CHEPTER 1
INTRODUCTION

1.1 Background

Since the 1980s, studies in Thailand have revealed that air-conditioning for cooling and electric lighting accounted for 60% and 20% respectively of the total electrical energy consumption of a commercial building. Moreover, the electrical energy from lighting is eventually converted to thermal energy and contributes 20% to the cooling load. (Chirarattananon, 1988)

The use of artificial light from electric lamps could be reduced by natural daylight. An atrium building is a building that is designed for using natural daylight. An atrium can be defined as a large volume space created by a floor opening or series of floor openings which connect two or more stories that is covered by transparent glasses at the top of the openings. Providing natural daylight is also used for other parts such as an enclosed stairway, mechanical and utility services of the building. Therefore, it has become popular building design, especially office and commercial building. Many advantages of atrium building result from introducing daylight into interior building. It can help to reduce cost of electrical consumption used by natural light during daytime. Besides, it provides work environments having more space with a connection between inside and outside environments.

To take advantage of daylight, the most important thing is to integrate and control sufficient daylight for the sustainable performance of the working environment in buildings. Thus, studying daylight performance of an atrium is very necessary for taking it into practice, especially in tropical climate that has an intensive natural light source.

The main problem of an atrium is thermal heat gain, especially in a tropical region having strong sunlight which causes high temperatures inside a building. Another problem is glare which has an adverse impact on human eyes. The problem is to be solved by reducing heat load and allowing the maximum daylight to reach the ground floor with the lowest glare as possible. Therefore, designers must have good understanding about atrium components such as the fundamentals of geometry, lighting, envelope construction, landscaping, thermal control, pressurization and air balance etc. This study evaluates the daylight in a tropical area in order to solve any problems that may occur.

1.2 Literature Review

There is much on developing atrium designs for different climates and regions. The previous research usually suggest about variations of atrium that is very essential to be concerned such as orientation to the sun, geometry of the atrium, structural roof system, surface reflectance of material and etc. The performance of daylighting in atrium was expressed in terms of daylight factor (DF) described the daylight level and its distribution in the atrium. Moreover, recent papers introduced simulation software to predict interior daylight illuminance for many sky types such as overcast and clear skies.

The daylight performance in atrium buildings has been expressed in terms of daylight factor (DF). It is illustrated mathematically as a ratio of the interior daylight level (E_i) to its corresponding exterior global daylight illuminance (E_{vg}).

Based on scale-model measurements, Kim and Boyer (1986) have also proposed a relationship between the shape of the atrium and daylight factor (DF) at the center of an open atrium. The result illustrated that the vertical daylight levels on the well wall and the room properties (size and surface reflectances) contributed an important effect on the daylight level in the adjoining space. Szerman (1992) derived nomograph from diffuse sky measurement. It was developed to predict mean daylight factor in office room connected with linear atria. A study of Aizlewood (1995) demonstrated that the well geometries and surface reflectances are very important parameters which have a direct effect on the vertical daylight levels at the atrium wall. Preliminary data indicated that the daylight factor (DF) for every reference point inside the atrium occurred because of the change in time and month. The geometry of the atrium was plotted showing the DF for each reference point. The DF was calculated by measuring the total horizontal illumination and the indoor illumination (Turki and Schiler,1997).

For atrium design process, there are effective daylighting parameters which that could optimized. For building orientation and form, Giovannopoulou, Schiler (2005) focused on the effect of atrium orientation on daylight performance in Los angeles, USA. In the south facing atria, results suggested a larger difference on the daylight levels than on the north facing atria because of the sun position in that area.

Atrium space with horizontal skylights is one of the promising forms of interior structure for the use of daylight in buildings. Geometry of the light well was illustrated in terms of well index (WI). It relates vertical surface to horizontal surface areas of the light well. The smaller is the value of WI, then the shallower is the atrium building. High WI value thus refers to a tall atrium building. A relationship between the daylight distribution and atrium's geometric shape index was finally developed. Aizlewood (1995) stated that vertical daylight illuminance is the most influent on daylight level in adjacent space. The well geometries and surface reflectances are very significant character of atrium. According to Liu et al. (1991), Baker et al. (1993), Kim and Boyer (1986), Calcagni and Paroncini (2004), the geometrical aspect has an strictly effect on the daylight performances of an atrium. The atrium's shape can be described and quantified with a number of Well Index. It can represent the relationship between the light-admitting area and the surfaces of the atrium. This parameter compare between several atrium shapes connected with a specific height of the building.

Furthermore, the reflectance of interior surfaces has highly influenced daylight values on the atrium space, especially for the base floor or the lowest floor. Calcagni and Paroncini (2004) studied the daylight factor at one point in the adjoining room of a ground floor in atria with various wall reflectances and Well Index (WI) values. In few papers suggested that increasing wall reflectance was not significant increase the daylight level on the ground floor. It is because of the fully glazed wall surface on the ground floor. Moreover, Iyer-Raniga (1994) increased floor reflectance at the edges of the well which could help to prove daylight levels in adjacent rooms. In case of deep atria, the surface reflectance of well is very important for the lower floor rather than the higher floor. Most previous studies have tended to focus only on one specific atrium plan form (square or rectangular or linear) and their geometries were altered by adjusting the atrium well height i.e. the SAR (well height/well depth). Mwaniki Wa-Gichia (1998) mentioned that reflected sunlight in the tropics could be the main source of interior daylight. Traditionally, urban development recognized the utility of building-reflected sunlight.

Almost all of the works mentioned above have described experiments to measure daylight illuminance and distribution using a scale model and artificial sky simulator. Another group of the works made use of computer simulation to predict daylight distribution in atrium building. Hopkirk (1999) suggested this method could give a more rapid evaluation of the design choices saving time and budget provided that the software is supported by validation studies. Radiance (Ward and Larson, 1996), a light simulation software, has been widespread use in the research. The software could give calculation results that agree well with the measurements from experiments, thus confirming its scientific validity Mardaljevic (1995), Aizlewood et al. (1997), Fontoynont et al. (1999) Radiance has become the most popular package for daylight modeling in the built environment.

When comparing the results between physical models and computer simulations, Giovannopoulou, Schiler (2005) stated that the physical model provided more accurate data than did computer simulation because the model was not concerned with specific conditions, such as materials, mass, etc. Several works are based on scale model-measurements in an artificial sky Calcagni and Paroncini, (2004) tested scale model under an artificial sky simulator in Lausanne (EPFL-Ecole Politechnique Federale de Lausanne) which provided the reproduction of CIE standard luminance distribution. They suggested that it could reproduce measurements without interference from meteorological conditions and compare several daylighting strategies that are exposed to the same conditions.

The advantages of the use of computer simulation are to save enormous amounts of time using predictions of daylight performance and changing site conditions to providing the freedom to perform tests regardless of external conditions that allow the recreation of any desirable sky conditions (Giovannopoulou and Schiler, 2005). Moreover, it could help save money and provide software for validation studies (Hopkik, 1999).

RADIANCE, a collection of programs for the graphical simulation and analysis of lighting, is in widespread use with several previous studies that have shown good agreement with the measure data (Aizlewwod et al., 1997). RADIANCE was developed by the Lawrence

Berkeley Laboratory (Berkeley, USA). It uses the technique of backward ray-tracing to calculate illumination levels in interior spaces. RADIANCE is equipped with some unique daylighting simulation capabilities using the CIE standard sky. It can also create specific sky conditions using Gensky function. RADIANCE has been used to predict internal illuminance with a high degree of accuracy for a range of sky conditions. Kim and Chung (2011). Computer simulations have been conducted using the ADELINE 1.0 software Hopkirk (1994). In the experiment of the high-rise opposing façade in clear sky conditions Mwaniki Wa- Gichia (1998) used ADELINE 1.0 in case of urban street with ten storey buildings on either side. The opposing façade is 300 m long, while the façade with the interior spaces is 100 m long. Moreover, a CIE standard clear sky is generated using the RADIANCE ray tracing program in ADELINE. Modelling of the buildings and street is done by SCRIBE MODELLOR within ADELINE, while illuminance calculations are done by RADIANCE.

Daysim, a new computational tool for dynamically calculating annual illuminance profiles, has adopted the Radiance algorithms and has added two other functions, the daylight coefficient and the Perez sky model (Reinhart, 2001). Laouadi and Reinhart (2008) used RADIANCE to compute daylight coefficient sets for rooms employing multiple dissimilar components. For atrium daylighting, RADIANCE was regarded as an efficient approach and several investigations have been performed. Besides, there is a real atrium case Galasiu and Atif (2002) which compared predicted values with on-site measured illuminance distributions. It was found that by exactly reproducing a space with complicated fenestration, a more accurate correlation between measured and RADIANCE simulated illuminance distributions could be obtained under various sky conditions. Aizlewwod et al. (1997) focused on atrium's space. Its model is opened atria with a simple square plan. RADIANCE simulations achieved good agreements with measurements in most cases, but slightly underestimated light levels for deeper atria and high reflectance surfaces.

Moreover, Saradphun (2011) introduced the computer simulation program, BESim, created by Hien and Chirarattananon (2005) to calculate the daylight in adjoining spaces in atriums utilizing measurement data taken at the station. The program can be used for daylight as well as thermal calculation. The program requires defining the coordinates of each flat interior section in a zone. The program utilizes the method of calculation of view factors between all surfaces in each enclosed zone created by a user. For daylight, it calculates sunlight illuminance through atrium using forward ray-tracing. For diffuse daylight from the sky, it uses flux transfer, or the radiosity method, to calculate the inter-reflecting light. It uses configuration factors to calculate illuminance at a given point on a work plane. In the present version, BESim uses the ASRC-CIE sky luminance and sky irradiance models that utilize CIE clear and turbid clear sky models, partly cloudy and cloudy sky models. Comparison between the calculated values and that of measurements was made in order to validate the program.

Almost all of the above research investigated daylight distribution in an atrium limited in high latitude regions for overcast sky conditions as the worst case scenario. Actually, real sky condition has a high variance of the daylight in the area. Saradphun (2011) studied about daylight in an adjoining space of an atrium building in a tropical climate, Thailand. On the top and the upper floors of the atrium, the interior light is influenced largely from the diffuse skylight and the direct sunlight. The average daylight illuminance on the southern, eastern and western areas of the adjoining space can be high up to 6,000-8,000 lx at the well edge but that at 10m. apart is about 500 lx. The monthly average daylight for the northern area of the space close to the well is quite high upto 25,000 lx due to the direct sunlight. For Thailand, the sun transverses toward south for eight months a year. The internal shade seems to be required to shade direct sunlight from the space and to improve the light distribution. The shade would help deliver more light into the lower floors as well.

Glare is one of the problems in atriums, especially in tropical climates. Almost all of the daylight in an atrium comes from sunlight causing excessive light on the top of the building. Littlefair (2002) suggested that solar shading such as blinds and baffles can help to reduce glare.

In addition, there have been a few papers that investigated the effect of a balcony wall on daylight performance in an atrium in terms of the daylight factor (DF). Du and Sharples (2011) studied about the daylight distribution in the atrium with balcony wall under the overcast condition. The result suggested that high balcony walls can block direct sky light and reflected light from entering rooms on different floors in atria. The average daylight factors in the rooms could be improved by increasing the reflectance of the wall surfaces.

Many recent papers have recommended that the atrium model should be studied regarding several roof systems and under real sky conditions in order to investigate the average daylight levels in rooms. Moreover, previous research is obviously limited to high latitude regions. Increase the quantity of light in the lower floors without glare in the top of the building.

1.3 Objective of the Study

The main objective of this study is to investigate the daylighting potential in adjoining spaces of the atrium buildings in tropical regions.
The specific objectives of the study are as follows:

- To conduct a physical experiment to measure the interior daylight in the atrium space
- To quantify the amount of daylight transmitted through the atrium and its distribution in the adjoining space of the atrium using simulation software based on the ray-tracing method.
- To investigate the relationship between the daylight illuminances in the adjoining spaces in atriums and the light well geometries and adjoining space configurations.

1.4 Scope of the Study

- This study compares the measurement of a scale model experiment with the results of a computer simulation. The model measured only interior daylight illuminance transmitted from the aperture.
- Simulation software based on the ray-tracing method was used to predict interior daylight illuminance at the points similar to the measurement points within the physical model. The software can calculate the distribution of daylight in the atrium building throughout the year. The study included assessment of the quality of the interior daylight.
- Data about solar irradiance and daylight illuminance were measured and recorded from the meteorological station at Bangkhunthien Campus, King Mongkut's

University of Technology Thonburi (KMUTT), Bangkok, Thailand. The data was assumed to be representative of a tropical daylight climate.

1.5 Organization of the Study

This thesis is organized in five chapters. Chapter 1 gives an overview of the atrium building and its daylight benefit. Brief descriptions of the results of the selected literature are provided. The objectives, scopes and limitations of the study are also given. Chapter 2 mentions methods of daylight prediction in atrium buildings and guidelines to using a physical scale model. The theories also include the fundamentals of solar radiation and daylight availability are important for analyzing the results from the experiments and the results from the simulation. Chapter 3 describes the method used in this study. A detailed description of experiments, scale model and facilities is given. In Chapter 4, the results from the experiment and the simulation study are presented. Conclusions and recommendations are given in Chapter 5.