Static and Dynamic Strategies for Improving Daylight Use in Side-Lit Classrooms: A Case Study

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Abstract

Daylight plays a very important role in educational buildings, as it allows to create a pleasant environment, to enhance students' performance and to provide better health conditions to the occupants.

For these reasons, and also to save energy in artificial lighting, a great body of literature has dealt with the study of daylight in schools in the past years. Although some quantitative criteria are already in use for assessing daylight effectiveness for several visual tasks – e.g. minimum illuminance values and daylight factors – the distinction between well and badly daylit spaces very often rely on qualitative issues, such as the avoidance of discomfort glare conditions.

Moreover, current design practices rely on standard sky patterns, and neglect the specific climate-related issues, and the time varying appraisal of the indoor space.

The present paper contributes to this research field by exploring the use of different strategies to enhance daylight levels in a school located in Sicily and selected as a case study. The building is mainly made up of side-lit classrooms, exposed to different orientations.

The strategies that are investigated rely both on traditional static devices (e.g. light shelves and reflective glazing) and on more advanced dynamic concepts (e.g. sensor-controlled blinds and electrochromic glazing). All the selected devices are already available on the market.

The daylight performance is assessed in the Radiance-based environment provided by DAYSIM 4.0; the model is calibrated upon a measurement campaign. To this aim several Climate Based Daylight Metrics (CBDM) are used to provide a deeper insight of the potentialities of each solution. Further developments are discussed in the conclusions.

1. Introduction

Daylighting in school buildings has been a subject of interest for many years, since daylight plays a crucial role in educational spaces. Indeed, daylight in schools is able to create a pleasant environment, to enhance academic performance, to promote better health, and to provide significant energy savings. For all of these reasons, the importance of daylight in schools is internationally recognized today (Meresi, 2016). In order to optimize daylighting in school buildings, several strategies are possible, mainly aimed to improve daylight uniformity within the classroom, to reduce glare risk close to the windows, and to avoid insufficient daylight availability in the back of the room (Reinhart and Weissman, 2012).

In this regard light shelves may be an effective solution. Light shelves consist in plane elements (horizontal or slightly inclined) placed in the upper part of a window (internally, externally or both) to control and redistribute incoming daylight. In particular, light shelves are expected to redirect incoming light by reflection towards the ceiling, and from there to the back of the room, while also reducing the high levels of daylight near the window. This obviously improves illuminance uniformity (Claros and Soler, 2002).

One of the main properties of a light shelf as a daylighting device is its reflectance. Light shelves reflectance can be specular or diffuse. Studies showed that specular light shelves are more effective than diffuse ones under low and medium solar altitudes (i.e. in winter), although the latter perform better at

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daylight within the classroom is not satisfactory (UDI < 300 lx), acceptable (300 < UDI < 2000 lx) or too high (UDI > 2000 lx) for normal visual tasks (see Fig. 6), thus complementing the spatial analysis provided by the sDA.

As expected, the worst performance pertains to the BLB scenario, where for almost 60 % of the time the mean illuminance is too low (UDI < 300).

However, even the use of electrochromic windows – coupled (ECL) or not coupled (EC) with a light shelf – significantly worsen the availability of daylight in the classroom, as demonstrated by UDI values very close to those of the BLB scenario.

On the other hand, the best performing solution is the adoption of reflective windows (R): in this case, acceptable mean daylight levels are achieved for more than 80 % of the occupancy period, while potential discomfort glare occurs only 10 % of the time. In fact, reflective windows reduce the excessive illuminance measured close to the windows, and establish a more pleasant visual environment if compared with the base case (B): here, acceptable daylight levels are predicted for around 70 % of the year, but potential discomfort glare could occur for more than 20 % of the time.

Finally, the results are interpreted in terms of *mean annual illuminance uniformity*, in order to appreciate the capability of the different strategies to evenly distribute daylight. The *illuminance uniformity* is the ratio of the mean to the maximum illuminance measured within the space.

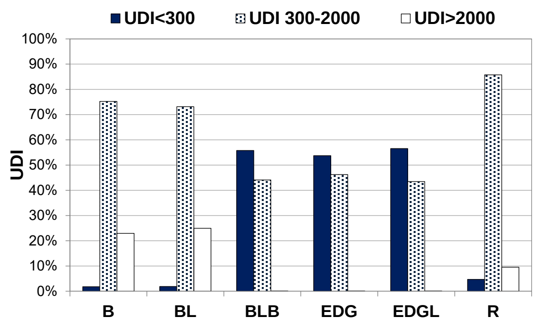

Fig. 6 – UDI values for the proposed solutions (spatial mean)

The results, reported in Fig. 7, show that none of these configurations can reach the minimum illuminance uniformity prescribed by UNI EN 12464 for classrooms in educational buildings (60 %), although the norm does not explicitly state the duration of the period of analysis.

The reader should not be misled by the fact that EC windows – especially if coupled to a light shelf – get the highest illuminance uniformity. In fact, the previous analyses suggest that the illuminance values are just 'uniformly low' within the room for these configurations. Better results are expected with reflective windows (R), since the illuminance uniformity rises to 50 %, while the base case (B) has a value of 46 %. Slightly worse results are given with the internal blinds, with or without light shelves.

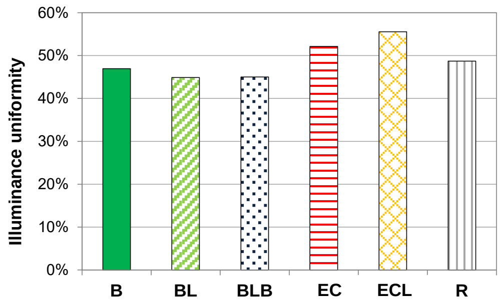

Fig. 7 – Mean illuminance uniformity for the proposed solutions

5. Conclusions

A daylight analysis of an existing classroom facing east has been carried out by means of both measurements and numerical simulations. The main issues of the classroom were found to be the too high illuminance values close to the windows and the uneven distribution throughout the space. To overcome these problems, the paper considered the adoption of different solutions already available on the market, and compared their performance by climate-based daylight metrics.

The outcomes of this analysis show that for this temperate climate, room exposure and geometrical configuration, reflective windows outperform electrochromic windows (with or without internal light shelves) and internal blinds in improving daylight distribution throughout the year. However, the exposure of the windows (south) is expected to have a great influence on the results.

The authors are conducting further analyses to study how other exposures, configurations, and logics or threshold values of activation for the dynamic devices could affect the results here presented. The energy needs for artificial lighting systems, as well as those for triggering the electrochromic windows and activating the internal blinds, will be considered as well.

Nomenclature

Symbols

A	Area (m^2)
DF	Daylight Factor (%)
E	Illuminance (lx)
I	Solar irradiance ($W\ m^{-2}$)
L	Luminance ($cd\ m^{-2}$)
sDA	Spatial daylight autonomy (%)
U	Thermal transmittance ($W\ m^{-2}\ K^{-1}$)
UDI	Useful daylight illuminance (%)

Greek letters

ρ	Reflectance (-)
τ	Transmittance (-)

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