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Quantifying the effects of interior surface reflectance on indoor lighting

Nastaran Makaremi[a,*], Samuele Schiavoni[a], Anna Laura Pisello[a,b] ,Francesco Asdrubali[c], Franco Cotana[a,b]

[a] CIRIAF- Interuniversity Research Center on Pollution and Environment "Mauro Felli", Via Duranti 67, 06125 Perugia, Italy
[b] Department of Engineering, University of Perugia, Via Duranti 93, 06125 Perugia, Italy
[c] Department of Engineering, University of Roma Tre, Via V. Volterra 62, 00144 Roma, Italy

Abstract

The current study analyzed the relationship between reflectance of interior surfaces and distribution of artificial light through visual comfort indices by DIALux evo software. The relationships were assessed through a statistical analysis by SPSS. The quantitative comparison between surface reflectance and these indices showed that wall visible reflection coefficient had the most important role for determining the variations of visual comfort parameters. The findings of this work could be applied in interior spaces mainly designed based on artificial lighting, such as museums, galleries and indoor exhibitions also by paying attention to energy saving perspective.

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Keywords: Interior surface reflectance; Artificial lighting; Visual comfort; Illuminance; Uniformity of lighting; Energy efficiency in buildings.

1. Introduction

Nowadays, people, especially in developed countries, spend most of their daily time indoors. Hence, buildings are responsible for a significant proportion of global energy consumption in order to provide a comfortable indoor climate for occupants. In a recent technical report by International Energy Agency (IEA) it was states that about 3000 TWh

* Corresponding author. Tel.: +39-075-585-3793; fax: +39-075-515-3321.
E-mail address: makaremi@crbnet.it

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(258 Mtoe) of the global electric energy is related to lighting purposes [1]. Focusing the attention on lighting consumption in the European area, official data collected by the European Environmental Agency in the 2014 reported that lighting accounts for about 10% of the household electricity consumptions (81.4 TWh corresponding to 7.0 Mtoe) [2]. In building sector, optimization of lighting performance while maintaining a desired indoor environment is of great significance to improve overall energy efficiency [3-5]. On the other hand, in order to meet the current main concern of worldwide international organizations to control global warming issues, reducing demand for electric energy could lead to mitigate carbon emission and environmental pollution [4,5].

In the past decade, there has been a growing interest in passive design strategies in order to improve the energy performance of buildings in terms of lighting electricity demand. In this view, optimization criteria to integrate artificial lighting and daylight as a clean and cost-effective alternative towards sustainability, is one of the key research targets in the field of building design and construction [4,6,7]. In addition to passive solar design, many other lighting control strategies have been applied to meet the EU's target for 20% increase in energy efficiency by 2020. Application of highly energy-efficient lighting technologies (LEDs), intelligent lighting control systems and automatic dimming, improvement of maintenance factor and use of task/ambient lighting are mostly considered to improve the energy performance of buildings leading to reduction of total energy consumption for lighting [8].

On the other hand, recent researches demonstrated that distribution of light inside buildings highly influenced by characteristics of indoor environment [9,10]. Hence, interior architecture and interrelated physical features could be considered as a substantial aspect in lighting demand, and energy use in buildings. In this panorama, several studies investigated the role of window-to-wall ratio, window orientation, depth and height of room, partitions height, glazing properties as well as interior shutters and indoor blinds in optimization of daylight to save energy and minimize the demand for artificial lighting in buildings [3,10].

Electricity consumption and energy efficiency strategies should be implemented in accordance with the visual comfort criteria [11,12]. Hence, providing comfortable visual conditions is as important as ensuring low energy consumptions. European standard EN 12665 defined visual comfort as "a subjective condition of visual well-being induced by the visual environment" [13]. "The amount of light", "the uniformity of light", "the quality of rendering colors", and "the risk of glare for occupants" are considered as the main physical factors which simultaneously describe visual comfort [12]. Therefore, many standards and criteria have been developed to specify lighting requirements for humans in different indoor work places and environments. In this regard, indoor lighting investigations with respect to artificial light and daylight are mostly carried out through experimental field measurement as well as computational simulation utilizing different metrics and indices such as "illuminance", "illuminance uniformity", "daylight factor", "Unified Glare Rating", "luminance", "visual comfort probability", etc.

Several studies proved that the acceptability of a lit room for satisfaction of occupants in terms of sufficient light for the task not only depends on the correct horizontal illumination of the task area but also on distribution of light on the vertical surfaces, and hence ambient lighting [8,14]. Accordingly, some investigations have been conducted to find out a proper range of useful reflectance for inner surfaces. In a study by Reinhart [15], the computational simulations ascertained the relationship between reduction of partition reflectance and decreasing the amount of daylight in an open-plan office. Additionally, the aforementioned study proved that increasing the reflectance of the ceiling positively influence the uniformity of the daylight distribution and energy saving in the spaces. [15]. Likewise, Grattia and De Herde [16] focused on the parameters influencing energy consumption in buildings and established a general design guideline for low energy office buildings. Their study suggested high reflectance values between 70% and 80% for ceilings and reflection coefficient above 50% for walls in order to maximize the distribution of daylight in the area. According to their analysis, the authors recommended reflection coefficient higher than 50% for horizontal surfaces i.e. ground and surfaces of work; although they noted that users prefer to have dark ground in order to facilitate maintenance. In addition, a simulation study based upon an Italian historical building clarified the effect of the reflectance value of the walls on the reduction of the LENI (Lighting Energy Numeric Indicator) index [17]. In fact, it is proved that, optical properties of interior surfaces and its effect on the lighting energy consumption is a key factor to optimize indoor lighting quality and quantity [8,10,18]. In point of fact, in design phase, it is necessary to consider surface reflectance as one of the main parameters to optimize the reflection and distribution of natural light and electric lights on the walls and consequently illuminance level in the space.

According to the lighting requirements for occupants, the European Standard EN 12464 [19] has recommended the following ranges of useful reflectance for major interior surfaces i.e. walls, floor and ceiling in indoor work places: