Building Simulation 2005

Ninth International IBPSA Conference
Montréal, Canada
August 15-18, 2005

CALCULATION OF THE HEATING AND COOLING LOAD OF BUILDINGS USING A SKY RADIANCE DISTRIBUTION MODEL

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ABSTRACT

We present a model for calculating the sky radiation values considering the sky radiance distribution for a simulated building. We use the sky luminance distribution model of the *CIE standard general sky* rather than the measured sky radiance distribution. In this model, different sky types of the *CIE standard general sky* are identified from values of horizontal global sky radiation *Eeg*, and normal direct solar radiation *Ees* without reference to the measured sky radiance distribution.

To evaluate the model, we calculated 1) the sky radiation values on east, west, north and south-facing vertical surfaces and 2) the annual heating/cooling load of a model room. Three sets of calculations were performed on the assumption of i) uniform sky, ii) measured sky radiance distribution, and iii) sky radiation model. The sky radiation model proposed in this study provides a better estimate of sky radiation values on vertical surfaces and heating/cooling load than estimates derived from a uniform sky model.

INTRODUCTION

The efficient use and conservation of energy requires accurate predictions of energy consumption. A meteorological model that simulates daylight energy and calculates heating/cooling load within buildings provides a precise prediction of energy use. In the research of such meteorological model, there is a trial of modeling the sky luminance distribution or the sky radiance distribution, which are generally assumed to be uniform in the field of daylight or solar radiation simulation. Some models have already been proposed. The typical models of the sky luminance distribution are shown in the following.

Perez et al., (1990, 1993) proposed a sky luminance distribution model called the All-weather model. This model estimates the relative luminance value of an arbitrary sky element by using five parameters derived from the zenith angle of the sun, *Skyclearness*, and *Skybrightness* (Perez et al., 1990, 1993). Based on the All-weather model, Kittler, Perez (Kittler, R. et al., 1998) modeled the relative sky luminance distribution to the zenith luminance using Gradation and Indicatrix functions. The authors defined 15 sky types that represent outdoor daylight conditions ranging from clear to cloudy sky. The sky types are defined by combinations of the parameter values of the Gradation and Indicatrix functions. The parameter values defining the 15 sky types are determined via data regression by sorting sky luminance data into six classes, with each class containing two functions (Kittler, R. et al., 1998). Kittler et al.'s (1998) model was adopted as the *CIE standard general sky* by the *Commission Internationale De L'eclairage* (CIE).

CIE Standard General Sky

The *CIE standard general sky* is a model of sky luminance distribution recommended by the CIE. This model represents cloudless skies and skies of homogeneous cloud cover. The relative luminance of the sky element L_a/L_z, whose angular distance from the zenith is Z (*figure 1*), is calculated from formula (1):

$$\frac{L_a}{L_z} = \frac{f(\chi)\varphi(Z)}{f(Z_s)\varphi(0)} \quad (1)$$

$$\varphi(Z) = 1 + a \cdot \exp\left(\frac{b}{\cos Z}\right) \quad (2)$$

$$\varphi\left(\frac{\pi}{2}\right) = 1 \quad (3)$$

$$f(\chi) = 1 + c \cdot \left[\exp(d\chi) - \exp\left(d\frac{\pi}{2}\right)\right] + e \cdot \cos^2 \chi \quad (4)$$

$$f(Z_s) = 1 + c \cdot \left[\exp(dZ_s) - \exp\left(d\frac{\pi}{2}\right)\right] + e \cdot \cos^2 Z_s \quad (5)$$

$$\chi = \arccos(\cos Z_s \cdot \cos Z + \sin Z_s \cdot \sin Z \cdot \cos|\alpha - \alpha_s|) \quad (6)$$

Formulae (2) and (3) represent the Gradation function and formulae (4) and (5) are the Indicatrix function and formula 6 represents the shortest angular distance between a sky element and the sun χ . The values of parameters *a-e* are shown in *Table 6*. The 15 different combinations of the values of the