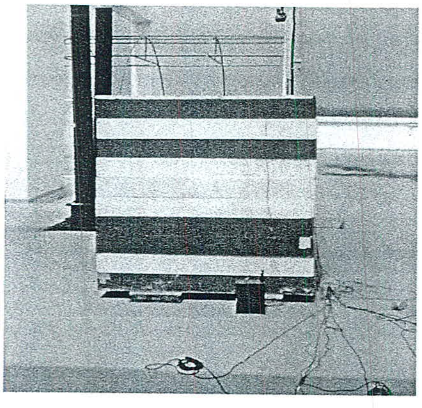
# CHAPTER 3
# METHOD

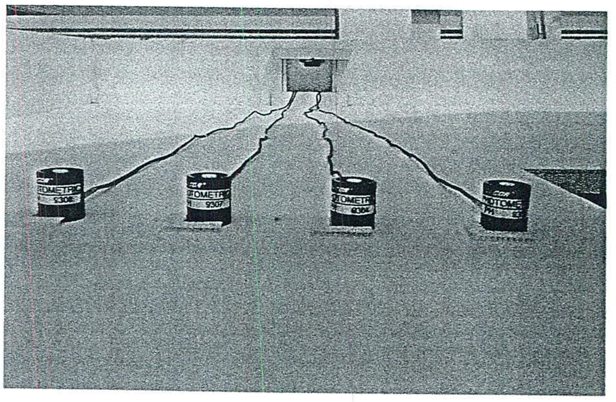
*This chapter narrates experimental methods of daylighting in atrium building in a tropical climate. The experiments were performed under real sky conditions by using a physical model to investigate daylight illuminance and distribution in an atrium space. A simulation software was used to predict the daylight levels in the adjoining space and compared with the measurements. Characteristics of tropical daylight in atrium and its energy saving potential from lighting system were analyzed by the validated simulation software.*

## 3.1 An Atrium Scale Model

A 1:25 scale model of a ten-storey square-shape atrium building was constructed for this study. The size of the scale was not too small to install light sensors inside the model as the work plane was level (2.7 cm. above the floor equivalent to 0.7 m.) and it was strong enough to erect on outdoor area on the roof deck of a seven-storey building KMUTT has high wind speed. Thus, the scale 1: 25 was a proper size to conduct the experiment. The model made from plywood and has dimensions of width 1.6 m., length 1.6 m. and height 1.4 m. The floor-to-floor height of the model is about 0.14 m. and floor-to-ceiling height is about 0.12 m. The model is equivalent to an atrium building with 40 m. width, 40 m. length and 35 m. height. The interior surfaces of the model were painted white with a visible reflectance value of about 0.85 (measurement value).

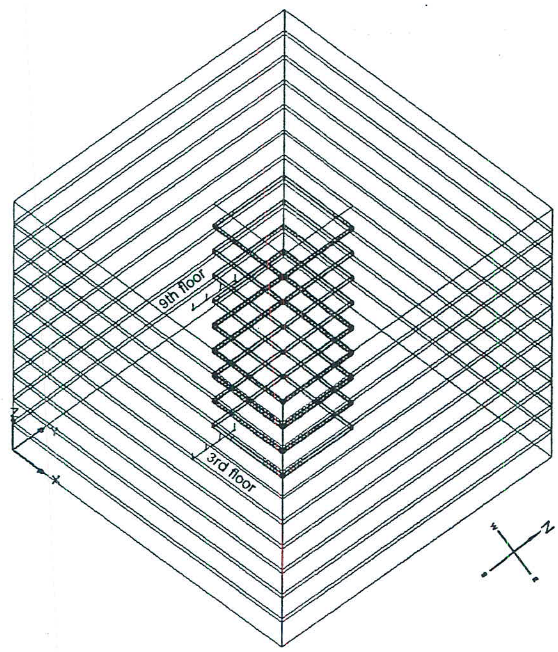


(a) Photograph of exterior view of the scale model



(b) Photograph of position of sensors for light Measurement

**Figure 3.1** A scale model of an atrium building




(c) 3D of scale model with light sensor positions

**Figure 3.1** (Continued)

A light well was located at the center of the atrium model. The dimensions of the well are 0.4 m. wide, 0.4 m. long, and 1.40 m. high, running from the top of the model to its base floor.

$$\text{Well Index (WI)} = \frac{\text{height(width+length)}}{2\times\text{width}\times\text{length}} \quad (3.1)$$

The well index (WI) is 3.5. The model has no balcony wall around the well (assuming fully clear glazed surfaces) and no obstruction/partition in the adjoining space. The aperture on the model roof top has no glazed or structural roof systems in order to exclusively study the effects of specific parameters (geometry and reflectance) on daylight levels without interference from different roofs, which distorted the light distributions in the atria. In the experiment, the model was erected on the roof deck of a seven-story building of the school of Bioresources and Technology in order to measure daylight in the atrium under real sky.

### 3.2 Light Sensors

Eight light sensors were used to measure daylight in the atrium model. As shown in Fig. 3.1(b), four light sensors were placed along the centre line of the floor space facing south.

The first sensor was located 8 cm. from the edge of the light well, which is equivalent to 2 m. in the actual building. The second sensor was located 8 cm. apart from the first one and so on for the third and the forth sensors. The position of the forth sensor is near the rear wall. The light measurements were carried out at work plane level 0.7 m. above floor. As the scale is 1:25, the light measurement is 2.7 cm high which is about 0.7 m. above the floor.

Two model light sensors were used in the experiment (limitations of equipment). Four sensors from EKO Instrument Co., Ltd. were used to measure the illuminance on the ninth floor. The remaining sensors from Li-cor were used for the third floor. Table 3.1 summarizes the sensor's properties.

**Table 3.1** Properties of the light sensors used in the study

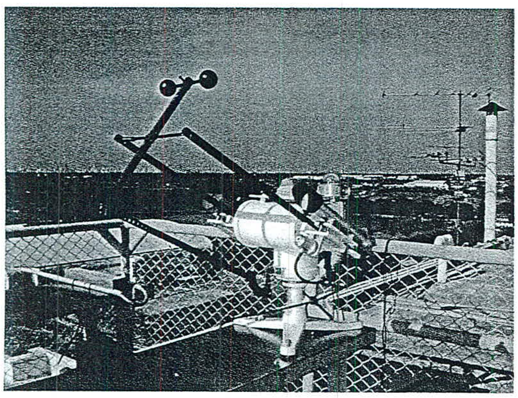
| Lux Meter | Sensor Specification |
|---|---|
| Model: ML-010S<br>Supplier: Eko | Measuring range: 0 to 200,000 lx<br>Cosine response at 30/60/80: 2/7/25 %<br>Temperature dependence: 1 % (at 50°C band) |
| Model: Li-210A<br>Supplier: Licor | Measuring range: 0 to 100,000 lx<br>Cosine corrected upto 80 degree of incidence<br>Temperature dependence: 0.15 % (at -20°C to 50°C) |

A data logger from National Instrument (NI) was used to record the daylight illuminance measured by the light sensors. The record was made for one-minute intervals starting from morning to late afternoon of the day.

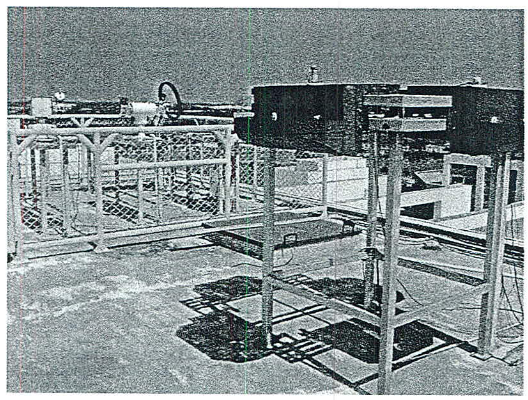
### 3.3 Daylight Measurement Station

As the experiments were performed under a real tropical sky, the daylight data describing sky conditions were gathered from a meteorological station erected on the roof deck of a seven-storey building of the School of Bio-resources and Technology, King Mongkut's University of Technology, Thonburi, Bang Khun Tien Campus. No tall building or structure offered obstruction. The site was at latitude 14.08°N and longitude 100.62°E. The station location was close to the experimental site.

The station could be classified as a research station in accordance with the International Daylight Measurement Program (IDMP) of the Commission Internationale de l'Eclairage (CIE) [Ref]. The solar irradiance measuring equipment were supplied by Eppley Laboratory and Kipp & Zonan, while the illuminance, luminance and vertical irradiance measuring equipment (including a sky scanning unit) were supplied by Eko Corporation, Japan. Beam normal illuminance and irradiance are measured directly by two sun trackers. Total vertical illuminance and irradiance in four cardinal directions are measured by a pair of an illuminance sensor and a pyranometer in each direction. Shading plates are used to block ground-reflected radiation. The sets of data recorded from the station shown in Appendix F. Figure 3.2 shows photographs of the station.



(a) Beam illuminance measurement



(b) Global and vertical illuminance measurement

**Figure 3.2** Photograph of the meteorological station

Daylight illuminance and solar irradiance were measured throughout the year. All data, except the sky luminance, were recorded at one-minute intervals while sky luminance data (145 points per each scanning time of 4.5 minutes) was recorded on 15-minute intervals. Signals from all illuminance and irradiance sensors together with signals from a zenith luminance sensor are logged onto a single data logger. The clock of the data logger is reset and its data copied every week. Data from the sky scanner are transmitted directly to a computer. The computer functions both as a controller and a data logger. Its time is synchronized with that of the illuminance and irradiance logger every week.

All data were verified in accordance with the IDMP (International Daylight Measurement Program) (Tregenza, 1993) quality assurance procedure and archived as 5-minute data. The station has been in continuous operation since its inception. About 20% of the data were lost due to hardware failures and short-term electricity outages. The loss also includes rejection of invalidated data as a result of the quality assurance procedure.

### 3.4 Simulation Software

A computer program based on the ray-tracing method was used in the calculation of daylight in an adjoining space in the atrium. The program requires input of physical model as 3-D model, site location and properties of material, etc. For daylight calculation, the two techniques used by simulation software are raytracing and radiosity. The raytracing technique tracks the path of a light ray as it bounces off or is refracted through the surface which is best suited for surfaces having specular reflections and refractions. For diffuse daylight from the sky, it uses the radiosity method. The original surfaces are divided into a mesh of smaller surfaces. In the radiosity process, the amount of light distributed from each mesh element to every other mesh element is calculated. The final radiosity values are stored for each element of the mesh. These values are retained even when the viewpoint is changed, making it possible to render numerous views with the same initial radiosity calculation. The radiosity technique is best suited for diffused reflections and shadows (Bryan and Autif, 2002)

Figure 3.3 shows the step-by-step flowchart calculation used to analyze the results of total interior daylight illuminance based on the ASRC-CIE sky luminance and sky irradiance models. According to Chirattananon (2003), ASRC-CIE model performs relatively well under the three sky conditions for tropical region having the highest frequency of occurrence is partly cloudy. ASRC-CIE model (Parez, 1990) utilize four CIE sky models, clear and turbid clear sky models, intermediate and overcast sky models. Perez's clearness index ($\varepsilon$) and brightness index ($\Delta$) are employed to identify sky condition and to weight contribution from each of the four CIE sky models.

The simulation software was used to predict the daylight illuminances in the space adjoining atrium. Comparisons between the calculated values and that of the measurements were made in order to validate the program.

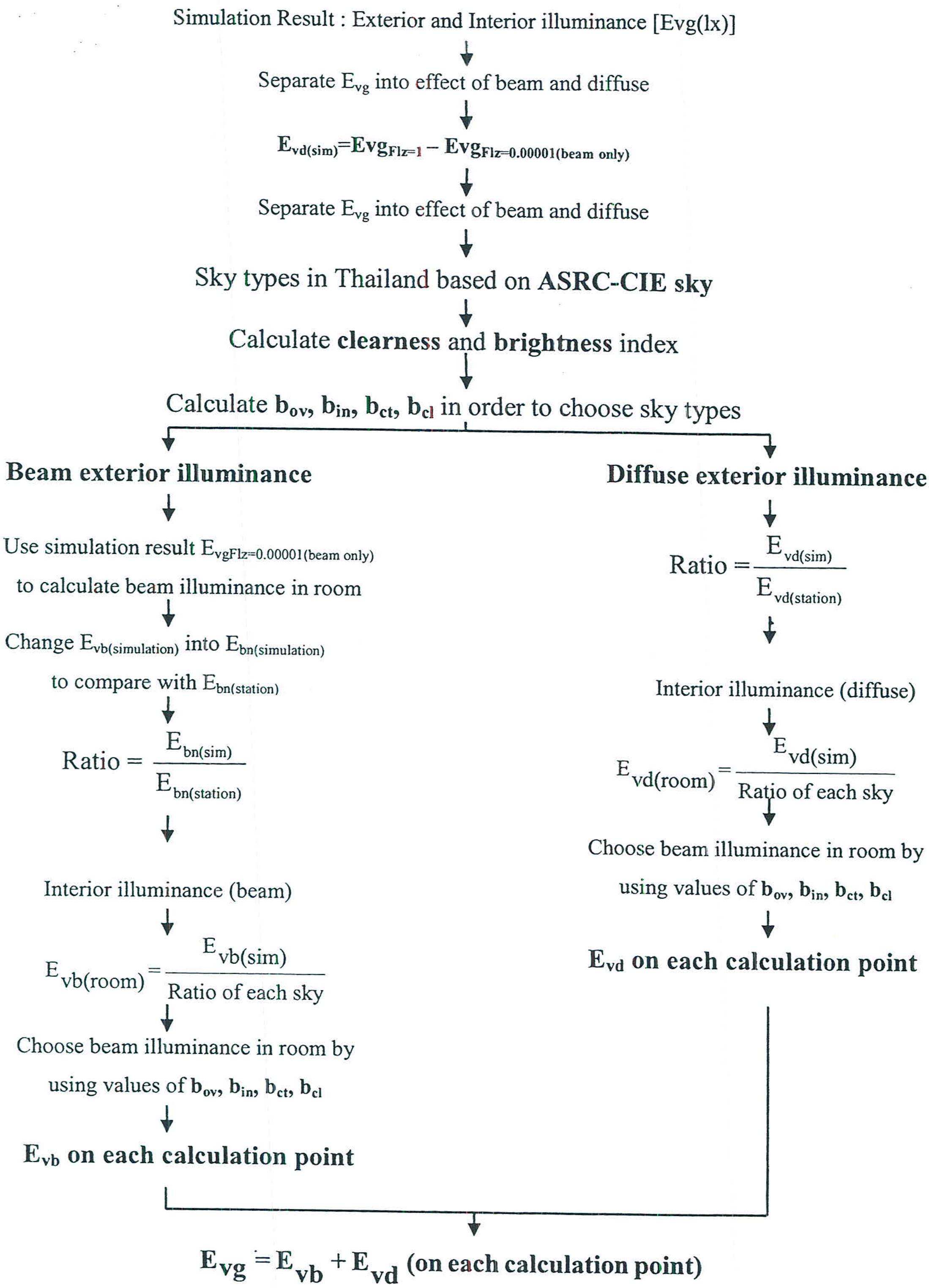



**Figure 3.3** Step-by-step flowchart calculation