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Lighting and energy performance of an adaptive shading and daylighting system for arid climates

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Abstract

Finding the proper trade-off between blocking direct sunlight, ensuring sufficient indoor daylighting and view out is a particularly delicate task especially in arid climates, due to harsh environmental conditions. As a tentative answer to this challenge, an adaptive shading and daylighting system (Shape Variable Mashrabiya – SVM) has been developed by the authors, described in an earlier paper. In this paper, we analyze how the SVM may affect annual lighting and global primary energy performance of an office building in Abu Dhabi: the SVM was applied to east and west façades and compared to external Venetian blinds, reflective and selective glazing.

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Keywords: adaptive shading daylighting system; arid climates; mashrabiya; daylighting analysis; building global energy performance

1. Introduction

Nowadays high-rise glazed towers have become the dominant architectural typology for new buildings in Middle-East countries. However, quite obviously, this kind of building is often unsuitable for the arid and desert climates that characterize these countries, as the annual high solar radiation can transform the building into a greenhouse with major visual and thermal discomfort issues. As a result, occupants use blinds frequently, thus reducing the amount of daylight in internal spaces and increasing the energy demand for electric lighting [1-2].

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In this context, this paper investigates the performance of a novel device which was designed and prototyped to meet as many of the requirements regarding the combination of visual and thermal comfort as possible in such a climate. The solution we came up with is an adaptive shading and daylighting system consisting of three identical opaque backscattering shields, carved with a pattern inspired by the local vernacular mashrabiya, and able to move relative to each other so as to switch between a closed position, in the presence of direct sunlight, and an open position, when skylight prevails (Fig. 1). This system, which was called *SVM* (*Shape-Variable Mashrabiya*) is able to effectively block the solar radiation in the presence of direct sunlight, thus avoiding overheating of building spaces and minimizing glare issues. At the same time, thanks to multiple internal reflections between the overlapping SVM shields, a high amount of direct sunlight is transformed into diffuse light providing more visual comfort to the users. On the other hand, when direct radiation is absent, the SVM allows important skylight penetration while restoring some view to the outside. An outstanding feature of the SVM is its ability to move without using electric energy, thanks to a specifically developed actuator that exploits the phase-changing properties of a material heated by solar radiation. The concept, design and investigation of the daylighting performance of the SVM were the object of a dedicated paper from the same authors [3]. The daylighting performance was calculated for a sample office room located in Abu Dhabi using Daysim. Results were expressed in terms of annual temporal maps of illuminances in the room using Useful Daylight Illuminance boundaries.

This paper focuses on a series of analyses which were carried out to:

- explore in more detail the lighting performance in arid climates of a sample room equipped with the novel SVM
- compare performance of SVM to the ones of other systems/technologies used to control the solar radiation, in order to reveal the SVM benefits
- assess how the SVM affects lighting and global primary energy performance (EP_{gl}) of a glazed office building.

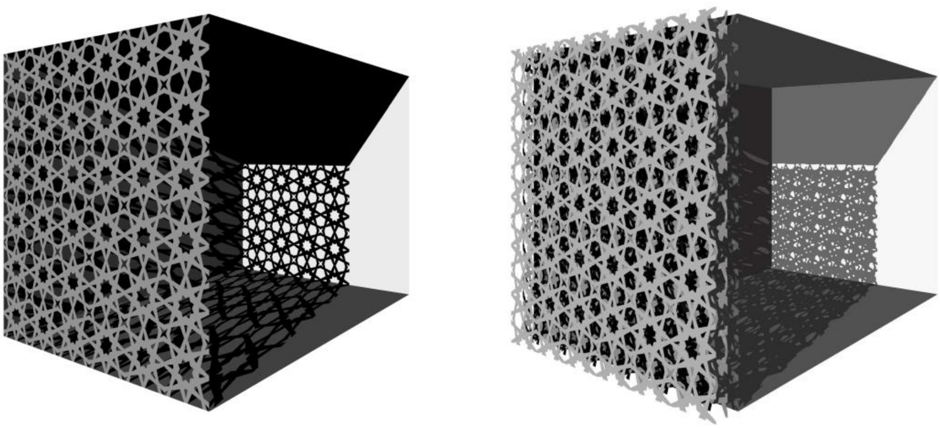

Fig. 1. Images of the SVM: opened (left) and closed (right) configurations.

2. Methodology

The present study consists of two steps. Step 1 focuses on daylight and represents an extension of results already published in [3]. The methodology followed here is the same used in the previous study. All analyses were performed for a sample peripheral cellular office located in Abu Dhabi (24.4°N, 54.7°E), a place with typical arid climatic conditions for which the SVM was designed. The office is 3.52 m large, 5 m deep and 3.04 m high, with one wall completely glazed. The light reflectance (LR) values of ceiling, walls and floor were set equal to 80%, 65% and 30%, respectively. The daylight analysis was carried out through a set of climate-based annual simulations calculating climate-based daylight metrics CBDM such as Daylight Autonomy (DA), continuous Daylight Autonomy (DA_{con}), maximum Daylight Autonomy (DA_{max}) and spatial Daylight Autonomy ($sDA_{300/50\%}$).

DA is the “percent of the occupied time throughout a year when daylight illuminance alone meets the illuminance target over a work plane E_{wp}” [4]. DA_{con} “attributes partial credit to time steps when the daylight illuminance lies