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Sizing analysis of interior lighting using tubular daylighting devices

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Abstract

Daylight access and indoor thermal comfort are key issues for high design level of sustainable buildings. In fact, daylight provides energy savings and visual comfort condition that can foster higher productivity and performance. This paper proposes a case study of sizing of daylight devices for zenith light. It enables the decision-making process of the designer to reach high levels of daylight factor. The proposed method is shown with an example of application. For the case study, a room in south of Italy, 24 different solar tunnels configurations and 12 cases with different number of skylights have been evaluated.

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Keywords: Daylighting, Daylight system, skylight, rooflight, solar tunnels, natural light, daylight factor, illuminance, internal comfort, energy consumption, transmittance, reflectance, overhang

1. Introduction

The climate change is considered as one of the main worries of the modern civilization. Starting from the construction sector, it is urgent to reduce the CO_2 gas emissions that cause the greenhouse effect and the temperature rise [1,2]. The recent inclination, encouraged by the European Energy Performance of Buildings Directive (EPBD), is aimed at decreasing energy use in the building sector [3]. The results of correct choices for the design of

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sustainable buildings involves positive environmental effects, reducing the consumption of natural resources and costs and especially ensuring a high quality of service for the end users and the whole community. Several studies have been carried out to give more information about a right choice of technical solutions for high energy performance buildings, focusing on the envelope and on the technical systems [4]. M.T. Ke al. [5] show that the daylight received through windows can significantly contribute to the reduction of lighting energy use in office buildings. It can be considered as a latent passive strategy for reducing the building energy use and bettering the visual comfort without any expensive operational cost and installation. Daylight access and indoor thermal comfort are key issues for a high design level provided that building occupants spend about 80% to 90% of the time in indoor activities [6]. In fact, daylight provides an agreeable and pleasant indoor environment that can foster higher productivity and performance [7]. Many researches analysed the performances of systems for natural lighting through numerical modelling and experimental tests [8]. On the other hand, Danny H.W. Li et al. [2] noted that several final users and designers do not invest in systems of natural light control, due to limited data and studies mainly about innovative devices systems. Tubular daylight device, also known as solar tunnel, is a novel way of using daylight [9]. As for traditional skylight systems, they are a good choice for some places without windows able to transmit daylight. There is a good number of researches made over the last decades on solar tunnels and on design of them (e.g. materials and shape) and on their application. Back in 2001, Zhang et al [10] developed a mathematical model aimed at predicting the daylight performance of solar tunnels with various configurations under all weather conditions in the UK. Robertson et al. [11] analysed four coordinated experimental measurements campaigns in order to provide coherent test data for a wide range of solar tunnel systems. Ciugudeanu et al. [12] presented a field measurements and software simulation results (DIALux, Lux calculator) for a case-study of a passive tubular daylight guidance system installed in a residential building in Cluj-Napoca, Romania. Mohammed Al-Marwaee [13] showed a survey of daylight guidance systems in 13 working buildings in order to have indications of the achieved conditions which are used as the bases for suggested design criteria. In the present study, an example of a correct design of such system providing a high-level daylight in indoor spaces, focusing on solar tunnels with different number and lengths, has been shown. To reach this aim, the authors analysed a case study, i.e. a room (4x4x3m) of a building located in the South of Italy without windows. The results have been compared with the values obtained simulating conventional skylight systems for the same room.

2. Methodology: The case study

In this paper, a sizing analysis of an interior daylight system has been carried out. The analysis has been conducted on daylight systems able to provide a high level of daylight factor [14] inside the buildings using solar tunnels. To reach this purpose, a room of a building located in Lecce has been investigated. The geographical coordinates are 40° north latitude and 18° east longitude and the elevation is 49 m from the sea.

Its size is 4,5 m in length, 4,5 m widths and 3,5 m height and the main facade is oriented towards North-East. The room has no windows.

The building envelope of the case study is shown in Fig 1. It has an inner coating of plaster (reflectance 0.90%, rugosity 0.03%, specularity 0.0%), while the floor has tiles (reflectance 0.90%, rugosity 0.03%, specularity 0.0%). The task plane, where the light properties have been evaluated, is a wooden table placed at the centre of the room characterized by following properties: reflectance 0.66%, rugosity 0.02% specularity 0.05%. Furthermore, the study has been carried out for two typologies of lighting systems with the follow properties:

- Skylights equipped by a double glazing with a light transmittance equal to 78%;
- Solar tunnels system with a Plexiglas outer dome and diffuser with 78% of light transmittance and an aluminium light tunnels with 78% of reflectance (Fig. 1) with two different lengths.
- Skylight and solar tunnel have the same diameter (0,65 m).