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The role of shading devices to improve thermal and visual comfort in existing glazed buildings

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Abstract

Buildings with large glazed surfaces may show severe thermal and visual discomfort issues, as an effect of the large incoming direct solar radiation. In order to avoid excessive solar gains and glare issues to the occupants, it is necessary to adopt suitable solutions that limit the incoming solar radiation, such as highly reflective coatings or movable shading devices. However, such devices must be accurately selected, according to the building location and to the exposure of the glazed façades, while also taking into account possible regulatory measures. This paper evaluates the effectiveness of a series of shading devices applied to an existing office building in Southern Italy. The building shows large glazed surfaces and has no overhangs, thus significant thermal discomfort is perceived in summer by the occupants. The aim is to identify those solutions that allow to improve thermal comfort while also keeping a sufficient illuminance level indoors, without disregarding the compliance with Italian regulations about the installation of shading devices and, of course, the need to keep costs on a reasonable level. The analyses are repeated for different building orientations, in order to provide general information.

Keywords: Refurbishment; Apartment block; Mediterranean climate; Passivhaus; Thermal comfort

1. Introduction

The solar radiation admitted through the glazed envelope of a building may have serious effects on thermal and visual comfort in the indoor spaces. Indeed, solar gains heat the indoor spaces, thus significantly contributing to the cooling load in summer; on the other hand, they have a positive effect in winter. Moreover, one should not forget the

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importance of the glazed surfaces for daylighting purposes: actually, if scarce daylight illuminance determines the need to use artificial lighting, excessive and uncontrolled daylight can lead to discomfort issues, mainly related to glare [1]. Hence, the correct management of solar gains is essential, especially in office buildings with large glazed surfaces. In particular, glazed façades facing south or west (in the northern hemisphere) are particularly vulnerable to overheating, inducing thermal discomfort and non-uniform daylight distribution. In these cases, a suitable shading strategy can be helpful to reduce the cooling load due to solar gains, and to improve daylight exploitation [2].

One of the strategies to control solar gains in buildings is the adoption of *smart dynamic glazing* [3]. The term "smart" indicates a glass that can switch its optical properties when needed, triggered by a voltage pulse (electrochromic glazing) or a high temperature (thermochromic glazing). This allows the building shell to be adaptive to climate, i.e. to admit solar energy only if there is a heating or daylight demand [4]. Smart glasses can prevent glare and thermal discomfort, and provide large energy savings for space cooling [1]. However, despite being already on the market, they are not very widespread, also due to their high costs. On the other hand, a *static reflective glazing* can reduce solar gains, but it cannot modify its properties when more incoming radiation is needed.

Finally, movable *shading devices* can suitably be used to control solar gains. Several studies concerning the effectiveness of shading devices in office buildings are available in the literature. As an example, Bellia et al. study the influence of external solar shading devices on the energy requirements of a typical air-conditioned office building (including space heating, space cooling and artificial lighting). The study considers overhangs on the south façade, and louvers on the east-west façades. The simulations are repeated for three different locations in Italy. The results show that, depending on the location and on the building orientation, the adoption of suitable shading devices can reduce the overall energy consumption by up to 24% [5]. In another study, external venetian blinds are identified as the most effective shading device to control heat gains and daylight through fenestrations in office buildings [6].

Atzeri et al. investigate the performance of outdoor and indoor shading devices in an office building located in Italy. Based on thermal and visual comfort, but also on primary energy consumption, their study shows that shading devices may increase the overall energy consumption if not properly conceived, due to the rising heating and lighting needs, while in case of internal shadings even the cooling needs might be penalized [7]. Stazi et al. compare several external solar screens (aluminium sliding perforated panels, aluminium horizontal louvers, aluminium and wooden shutters), taking into account their performance in terms of energy saving, thermal comfort, daylighting and Life Cycle Assessment. Their study, based on experimental measurements and dynamic simulations, suggests that the wooden slats could be a good compromise for the different considered aspects [8]. On the other hand, Freewan looks at the effect of three different outside shading devices (diagonal and vertical fins, egg crate) on thermal and visual performance for an office building in Jordan, with the façade oriented due south-west. He finds out that egg-crate shading devices perform well on a yearly basis, as they block sunrays in hot periods and allow some sunrays to enter in cold periods [9]. Lau et al. find similar conclusions for a high-rise office building in Malaysia [10].

However, the view to outside is another relevant issue when assessing the performance of a shading device. In fact, external horizontal flat or curved louvers may reduce overheating and improve indoor illuminance in offices, but they may also prevent a view to outside. In this case, either perforated louvers or the adoption of a large gap between the louvers may be preferable, even if thermal and visual performance might be penalized [11]. Finally, the adoption of a dynamic control, to modify the position and the slat angle for venetian blinds according to the sun position, is able to optimize daylight utilization in office buildings [12]. In real applications, the interaction of the occupants with roller shades and dimmable electric lights plays a fundamental role, and is not easy to predict [13].

In this paper, an existing office building with large glazed surfaces is considered. The building is located near Palermo, in Southern Italy; due to the high incident solar irradiance, and to the absence of any kind of overhangs, the occupants report pronounced thermal discomfort in summer, unless air-conditioning devices are switched on, which determines a very high electricity consumption. Starting from such a situation, the effectiveness of a series of shading devices is tested, in order to identify those solutions that improve thermal comfort while also keeping a sufficient illuminance level indoors. To this aim, dynamic thermal and daylighting simulations are performed, to calculate the indoor operative temperature, the Intensity of Thermal Discomfort and the illuminance distribution within some representative rooms. The selected solutions comply with Italian regulations about the installation of shading devices and, of course, account for the need to keep costs on a reasonable level. The analyses are repeated for different building orientations, in order to provide general information.