

CHAPTER 1

INTRODUCTION

1.1 Background

Different from that of solar irradiance, measurements of daylight illuminance do not figure into the routine observational programs of most meteorological stations in the globe. However, the data for illuminance are essentially required for the precise solution of many practical problems, such as incorporating natural daylight into building design through fenestrations and/or roof apertures. Such problems have been considered more substantially in recent years due to the rising interest in energy conservation and in passive daylighting design for buildings.

Under the patronage of the Commission Internationale de l' Eclairage (CIE) and the World Meteorological Organization (WMO), the International Daylight Measurement Program (IDMP) was officially launched in 1991 to alleviate the state of being and to help promote daylighting. Over the last 20 years, a daylight measurement network has evolved, with more than 40 daylight measurement stations in North America, Europe and Japan taking part in this program. Only a few stations located in tropical areas participate in this program, namely in Singapore, Indonesia and India [6]. According to the IDMP, the stations can be categorized into three levels: basic class, general class and research class, depending on types of sensors installed and available recorded data. A procedure for data quality control was established for data verification [5]. Even with the pronounced progress of IDMP, daylight data are still scarce, especially for tropical regions.

An alternative method to increase illuminance data is through the use of luminous efficacy. The efficacy might be thought of simply as a multiplicative factor of the solar irradiance. The corresponding amount of the daylight illuminance for a given amount of irradiance can be calculated as

$$E_v = K \times E_e, \quad \text{Equation 1.1}$$

where E_v is the daylight illuminance, E_e is the solar irradiance and K is the luminous efficacy of solar radiation.

Luminous efficacy is not a constant because it varies with climate conditions. In the past several decades, much research has been conducted in many locations primarily across Europe and North America in the attempt to develop accurate efficacy models to predict luminous efficacy [7-16]. Intensively, some of those models have been evaluated for their prediction performance against the data from different stations around the globe [21]. These activities offer insight towards understanding the characteristics of the daylight efficacy. It is possible to find as well some research produced for subtropical and tropical regions such as HongKong and India [24-26].

Nowadays, most of the efficacy models have been established for high latitude regions in Northern America and Europe, such as England, France and Spain. Research on daylight efficacy seems to be very scarce in hot and humid tropical climate.

1.2 Rationale

The availability of the exterior daylight illuminance is the data required by various engineering software for analyzing and simulating a daylighting system [3-4]. Daylight reaching a point in building interior comprises illuminance from the patches of sky visible from the given point and that reflected from the daylit surfaces, such as walls opposite to windows. With strong daylight in the tropics, the contribution of the part of reflected daylight from surfaces is considerable [2]. The prediction of daylight in buildings requires information regarding the incident light on opposite buildings and other reflecting surfaces. The simulation software generally employs the efficacy models to generate the exterior daylight illuminance from the irradiance data included in the local weather data files.

It is common knowledge that daylight in tropical region is abundant and daytime is long throughout the year. An understanding of availability and variation of solar irradiance and daylight illuminance can help determine building configurations in such a way that external heat gain from solar irradiance is minimized while the use of daylight is enhanced.

In Thailand, energy auditing reports have reported that for commercial buildings, about 60% of cooling load is contributed from external heat gain from solar irradiance while half of the rest is obtained from heat dissipated from electric lighting. Typical electric consumption and power demand of a commercial building are thus $220 \text{ kWh.m}^{-2}.\text{Y}^{-1}$ and 110 W.m^{-2} , respectively [1].

Daylighting technology is perceived to conserve energy and to be applicable to commercial buildings in Southeast Asia. With a proper design, daylighting reduces electrical load from both air-conditioning systems and lighting systems. Previous research studies showed that daylight-integrated electric lighting in commercial buildings could reduce more than 50% of energy and power use from those due to lighting [2].

In Thailand, the Department of Alternative Energy Development and Energy Efficiency (DEDE), Ministry of Energy, 53 erected stations in all regions in order to establish a station network [3]. All stations provide basic information on temperature, humidity and other standard meteorological data. Unfortunately, no one takes records of daylight data. During past decade, there are only few stations established to measure daylight, those of which a purpose to conduct research on daylighting [3]. Availability of daylight illuminance database seems to be critical in Thailand.

1.3 Objectives of the Study

The main objective of the study is to investigate the daylight efficacy, the correlations between daylight illuminance and its corresponding solar irradiance in tropical climates.

Specific objectives of the study are:

- characterization of the luminous efficacy of the three basic irradiance components of global, diffuse horizontal and beam normal,
- evaluation of performance of the existing efficacy models in predicting the tropical luminous efficacy and,
- development of efficacy models for global and diffuse horizontal components for tropical climates.

1.4 Scopes of the Research Work

The research undertaken in this study employs the observed illuminance and irradiance data from two meteorological stations. The first set of the data was gathered from a station located at Asian Institute of Technology (AIT) 40 km. north apart from Bangkok. The data was compiled from 1999 to 2004. The second set of the data was gathered from a new station erected at the roof deck of a seven-story building of the school of Bioresources and Technology, King Mongkut's University of Technology, Thonburi. This data set is a three-month data set covering January-March 2011. Although the data was gathered just from the two stations in Bangkok, Thailand, it is assumed that the data can be representative of tropical daylight climate.

Although there are a number of atmospheric factors influencing the variations of the luminous efficacy, only three insolation parameters i.e sky clearness, sky brightness and solar zenith angle were examined.

This study does not cover the development of the efficacy model for beam irradiance.

1.5 Organization of the Thesis Report

This thesis report is organized into five chapters. Chapter 1 introduces the background, rationale and objective of the study. Chapter 2 presents a review of relevant research literatures of luminous efficacy conducted by various researchers. A number of efficacy models are also summarized in this chapter. Chapter 3 describes the method of this study. Chapter 4 presents the research results conducted for tropical luminous efficacy, covering the characterization of variation of tropical luminous efficacy, the performance evaluation of the existing efficacy models against the tropical daylight data, and the development of the efficacy model specific for the tropics. Conclusions and recommendations are drawn in Chapter 5.