ABSTRACT

Analyzing Spatial Daylighting Illuminance Distributions in 3-Sided Atria

Kim, Min-Sung
Directed by Prof. Song, Kyoo Dong
Department of Architectural Engineering
Graduate School, Hanyang University

In atrium spaces, the direction of incoming natural light is a major factor for photomorphogenesis of interior trees and plants. Especially, 3-sided atrium spaces have distinct directional characteristic of incoming natural light due to the large area of the vertical glass wall. The direction of incoming natural light is mainly determined by the sun's location, the orientation of the vertical glass wall, and the geometry of atrium space itself which can be characterized by well index(WI).

In this study, a computer program which can estimate the spatial vector illuminances in atrium spaces was developed based on the Monte Carlo method and ray-tracing technique. The accuracy of the computer program was examined by the measurements with physical scale models.

Then, a series of parametric computer simulations was performed to determine the spatial vector illuminances and scalar illuminnaces in 3-sided atrium spaces with different geometric and photometric properties. The major variables involved in the computer simulation were sun's altitude angle, atrium orientation, well index(WI), and the transparency of the atrium roof.

This thesis consists of a total of six chapters, and each chapter can be summarized as follows:

In Chapter 1, the background and purpose of the study, the scope and methodology of the study were described.

In Chapter 2, theories related to spatial vector illuminances in atrium spaces were reviewed. In addition, the growth of interior trees and plants were reviewed in terms of the direction of incoming natural light. Then, the basic theories such as Monte Carlo method, ray-tracing technique, and Perez sky model were also reviewed.

In Chapter 3, the concept of the computer program and the modeling techniques for direct beam sunlight and diffuse sky light were described.

In Chapter 4, the methodology and the results of the scale model measurements to validate the accuracy of the computer program were described

In Chapter 5, a series of computer simulations were performed on 3-sided atrium spaces with different geometric and photometric properties to determine the spatial vector illuminances and scalar illuminances for different sun's altitude angles.

In Chapter 6, the conclusion of the study were stated.

The results of the study can be summarized as follows:

1. The computer program based on Monte Carlo method and ray-tracing technique was able to determine the spatial illuminances that cannot be determined by the conventional daylight factor method or flux transfer method. The accuracy of the computer model was validated through a series of physical scale model measurements with the error ratio of less than 5 percent.
2. It was also possible to quantitatively evaluate and visualize the spatial vector illuminances and scalar illuminances for different sun locations, atrium well indices, and transparency of the atrium roof.

3. The results obtained from the parametric computer simulation showed that there were distinct directional characteristics of spatial vector illuminances when direct beam sunlight was transmitted into the atrium space. When the glass wall was oriented toward the south, the variables involved in the computer simulation had great effects on the direction of spatial vector illuminances.
4. It was also observed that the reflected light rays from the wall surfaces notably affected the directions of vector illuminances in the atrium space.
5. In the case of 3-sided atrium with an opaque roof and a north-oriented glass wall, the directions of vector illuminances were not much affected by the sun location and well index. In this case, the directions of vector illuminances were mostly uniform throughout the atrium space, because only diffuse sky light was transmitted into the atrium space. The indoor illuminances were maintained in the range of 10,000 ~ 15,000 lx in the most daytime throughout the year.
6. Finally, it was concluded that the computer program developed in this study could be an effective design tool to quantitatively evaluate the spatial illuminance distributions in atrium spaces.