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Daylight performance of a naturally ventilated building as parameter for energy management

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Abstract

Daylight is an important element of energy efficient buildings. Energy savings from artificial lighting during the daytime can have significant impact on the energy sustainability residential buildings. For a city like Mumbai, where the buildings have limited access to daylight due to the sprawling of densely packed high rise buildings, energy saving from daylighting can be an effective driver of sustainability. Under this purview, it is prudent to evaluate the effects of various building design elements like orientation and window-to-wall ratio (WWR) on energy saving potential through daylighting. In this study, two parameters of daylight incidences: Useful Daylight Illuminance (UDI) and annual light exposure, were studied to understand the daylight performance of a high rise residential building. UDI values were then reiterated by varying the orientation and WWR. The results showed that the building performed best at the South-East orientation with a WWR of 50% which allowed 63% more ambient illuminance in the functional space. This study also unveils the paradigm that ambient illuminance inside the functional space of the building may be independent of total incident annual light exposure in the rooms. That means more annual exposure does not necessarily means better lighting conditions within the indoor functional space. Hence, this study creates a way forward in designing energy efficient buildings using UDI as a daylight performance metric.

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Keywords: Urbanization; daylighting, energy management; useful daylight illuminances; window-to-wall ratio

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1. Introduction

India is experiencing urbanization faster than the anticipated rate. Non-compliances to building codes and inefficient building designs have transformed the building sector into a high energy demanding sector. The building energy demand is growing at an unpreceded rate of 8% of which residential sector itself accounts for 25% [1] of the total energy consumption. The majority of this energy is consumed for artificial lighting, cooling and ventilation through fans.

Daylighting can be a useful strategy for energy efficient buildings. It can be a key driver of energy sustainability in residential as well as commercial buildings, with energy saving potential upto 45% [2]. It has been proven to have positive impact on the occupants' health and efficiency [3], [4]. The prediction of daylighting illuminance is a critical factor in daylight designing. Traditional methods in predicting daylighting illuminance such as daylight factor (DF) and daylight autonomy (DA) has limitations in terms of its flexibility in illuminance calculations owing to the dynamic nature of sky condition and the sun path [5]. On the other hand, climate based approach, such as the Useful Daylight Illuminance (UDI), not only predicts hourly daylight data for sensor points, but also reduces the computation time of the overall simulation. UDI gives a range of daylight illuminances, which has more realism in terms of daylight dynamics throughout a day and year, rather than assigning a threshold value of 500lux, which is the daylight autonomy (DA) [5]. UDI categorizes the indoor illuminances into UDI-supplementary and UDI-autonomous. While UDI-supplementary (100-200 lux) might trigger the need for artificial lighting within the indoor space, UDI-autonomous (200-2000 lux) represents the visually ambient range where the occupants can perform daily activities in day-lit conditions [6].

Mumbai, in India, being one of the most densely populated cities in the world, is facing huge challenges in catering to the growing housing demands. This has resulted in the sprawling of densely packed high rise buildings throughout the city. While such development is better from the point of minimizing energy usage for transportation, the close proximity of the high-rises pose a severe threat to sky and daylight penetration. This in turn affect the quality and the quantity of daylight received, especially at the lower floors [5]. Using the principles of building design for maximizing daylight penetration, multiple scenarios can be designed to simulate the performance of buildings based on the various combination of building design elements like orientation and window- to-wall ratio (WWR). These simulations are performed to study the overall effect of such design elements on the useful daylight illuminance on the building.

Hence, the hypothesis of this study is that with more UDI inside the room artificial lighting needs can be reduced for better energy management. The objectives of the study are:

- To understand the effect of different orientation on the percentage of UDI in the building.
- To understand the effect of varying WWR on $UDI_{100\text{-}2000}$(%).

Table 1 Physical parameters of the building

Parameters	Values
Building type	Residential
Construction Type, No. of floors	RCC, 11
Location	Powai, Mumbai
Coordinates	19.13 (N),72.91 (E)
Floor area	839.63 m^2
Orientation	North
Window-to-wall ratio	20%
Cooling and Ventilation	Fans and Natural Ventilation
Artificial Lighting Load	834.6kWh/annum