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A daylight factor model under clear sky conditions for building: An experimental validation

Madhu Sudan [a,*], G.N. Tiwari [a], I.M. Al-Helal [b]

[a] Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

[b] Department of Agricultural Engineering, College of Food and Agricultural Science, King Saud University, Riyadh 11451, Saudi Arabia

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Abstract

In the present paper, daylight factor model (DFM) has been developed for daylight aperture which has been experimentally validated for east oriented wall window under clear sky condition. The correlation coefficient (r) and the root mean square percentage error (e) are in the range of 0.96–0.99 and 5.1–7.9%, respectively. It has been seen that there is a close agreement between modeled and measured values. The annual average daylight factor (DF), sky component (SC) and internally reflected component (IRC) values for the room were determined to be 1.8%, 1.2% and 0.6%, respectively. It is observed that the south oriented window has maximum DF while it is minimum for north oriented window. It is also concluded that the window in the upper position allows higher illuminance of the rooms compared to a wall window toward the bottom of the room.

Keywords: Daylight factor; Illuminance; Sky component; Internally reflected component

1. Introduction

The daylighting concept in building is an important issue for the architectures and the researchers. It affects the functional arrangement of spaces, occupant comfort (visual and thermal), structure and saving of fossil fuel during the daytime (Roche et al., 2000; Chow et al., 2013; Goiaa et al., 2013). Daylight is an essential component of the solar passive building design. To enhance visual comfort, physical health, energy-efficiency and green building developments, daylighting is an impressive and sustainable development strategy. Window openings furnish a dual function not only of allowing daylight for indoor environment with a pleasing atmosphere, but also of allowing people to maintain visual contact with the outside world (Li, 2010). The quality of the daylight source closely matches with the human visual response due to which it has been considered as the foremost source of light for good color rendering (Edwards and Torcellini, 2002; Chan and Tzempelikos, 2013). It provides sense of sprightliness and brightness that can have a considerable positive impact on the people. In the building, daylighting can be supplied by a proper opening such as windows which gives attractive indoor environment (Sherif et al., 2012; Zheng et al., 2013; Ghisi and Tinker, 2005). Field measurements on buildings show that the consumption of energy in US buildings is 20–40% and for Indian buildings more than 20% of the total electrical consumption and the use of grid based electricity is directly related to pollution and global warming due to fossil fuels as the input (Li, 2010; Balcomb, 1994; Sudan and Tiwari, 2014). So, employment

* Corresponding author. Tel.: +91 9990061421.
E-mail address: msudan.esz@gmail.com (M. Sudan).

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Nomenclature

A_f	floor area (m^2) of a room
A_g	glazing area of the window (m^2) for a room
A_t	total area of room-surfaces (m^2)
DFM	daylight factor model
DF	percentage daylight factor (%)
ERC	percentage externally reflected component (%)
E_{ERC}	illuminance due externally reflected component (Lux)
E_{IRC}	illuminance due internally reflected component (Lux)
E_{SC}	illuminance due to sky component (Lux)
E_i	internal illuminance (both direct and diffuse) a room on horizontal working surface (Lux or lm/m^2)
E_o	outside illuminance (both direct and diffuse) on horizontal surface (Lux or lm/m^2)
EW	east window
H	total height of a dome (m)
H_R	total height of a room (m)
h	vertical height of the given point above the ground surface (m)
$H_{1\mathrm{cw}}$	vertical height between working surface and center of the window (m)
$H_{2\mathrm{cw}}$	vertical height between ceiling of room and center of the window (m)
IRC	percentage internally reflected component (%)
L	total length of a room (m)
l	perpendicular length of the given point from the wall window (m)
M	maintenance correction factor
NW	north window
O_F	orientation factor for glazing
R	average reflectance of all room-surfaces
SC	percentage sky component (%)
SBC	SODHA BERS COMPLEX
SW	south window
w	perpendicular length of the given point from perpendicular axis along the width axis of the wall window (m)
WW	west window

Greek letters

β	inclination of the window (°)
θ_w	angle between the given point and the perpendicular axis to the window (°)
θ_i	angle of incidence (°)
θ	vertical angle of visible sky from the center of the window (°)
τ	transmittance of glazing

of the proper daylighting technologies in the buildings results in less energy use and good visual performance (Wright and Letherman, 1998; CIBSE, 1999; Calcagni and Paroncini, 2004; Nabil and Mardaljevic, 2006). The losses in the US condition are less compared to the losses for Indian condition due to the advanced technologies used in US. The situation in India is worse therefore there is strong need to study daylighting for Indian climatic conditions.

The daylight factor (DF) consists of three components: the sky component (SC), which is the part of light from the sky, the externally reflected component (ERC), created by outer reflective obstruction illuminated by the sky, and the internally reflected component (IRC), generated by the reflection of the light on the interior surfaces of the building. The sum of these components is called the daylight factor (DF) (Acosta et al., 2013; Hopkinson et al., 1966). The analysis of DF depends on several characteristics of an atrium building: the sun orientation, the atrium shape, the atrium roof transmittance, the surfaces reflectivities of the atrium, and the penetration of daylight into the adjoining spaces (Canziani et al., 2004; Courret et al., 1998; Calcagni and Paroncini, 2004). The DF also depends on the orientation of the daylight aperture (with reference to the sun and the room orientation), any surrounding obstruction and the optical phenomenon (namely transmission, reflection and light scattering) occurs at the fenestration system through which daylight enters into the room. Architects use the daylight factor in the building design to estimate the sufficient internal daylighting for the occupants of the space in order to carry out their normal duties (Greenup and Edmonds, 2004; Li and Wong, 2007).

In the past, many researchers have studied DF extensively at ground level (CIBSE, 1999; Du and Sharples, 2011). CIBSE, 1999 have developed a very interesting DFM for the building at ground surface (CIBSE, 1999) which was validated experimentally by Chel et al. (2009) without considering the time of the day and vertical height of working place. Chel et al. (2010) had proposed a model for rooftop aperture in the skylight integrated dome shaped building by considering only time of the day and vertical height of working surface.

In the present study, a model for a room has been developed by incorporating some of the important parameters like inclination, position and orientation (south, north, east or west) of the window with reference to the sun. The vertical height, width and length of a given point from the window inside the room have also been considered in development of present model. The daylight factor has been calculated for a given point, unlike existing model which determine the value only at vertical height. Further, the study has been done for different position