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Climatic Data for Building Energy Design in Hong Kong and Mainland China

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Abstract

Climatic data are very important to building energy design and their development and selection should be considered carefully. The quality of climatic data and information will determine the effectiveness of building design strategies and the accuracy of design load and energy calculations. It is essential for developing countries like China to establish accurate and detailed weather data so as to achieve energy efficiency in buildings and sustainability in energy development.

Weather data of Hong Kong and Mainland China have been investigated. Major climatic properties are examined to develop a better understanding of the climate of China which is diverse and complex. Quality of the climatic data and problems in developing them are studied. Important considerations for using climatic data in architectural design and building energy simulation are discussed to help improve building design and gain the maximum benefits from the local climatic conditions.

1. Introduction

"Weather data are one of foundation stones of our [building services] industry since it is the building and its services which protect us from its extremes and create an appropriate internal environment. Without accurate weather data, we could neither design efficient or effective services nor predict energy use" --- Forward by P. G. T. Owens [1].

This statement made some 13 years ago is still valid at present, although the data Mr. Owens referred to has grown and evolved gradually in the world. More accurate and recent weather data were developed recently in the UK [2, 3] and the USA [4] to satisfy the needs of modern architectural design and to address the concern for energy and environmental issues. At the same time, there is also a general increase in demand for building climatic data in the developing countries in Asia.

Hong Kong and other cities in the People's Republic of China had their economies, building developments and energy demands rapidly expanding during the past 20 years. The pressure for energy efficiency and the request for modern and better building design have created an urgent need for weather information. Although meteorological measurements have been carried out for many years at these cities, little work has been done to compile detailed weather data for building design and to investigate the climatic characteristics with regard to architectural and urban development. Existing climatic data for Hong Kong and Mainland China are limited and should be expanded [5].

To establish building climatic data and use them effectively in energy design, a clear understanding of local climatic properties and building design requirements is essential [6]. The climatic data of Hong Kong and Mainland China have been investigated. Major climatic properties and important considerations for building energy design and simulation are examined. It is hoped that more climatic data and practical information for

locations in Asia and other developing countries can be developed in the near future to help improve building design and achieve sustainable and energy efficient buildings throughout the world.

2. Quality of Climatic Data

For meteorological measurements, a system of quality control is usually implemented to ensure internal and temporal consistency of the data [7]. The 'quality' of climatic data to be discussed here does not mean the error checking and consistency maintenance carried out by meteorologists. It refers to the breadth and types of weather data developed and used by building researchers and designers.

The Breadth of Weather Data

The breadth of a climatic database is determined by the number of years that the weather data are available. In general, the longer the period of records and the more recent the weather data, the better the results. For normal applications, a period of 30 years is considered representative and stable, and it has been adopted by the World Meteorological Organization (WMO) as a long-term climatic index [7]. On the other hand, building designers often consider a period of 10 to 15 years the minimum period to encompass major climatic events [2].

However, the weather data maintained at different countries and locations may vary in length and quality [8]. Certain climatic elements are basic in most weather stations and have a long history of measurement, such as air temperature and atmospheric pressure. Other elements have been measured for only a few decades and have much less data, such as global solar radiation. Some other parameters, such as diffuse solar radiation, are not measured at most weather stations because they are not crucial to weather forecasting. The study of building climatic data is often limited in its content due to the data available.

Table 1 shows the availability of major weather data for building design in Hong Kong [9, 10]. Although many weather parameters have a long history of measurement (over 100 years), the database is limited by a lack of solar radiation data. Daily total horizontal global solar radiation (GSR) has been recorded in Hong Kong since June 1958 but hourly GSR measurements only started in December 1978. The direct and diffuse components of solar radiation which are important for building and solar systems design, are not measured by the weather station. To derive the solar radiation data, algorithms that relate existing data such as cloudiness and sunshine duration are needed. Another problem with the weather data is that many hourly data in early years (pre-World War II) are kept in printed version only. If they are to be included in the weather database, efforts are needed to convert them into computer files.

Table 1 Availability of major weather data for building design in Hong Kong

Weather parameter	Period of records *	No. of years
Dry-bulb temperature (^{o}C)	1884-1939, 1947-1996	106
Wet-bulb temperature (^{o}C)	1884-1939, 1947-1996	106
Dew-point temperature (^{o}C)	1884-1939, 1947-1996	106
Atmospheric pressure (Pa)	1884-1939, 1947-1996	106
Cloud amount (oktas)	1884-1939, 1947-1996	106
Sunshine duration (hour)	March 1884-1939, 1947-1996	106
Wind direction (0-360)	1884-1939, April 1947-1996	106
Wind speed (m/s)	1935-1939, April 1947-1996	55
Global solar radiation (MJ/m^2)	June 1958-1996 **	39

Notes: * No records for the years 1939-46 during World War II.

** Hourly measurement of global solar radiation only started in December 1978 (before that, only daily total values were taken).

The Types of Weather Data

The types of weather data required are closely related to the development of building design and analysis methods. In the early days, simple outdoor design temperatures and climatic conditions was the only information for building thermal design, which was carried out using manual procedures. Later, bin weather data and simplified hourly weather data were being used for simple energy calculations. At present, architects and engineers are often required to perform detailed energy analysis and computer simulation using full hourly climatic data.

It is generally believed that rise in (building energy) simulation and its increasing use by building designers is a major driving force for enhancing the climatic data [3]. However, the needs of weather data in simulation are at present not clearly understood since the use of simulation methods in building design is still developing. A brief examination of the climatic data for use in simulation will indicate a variety of different approaches and qualities of data [11].

The types of weather data used may also vary with local design practices and conditions. In China, climatic data for building thermal design are provided in design codes [12, 13] and related standard [14]. The available data are synoptic (summary-only) and include outdoor design conditions, climate descriptions and empirical solar radiation data. Summaries of the climate for over 200 cities and locations in China are provided. However, due to paucity of meteorological records, hourly data for simulation are of a poor content or completely lacking. Moreover, according to the guidelines of the State Meteorological Administration of China, meteorological data are not available to the public and restricted to official use only [15]. Data are available only with a special permit from the administration. This has imposed great difficulties to the study of climatic data.

It is impossible to describe and give all the weather data of China here, but it will be useful to develop an overview of their major properties and controlling factors.

3. Climatic Properties of Mainland China

China is a large country with a vast territory and complex topography. The main feature of the climate of China is its diversity and complexity which together lead to the existence of a great number of climate types [15]. For the purpose of building thermal design, the climate of China can be classified into five main types as shown in Table 2, and the country can be divided into several climatic regions as shown in Figure 1 [12]. The zoning is based on the monthly average temperatures of the coldest and hottest months of the year (usually January and July, respectively), and the number of days with the daily average temperature below 5 °C and 25 °C. While the latitudinal and longitudinal distances represent an important climate-controlling factor, the physio-geographical setting and landforms will also affect the climate at a particular location.

As China is located on the southeastern sector of the Eurasian continent towards the Pacific Ocean, air masses of either continental or maritime origin will affect its climate. The monsoons represent the overwhelming climate and weather regime for China which govern the climatic conditions throughout the year [16]. In general, winter monsoon from mid-Siberia and Mongolia brings cold and dry air masses to China during the winter period; summer monsoon from the subtropical anticyclone in the Northwest Pacific and the cross-equatorial flow from the southern hemisphere generates precipitation and warm weather during the summer period. The two distinguished monsoons together create large differences in seasonal climatic conditions. Table 3 gives a summary of the major climatic conditions for eleven cities in China (including Hong Kong); their geographical locations are also shown in Figure 1.

Table 2 Method of classifying climatic regions for building thermal design in China

Climatic region	Climatic zoning criteria	
	Main index	**Supplementing index**
Very cold	CMA temperature ≤ -10 °C	D5 ≥ 145 days
Cold	CMA temperature = -10 to 0 °C	D5 = 90 to 145 days
Hot summer, cold winter	CMA temperature = 0 to 10 °C HMA temperature = 25 to 30 °C	D5 = 0 to 90 days D25 = 40 to 110 days
Hot summer, warm winter	CMA temperature > 10 °C HMA temperature = 25-29 °C	D25 = 100 to 200 days
Warm	CMA temperature = 0 to 13 °C HMA temperature = 18 to 25 °C	D5 = 0 to 90 days

Notes: CMA = coldest month average; HMA = hottest month average;
D5 = number of days with daily average temperature below 5 °C;
D25 = number of days with daily average temperature below 25 °C.

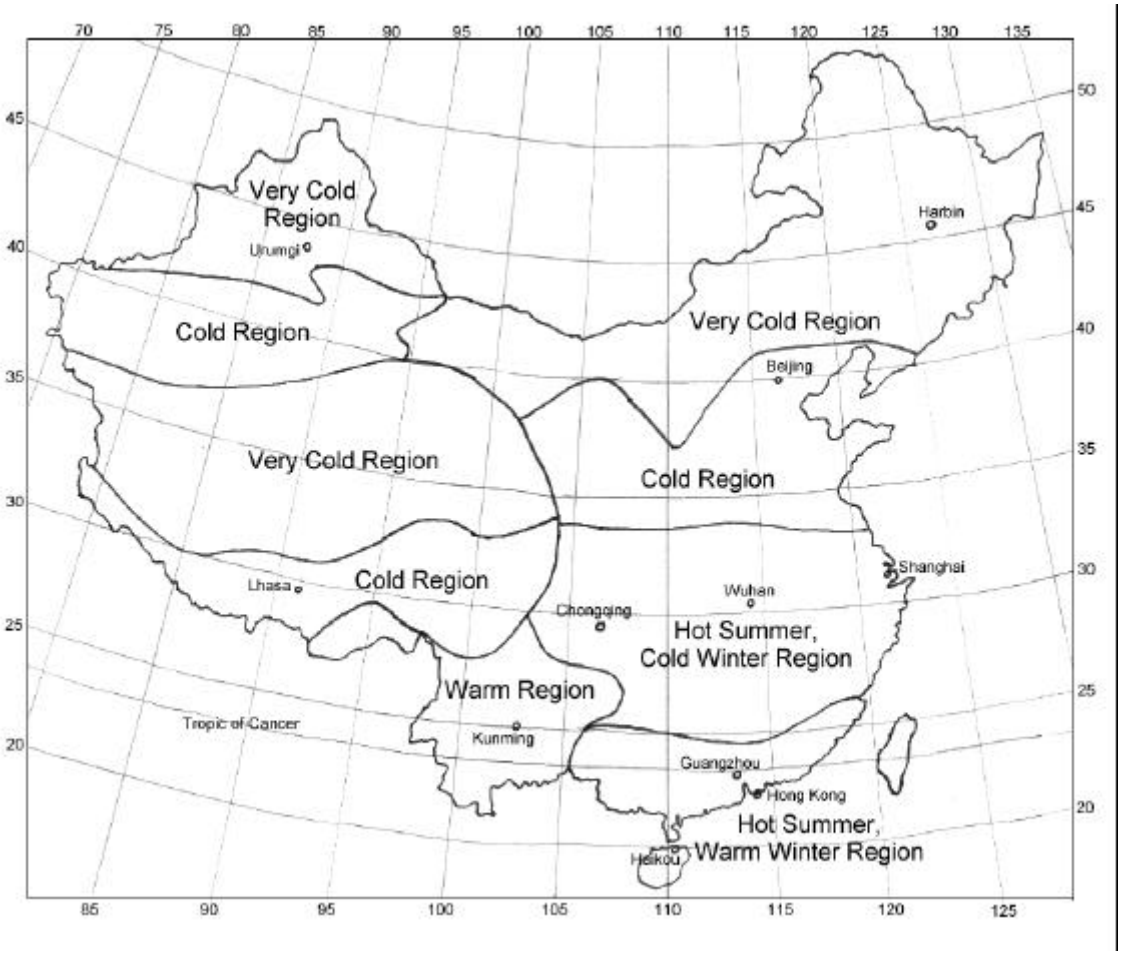

Figure 1 Climatic regions for building thermal design in China

Table 3 Summary of major climatic conditions for cities in China

Location	Lat. (north)	Long. (east)	Elev. (m)	Dry-bulb temperature (°C)				Rel. humidity (%)		Sunshine Hours	
				Annual average	Annual diff.	HMA	CMA	HMA	CMA		
Beijing	39°48'	116°28'	31.5	11.5	30.4	25.8	-4.6	78	45	2780.2	
Shanghai	31°10'	121°26'	4.5	15.7	24.3	27.8	3.5	83	75	2014.0	
Guangzhou	23°08'	113°19'	6.6	21.8	15.1	28.4	13.3	83	70	1906.0	
Chongqing	29°31'	106°29'	351.1	17.8	20.9	28.1	7.2	71	83	1140.5	
Kunming	25°01'	102°41'	1891.4	14.7	12.1	19.8	7.7	83	68	2470.3	
Wuhan	30°37'	114°28'	23.3	16.3	25.8	28.8	3.0	79	76	2058.4	
Harbin	45°41'	126°37'	171.7	3.6	42.2	22.8	-19.4	77	74	2641.0	
Urumgi	43°47'	87°37'	919.9	5.7	38.9	23.5	-15.4	44	80	2733.6	
Lhasa	29°40'	91°08'	3648.7	7.5	17.7	15.4	-2.3	54	28	3007.7	
Haikou	20°02'	110°21'	14.1	23.8	11.2	28.4	17.2	83	85	2239.8	
Hong Kong	22°18'	114°10'	33	23.0	13.0	28.8	15.8	80	71	1948.1	

Notes: 1. Period of records: years 1951-80 for the cities in Mainland China; years 1961-90 for Hong Kong.
2. CMA = coldest month average; HMA = hottest month average; annual diff. = HMA - CMA

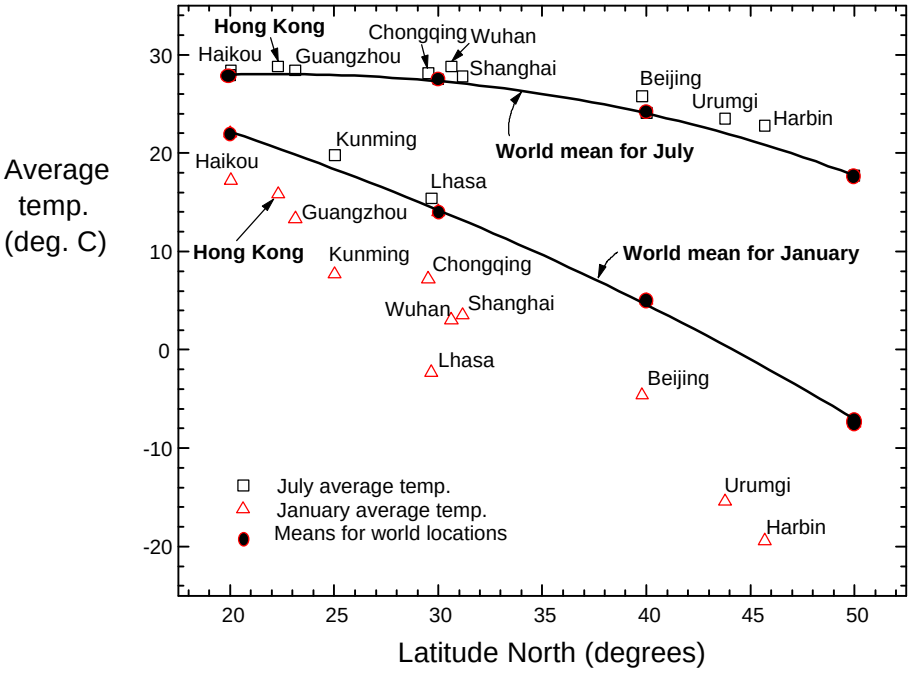

Figure 2 Comparison of average temperatures in January and July

As compared with other places in the world with similar latitudes, locations in China generally have colder winter and warmer summer [17]. Figure 2 shows that the average temperatures of the cities in China in January and July. The mean values of average temperatures for locations in the world with similar latitudes are given as two solid lines in the Figure. It can be seen that, except Kunming and Lhasa which have very high altitudes, all the Chinese cities have colder January and warmer July than the means of the world. Winter heating requirements in China is

important, particularly in the cold regions, and therefore, building thermal insulation against heat loss is the main focus for building energy design. Air-conditioning and cooling requirements in southern China are also growing in importance as the living standards of the people are rising steadily.

4. Climatic Properties of Hong Kong

Hong Kong is located at latitude 22°18' north and longitude 114°10' east (this refers to the main weather station at Tsimshatsui, Kowloon). The Hong Kong Observatory (previously Royal Observatory Hong Kong) is responsible for meteorological measurements and records in Hong Kong (see also Table 1). Information about the Observatory and the weather data in Hong Kong can be found at their Internet home page (climatological normals and some summary weather data are provided): http://www.info.gov.hk/hko/.

Study of the climatic data of Hong Kong is essential because the meteorological records at Hong Kong represent one of the longest, homogeneous data sources in all of China (Shanghai and Beijing are the two other such sources) [15]. Hong Kong has a subtropical climate which is typical in the Guangdong province of China, and the climatic data of Hong Kong can be used for regional climatology study for southern China. Figure 3 shows the monthly values of three major climatic elements of Hong Kong for the years 1961-90.

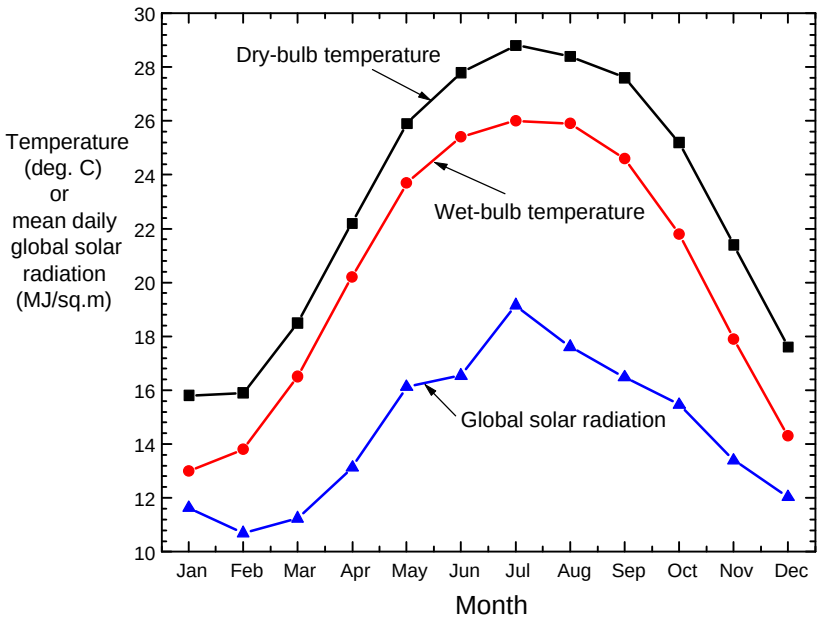

Figure 3 Monthly values of three major climatic elements of Hong Kong for the years 1961-90

The four seasons in Hong Kong look like this. In the winter months between November and February, a winter monsoon coming from the north and northwest directions brings to Hong Kong cold and dry air from the continental anticyclone in Mainland China. The spring season is short and usually characterised by cloudy skies, periods of light rain and sometimes very foggy and humid conditions. In the summer months between May and September, the monsoon blows from the south and southeast directions. The weather is mainly tropical, hot and humid with occasional showers or thunderstorms. The autumn is short as it lasts from mid-September to early November. The winds become more easterly in direction. The amount of cloud in sky and humidity decrease rapidly at this time.

To improve the climate design data of Hong Kong, Lam and Hui [5] have studied the outdoor design conditions for heating, ventilating and air-conditioning (HVAC) design based on recent meteorological data. It is found that potential exists for achieving better design and energy savings if the design weather conditions are carefully

selected and analysed. Hourly weather data files for building energy simulation were also being investigated and developed by Lam, Hui and Chan [18]. It is believed that the weather files and information can facilitate building energy simulation techniques in Hong Kong and contribute to a better understanding of building energy performance.

5. Discussions

The task of building up climatic data and information for building design should not be overlooked since it requires enormous efforts to collect, prepare and process the weather data. Incompatible data formats, different recording techniques and lack of data homogeneity are making the task more difficult. Knowledge in climatology and architectural/engineering design is needed to ensure integrity, quality and applicability of the climatic data. Rational judgement, experience and knowledge of the location and local climate are important for constructing reasonable design data from the raw meteorological records.

Unfortunately, the availability of meteorological records is often a key limiting factor to establishing of building climatic data. Although building design requires only a subset of the meteorological data (mainly surface observations, like temperature, humidity and solar radiation), it is often difficult to obtain all the weather data in complete form. The lack of solar radiation data is the most important problem at present and should be remedied by research and climatological measurements.

Applications of Climatic Data

Climate is by nature a complex theme and its description depends upon the specific reason and purpose of application [15]. In China, climatology has a very long history and the knowledge developed from ancient climate studies has provided valuable information for agricultural and social development [16]. However, the study of urban and city climate is relatively new in modern sciences, and the application of climatic data in building energy design is developing only recently. To gain the maximum benefits from local climatic conditions, it is useful to relate Chinese traditional understandings on climate to modern climatology for building design, such as in solar chart and architecture design [19].

Selection of weather data for building design requires proper judgement of the situation concerned. Different types of data will be required for different applications. Table 4 gives the common uses of climatic data in building energy design. The intended application should be carefully considered when developing and selecting the climatic data.

Table 4 Common uses of climatic data in building energy design

Design aspect	**Examples of design tasks**	**Climatic data required**
Solar design strategies	• Shading and sun control • Passive solar design • Active solar system design • Solar photovoltaics design	• Solar path and position • Temperature and solar radiation data • Sunshine duration and cloudiness
HVAC system design	• Design load calculations • Air-side system design • Plant and equipment design	• Temperature, humidity and solar data • Wind and pressure data • Extremes and averages of data
Building energy simulation	• Simulation using design days/weeks • Simulation using typical years • Simulation using multi-years	• Basic elements same as HVAC design • Design days/weeks data • Typical year and multi-year data

Interpreting the Climatic Data

Interpretation of the climatic data is as important as their quality. Building designers are interested in studying seasonal and diurnal variations of the climate in order to develop effective strategies for energy efficient buildings [20]. To ensure meaningful results, the rationale behind the weather data should be considered in context. Inherent properties and limitations of the data should be understood, whereas building design requirements (both present and future) should be kept in mind.

When choosing weather data for simulation, the purpose and end-use of the building energy simulation must be considered [11, 18]. A typical year of 8,760 hourly data is most commonly used nowadays and its effectiveness will depend on the selection method of the typical year and the characteristics of the simulation system. Multi-year data may also be used to carry out detailed analysis over the long-term [21].

6. Conclusions

Climatic data and information are very important to building energy design and simulation. The quality and characteristics of the data must be considered carefully in order to obtain accurate and reliable results. Architects and building engineers should develop better understandings of the climate through study and analysis of the weather data and building energy performance.

To achieve energy efficiency in buildings and sustainability in energy development, it is essential for developing countries like China to establish accurate and detailed climatic data. It is hoped that the information provided here will contribute to a better understanding of the climatic characteristics of China.

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