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ScienceDirect

Solar Energy 103 (2014) 364–377

SOLAR ENERGY

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Balancing the daylighting and energy performance of solar screens in residential desert buildings: Examination of screen axial rotation and opening aspect ratio

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Received 14 May 2013; received in revised form 22 January 2014; accepted 11 February 2014

Communicated by: Associate Editor J.-L. Scartezzini

Abstract

Solar screens are typically used to control solar access into building spaces. They proved their usefulness in improving the daylighting and energy performance of buildings in the hot arid desert environments which are endowed with abundance of clear skies.

The daylighting and energy performance of solar screens is affected by many parameters. These include screen perforation, depth, reflectivity and color, aspect ratio of openings, shape, tilt angle and rotation. Changing some of these parameters can improve the daylighting performance drastically. However, this can result in increased energy consumption. A balanced solution must be sought, where acceptable daylighting performance would be achieved at minimum energy consumption.

This paper aims at defining solar screen designs that achieve visual comfort and at the same time minimum energy consumption in residential desert settings. The study focused on the effect of changing the solar screen axial rotation and the aspect ratio of its openings under the desert clear-sky. The individual and combined effects of changing these parameters were studied.

Results of this study demonstrated that a non-rotated solar screen that has wide horizontal openings (aspect ratio of 18:1) proved to be successful in the north and south orientations. Its performance in the east/west orientations was also superior. In contrast, the screen that was rotated along its vertical axis while having small size openings (aspect ratio of 1:1) proved to be more successful in the east/west orientations. Its performance in the north orientation was also good. These solutions enhanced daylighting performance, while maintaining the energy consumption at a minimum.

Moreover, it was observed that combining two screen parameters which proved useful in previous studies on daylighting or thermal performance does not add up to better solutions. The combined solutions that were tested in this study did not prove successful in satisfying daylighting and thermal performance criteria at the same time.

This study confirmed the results of previous publications on the usefulness of using solar screens in desert environments. Solar screens could significantly enhance daylighting performance and visual comfort. They provided 66–97% "daylit" areas in the tested spaces. In addition, use of solar screens reduced energy consumption by up to 25% in comparison with a non-screened window.
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Keywords: Clear sky; Daylighting; Desert; Energy consumption; Solar screen

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http://dx.doi.org/10.1016/j.solener.2014.02.025
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1. Introduction

Daylighting is one of the effective approaches for improving the energy-efficiency of buildings. Provision of natural daylight in residential buildings could be especially useful as it improves the quality of space and wellbeing of users. This becomes more effective in desert locations, as they are endowed with abundance of clear-skies. However, uncontrolled daylighting could result in uncomfortable glare. They could also result in the overheating of spaces, due the admittance of direct solar radiation in the hot-arid climate of the desert.

Fixed solar control systems, such as solar screens, have traditionally evolved to control solar penetration in the buildings of the middle-east; having names such as "Mashrabeya" and "Rawshan". Other solar control systems of a similar nature were also found in Japan, Spain, South-East Asia and South America. They were typically made of fixed perforated panels composed of a lattice of wooden cylinders or other shapes connected with wooden joints (Harris, 2006). These panels were typically fixed externally in front of windows and other building openings (Fig. 1).

A number of publications addressed the parameters of external solar screens which influence daylighting performance and energy consumption. The study by Aljofi (2005) examined the effect of screen shapes on daylight distribution in certain tested spaces. Study results showed that the highest value of reflected light contribution was found in the central zone for all shapes of solar screen cells. Moreover, illumination values were lower when rounded shape screen cells were used, as compared with other shapes. Also, the contributed reflected light was found to be directly proportional to screen cell diameter. In a more recent study, Sabry et al. (2011) investigated several solar screen parameters, such as its rotation angle. It was found that average room illuminance was directly proportional to screen rotation angle. The paper by Sherif et al. (2012a) examined the minimum perforation rate of solar screens that provides adequate daylighting performance in different orientations in the desert. The impact of external perforated solar screens on energy consumption in desert locations was explored by Sherif et al. (2011a). The study found that the use of screens had a significant effect on reducing cooling energy, especially in the south, west and east orientations. Also, it was found that screens with a perforation range between 80% and 90% had the highest saving rate. Further studies by the same authors also revealed that the most significant saving was achieved when using screens with depth to perforation ratio 0.75/0.75.

Balancing between the provision of natural daylight and reduction of energy consumption by use of solar control systems was addressed in a number of other studies. Sherif et al. (2011b) investigated the influence of screen opening shape on daylighting performance and energy consumption in a desert climate. The aspect ratio of screen openings (horizontal:vertical) was examined. The aspect ratios that improved daylighting behavior while resulting in a marginal effect on energy consumption were identified. A screen opening aspect ratio of 18:1 was recommended for screens protecting windows facing north. A screen opening aspect ratio of 1:1 was recommended for screens protecting windows facing south. As for the protection of windows facing east and west, the study left it to the designer to select the more suitable screen aspect ratio based on whether the improvement of daylighting was worth the compromise in energy consumption. In another paper, Kim et al. (2012) compared conventional daylighting devices in regards to their effect on the reduction of heating and cooling energy consumption of a living space in South

Fig. 1. Traditional solar screen "Mashrabeya" (Hood, 2010).

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