P is being drafted to provide a comprehensive source of climate data for those involved in building design (ASHRAE, 2005b). This new standard will offer a variety of climatic information used primarily for the design, planning and sizing of buildings' energy systems and equipment. It is hoped that the information will represent a valuable resource available for referencing in other building design standards.

To streamline the calculation methods and presentation formats of building climatic data, the International Organization for Standardization (ISO) is establishing some standards on hygrothermal performance of buildings (ISO, 2005a; ISO, 2005b; ISO, 2003). Hopefully all these efforts combined will help to resolve the problems of inconsistent formats, homogeneity and complexity of weather data from various sources.

3.2 Types of Information

For practical engineering design situations, the following types of climatic data and information are most commonly used (Kjelgaard, 2001):

- Outdoor design conditions (such as summer/winter design temperatures)
- Bin data and degree-day data (cooling and heating degree-days or degree-hours)
- Temperature and humidity data for estimating economizer and heat recovery savings (such as frequency of occurrence bins and coincident parameters)

For researchers and energy engineers who will perform detailed building energy analysis and simulation, more sophisticated and comprehensive climatic data are needed (Hui and Cheung, 1997a & 1997b). For instance, development of typical weather years and the related full hourly data are important for building energy research and modelling (ASHRAE, 2001b; Lam, Hui and Yuen, 1992; Thevenard and Brunger, 2002). Examples of the typical year data include:

- Test Reference Year (TRY)
- Typical Meteorological Year (TMY)
- Weather Year for Energy Calculations (WYEC)
- Example Weather Year (EWY) (from CIBSE)
- Design Reference Year (DRY) (from Europe)

For architects responsible for developing building concepts at early design stage, they will find it more constructive to use climatic charts and graphics (Loftness, 1982; Olgyay, 1963). It is common in many architectural (and sustainable) design guides and reference books to include graphics and brief summaries of climatic characteristics. Climatic data designed for architectural purpose should consider the needs of end-users and the building design process.

3.3 Research and Development

At present, there are a few active professional groups interested in the subject and they have contributed to the research and development of building climatic data and standards.

- ASHRAE Technical Committee 4.2, Weather Information
- ASHRAE Technical Committee 4.7, Energy Calculations
- CIB Task Group TG21, Climatic Data for Building Services
- ISO Technical Committee TC 163, Thermal Performance and Energy Use in the Built Environment, Sub-Committee 2 Calculation methods

The study of climatic design requires knowledge in climatology and architectural/engineering design. The task of setting up the climatic data and information should not be overlooked since it requires enormous efforts to collect, prepare and process the weather data. Usually joint effort with the local weather station and researchers is needed. Proper judgement, experience and knowledge of the local climate are important for constructing reasonable design conditions from the available meteorological data.

4. ANALYSIS OF WEATHER DATA

A long-term weather database has been developed based on the past 114 years of meteorological data in Hong Kong, provided by the Hong Kong Observatory (www.weather.gov.hk). Table 2 shows the weather parameters being studied. By examining the practical issues of building design, useful climatic information and patterns are identified. Some major findings of the research analysis are described in the following sections.

Table 2: Weather data of Hong Kong (latitude 22.3^o N, longitude 114.2^o E)

Weather parameters *	Period of records **	No. of years
[DBT] Dry-bulb temperature (^{o}C)	1884-1939, 1947-2003	114
[WBT] Wet-bulb temperature (^{o}C)	1884-1939, 1947-2003	114
[DPT] Dew-point temperature (^{o}C)	1884-1939, 1947-2003	114
[ATM] Atmospheric pressure (Pa)	1884-1939, 1947-2003	114
[CLD] Cloud amount (oktas)	1884-1939, 1947-2003	114
[SUN] Sunshine duration (hour)	March 1884-1939, 1947-2003	114
[WDR] Wind direction (0-360)	1884-1939, April 1947-2003	114
[WSP] Wind speed (m/s)	1935-1939, April 1947-2003	63
[GSR] Global solar radiation (MJ/m^2)	June 1958-2003	47

Notes: * Data are measured at Hong Kong Observatory in Tsimshatsui, except SUN and GSR which are measured at the King's Park weather station in Tsimshatsui (HKO, 1993-2004).
** No records for the years 1939-46 during World War II.

4.1 Degree-days and Psychrometry

The degree-day method is commonly used to estimate energy consumption in the early stages of thermal design (Lam, 1995). To evaluate the long-term variation of degree-day temperatures in Hong Kong, a comprehensive set of degree-day figures have been established. Figures 1 and 2 show respectively the yearly cooling and heating degree-days over the 114-year's period (calculated for a reference temperature of 18.3 ^{o}C). It can be seen that the city is warmed up as indicated by the increasing cooling degree-days and decreasing heating degree-days. This has significant implications to urban climate and energy use.

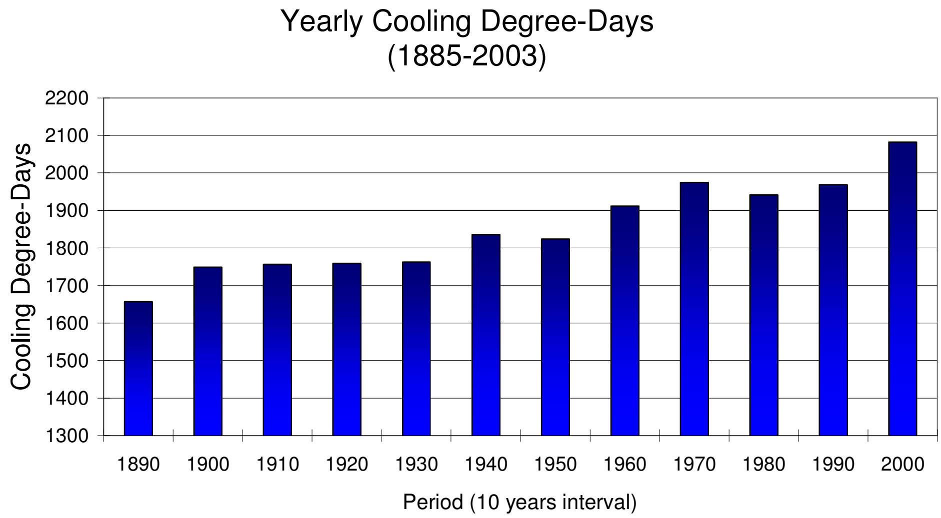

Figure 1. Yearly cooling degree-days in Hong Kong

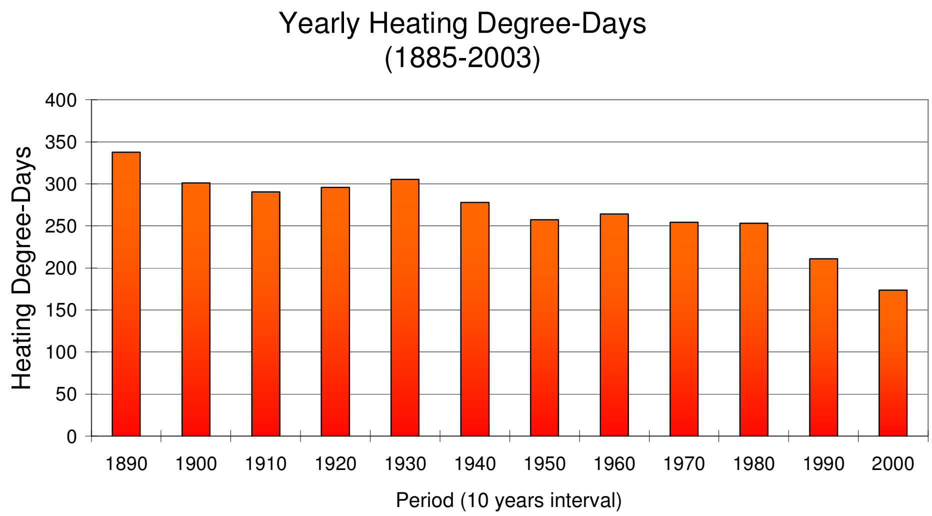

Figure 2. Yearly heating degree-days in Hong Kong

Figure 3 indicates the frequency of occurrence of the Hong Kong's climatic conditions plotted on a psychrometric chart. The ASHRAE comfort zones are also put down here to illustrate the analysis between thermal comfort and outdoor climate, which is the basis of bioclimatic design and analysis.

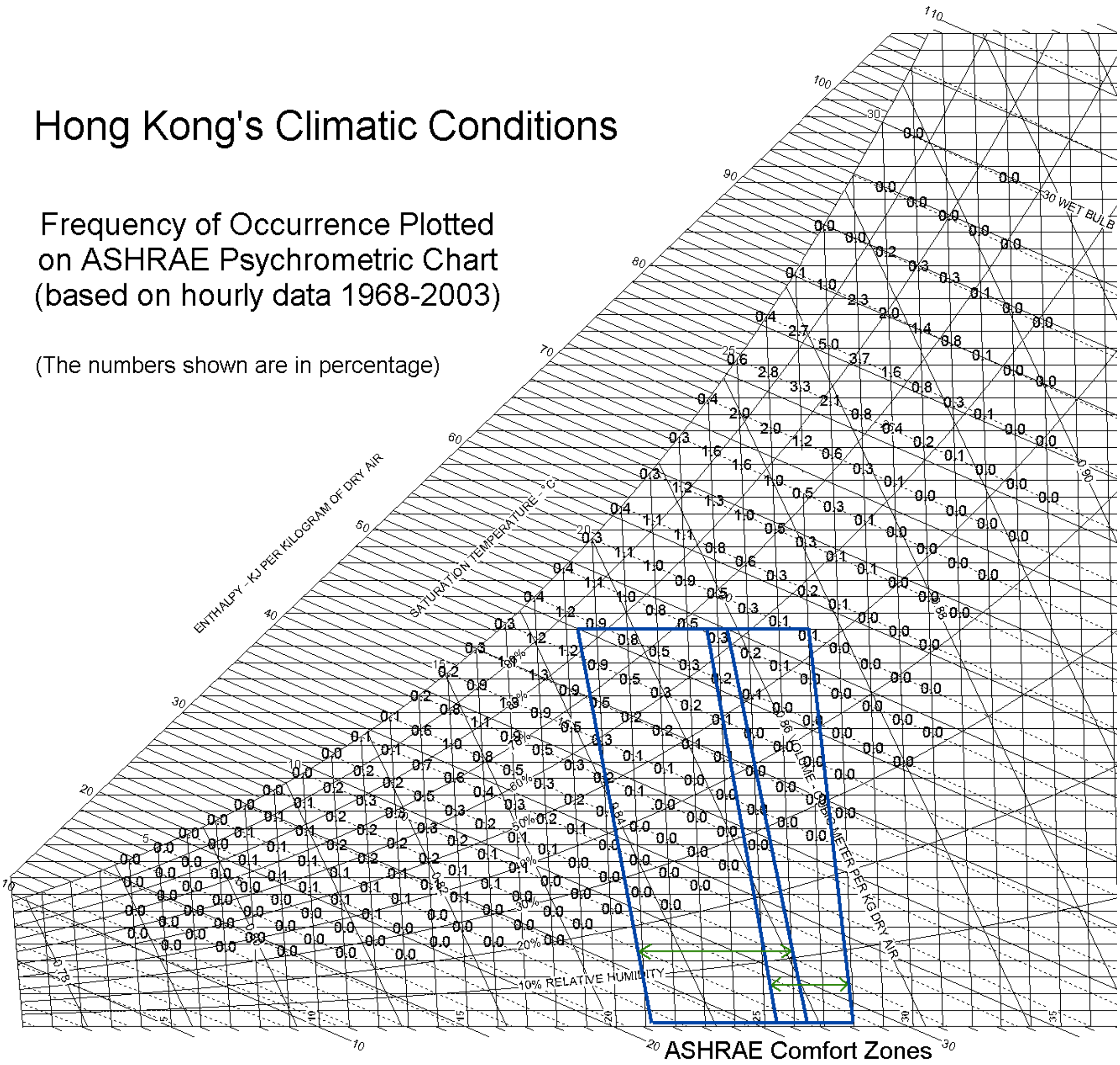

Figure 3. Hong Kong's climatic conditions plotted on ASHRAE psychrometric chart

4.2 Solar Data and Daylighting Design

Frankly speaking, the data available for studying solar climate is limited because the measurement of daily global solar radiation (GSR) only started in June 1958 and hourly GSR commenced in December 1978. Also, the Hong Kong Observatory at present cannot provide the direct and diffuse components of GSR and the outdoor sky illuminance data (Lau, 1989; Lam and Li, 1996). This will affect the accuracy of some solar design, building energy and daylighting analyses. Although other solar related data such as sunshine duration (SUN) and cloud amount (CLD) are available for 114 years, they cannot be adopted easily in building design for assessing solar conditions.

To tackle with this problem, some local researchers have worked hard to develop empirical solar radiation and daylight models so that the essential solar data necessary for building design and research can be predicted (Li and Cheung, 2005; Li, Lam and Lau, 2002). As solar heat gain and the use of daylight are two critical factors of energy efficient buildings in Hong Kong, further research and development is needed to build up a sound database and more practical information for solar and daylighting designs (Li and Lam, 2001; Li, Lam and Wong, 2005).

4.3 Wind Data and Ventilation Design

For cities with a hot and humid climate like Hong Kong, ventilation design is very important for enhancing building environmental performance and meeting comfort requirements. To design a sustainable building under such a climate often means promoting natural ventilation and mixed-mode ventilation which will reduce the operation and consumption of mechanical systems (Givoni, 1998). Keep in mind, an effective ventilation strategy depends on thorough understanding of the interacting pressures and forces, such as wind and stack effects. The design and analysis of a naturally ventilated space could become an extremely complicated numerical problem that requires solutions of "computational fluid dynamics (CFD)" or solving of sophisticated fluid flow equations. The external wind conditions form a determining factor that will affect the calculations, but yet the actual effect is difficult to imagine, not to mention compute.

Fortunately, building designers such as architects are good at manipulating these natural forces into the architecture and find out the likely design solution that gives a reasonable outcome. By integrating intuitions and calculations, they can assess ventilation design options and analyse the performance throughout the year or seasons. The information they read may include prevailing wind directions, probable and maximum wind speeds, and a "wind rose".

If the ventilation design is so critical, a scientific detailed analysis may be required at a later stage to verify the initial design proposal and fine-tune the design strategy. When this analysis is carried out, sufficient wind data will be needed (Yik, Lo and Burnett, 2003). In fact, a similar approach for wind load assessment is being used for structural and vibration engineering design (Jeary, 1997). Moreover, wind data and statistics are also important for wind power projects which help promote renewable energy (Wong and Kwan, 2002).

In Hong Kong, wind data is recorded at some locations around the territory by using automatic weather stations (Lui, 1991). If the wind data available does not fit well with the project location, then an onsite wind survey and/or measurements are recommended.

5. DISCUSSIONS AND CONCLUSIONS

Belcher, Hacker and Powell (2005) pointed out that to adapt buildings and cities for climate change, it is necessary to construct design weather data for future climates. The selection of extreme and near-extreme data based on risk assessment is suggested by Chow, et al. (2002) and a rational approach considering system reliability is proposed by Chen, Yik and Burnett (2005). In order to evaluate the risk level and allow for climate change, inherent properties and limitations of the weather data must be studied and understood.

Using the right typical weather year is also important for meeting different needs and various applications such as renewable energy systems (Yang and Lu, 2004). In some situations, multi-year weather data will be required for assessing energy performance of a specific year or over a long-term period (Hui and Cheung, 1997b). For example, multi-year building energy simulation may be used for measurement and verification (or efficiency valuation) in energy saving performance contracts.

Climatic data are very important to sustainable building design. The quality of weather data and information will determine the effectiveness of building design strategies and the accuracy of design load and energy calculations. With the growing importance of performance-based design, it is crucial to examine carefully the weather data we are currently using for building and HVAC design.

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