Available online at www.sciencedirect.com

ScienceDirect

Solar Energy 105 (2014) 512–528

SOLAR ENERGY

www.elsevier.com/locate/solener

Comparison on solar shadings: Monitoring of the thermo-physical behaviour, assessment of the energy saving, thermal comfort, natural lighting and environmental impact

F. Stazi [a,*], S. Marinelli [a], C. Di Perna [b], P. Munafò [a]

[a] Dipartimento di Ingegneria Civile, Edile e Architettura (DICEA), Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy

[b] Dipartimento di Ingegneria Industriale e Scienze Matematiche, Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy

Received 22 July 2013; received in revised form 3 April 2014; accepted 7 April 2014
Available online 10 May 2014

Communicated by: Associate Editor J.-L. Scartezzini

Abstract

The paper presents an analytical and experimental study on external solar shadings. The purpose is to compare the behaviour of different typologies in various seasons in a Mediterranean climate from the point of view of thermo-physical behaviour, energy consumptions, thermal comfort, day lighting and environmental impact. The study included two phases:

i. Simultaneous summer monitoring of different devices typical of a perimeter office building: *sliding perforated panels, ventilated double-glazed window, aluminium horizontal louvers*;
ii. In-depth study of the louver shading devices through the analysis of the impact of adopting different materials, length of slats and vertical distance between slats. Configurations mainly adopted on residential buildings were also considered. The following activities were carried out: simultaneous winter monitoring of different louver shading devices, *aluminium horizontal louvers, aluminium persiana, traditional wooden persiana*; dynamic thermal simulations (Energy Plus software) to analyse energy consumptions, indoor thermal comfort and daylighting for different seasons and louvers configurations; assessment of the environmental impact with LCA analysis (SimaPro software).

The study made it possible to highlight different behaviours of the shadings depending on their specific characteristics. The shade permeability influences the presence and efficacy of the stack effect in the air channel behind it while its geometries and materials (with relative optical and thermal properties) have an impact on the temperature trends of the adjacent layers, on yearly consumptions, on indoor thermal comfort and on uniformity level of the natural light. The results demonstrate that the wooden solution could to be a good compromise between the different aspects and that adopting an aluminium louver screen it is important to choice configurations characterized by wide and movable slats.

Keywords: Solar shadings; Louver; Energy efficiency; Experimental study; Environmental impact

* Corresponding author. Tel.: +39 071 2204783, mobile: +39 328 3098217; fax: +39 071 2204378.
E-mail address: f.stazi@univpm.it (F. Stazi).

http://dx.doi.org/10.1016/j.solener.2014.04.005
0038-092X/

1. Introduction

The new regulations on energy saving have determined the super insulation of opaque envelopes. In temperate climates, such envelopes, characterised by a significant thickness of insulating material, act as thermal barriers against heat loss, thus avoiding the dispersion towards the outside of the internal heat gains (coming from equipment, people, solar radiations through transparent surfaces) and completely devolving to windows the thermal exchanges between indoor and outdoor. This determines the increasing importance of the design of external louvers, which have to meet sometimes contrasting requirements: maximizing the solar irradiation during the winter, avoiding as much as possible thermal dispersion and minimizing the solar gains during the summer, always guaranteeing the necessary level of natural lighting.

The impact of shading devices on energy saving, thermal comfort and daylighting performance has been studied experimentally and theoretically.

A great number of studies focused on different types of internal blinds, either *installed in the internal side of the glazing surface or inserted in a double skin façade*.

Some interesting experimental studies on this issue have been carried out by Cuevas et al. (2010) that built up a test bench with the aim of comparing different internal blinds and proposing an empirical model. Various blind configurations were tested: single curtains, double curtains, PVC blinds, wood blind, venetian blinds and polyester blinds. The observations were focused on the heat transfer coefficient and the authors concluded that this parameter is strongly influenced by the position of the screen and its permeability to the air flow. Serra et al. (2010) carried out an experimental investigation on the performance of different climate façades in the Italian climates. The research involved the implementation of test cells equipped with two different solar shading devices placed in the cavity, aluminium venetian blind and PVC reflecting roller screen. The authors demonstrated that the former should be preferred for its higher ability to pre-heat the ventilation air. On the same year, Bessoudo et al. (2010) performed a very extensive research consisting of experimental and analytical phases on various screening systems with the aim of optimizing comfort and energy saving in office buildings with large glazing areas. The researchers carried out a winter monitoring of internal shading devices (venetian blind and roller shade) and emphasized the importance of the choice of shadings to avoid thermal discomfort for overheating in sunny days even in the cold climate of Montreal. A simulation model is then validated by the authors through comparison with measured values and used to generalize the study to different glazing and shading properties (Tzempelikos et al., 2010). The authors demonstrated that the internal comfort levels strictly depend on the combination between shade absorptance and glazing properties (thermal resistance and solar transmittance).

Very rarely studies have been performed on the detailed experimental comparative evaluation of *external shading systems* while the studies on this issue mainly regard analytical investigations.

Tzempelikos et al. (2007) used a coupled lighting and thermal simulation module to evaluate the simultaneous impact of glazing area, shading device properties and shading control on building cooling and lighting demand. In this case the study focused on *external roller shades*, with thermal and day lighting simulations for perimeter office spaces in cold climates, but no experimental investigations were made. An interesting experimental study on external shading devices was carried out during the summer in UK climates (Brighton) by Ylitalo (2012) with the aim of compare internal and *external blinds* keeping the latter open at the bottom to allow the entry of natural lighting. The authors concluded that the external shade is preferable because it significantly reduces (down to 3.5 °C) the indoor summer peak temperatures.

Regarding the *external louver shading devices* various studies have been carried out with the purpose of studying the performances at the changing of some project parameters, but they are mainly of analytical type and generally focused on shadings with high vertical distances between slabs (ranging from about 0.2 m to 0.5 m). This kind of configuration is typical of office applications where the shadings have the function to shield the direct irradiation thus avoiding glare rather than obscure (as in the case of screens adopted for residential uses). From Portugal Palmero-Marrero and Oliveira (2010) carried out an in-depth study on horizontal and vertical louvers layouts with distance between slats that varies between 0.23 m and 0.26 m according to different latitudes. The authors demonstrated that such a device can guarantee indoor comfort and energy saving but they also highlighted the necessity of adopting an automatic control of the louvers in coldest climates to avoid high heating consumptions. The same conclusion was drawn by a group of Danish researchers, Nielsen et al. (2011), on a simulation model with small louver vertical spacing (about 0.05 m). The authors underlined how the conflicting aspects of energy need for heating, cooling and artificial lighting should be evaluated simultaneously to identify the best performing facade. They also demonstrated that the adoption of a dynamic solar shading constitutes the best design alternative.

A high distance between slats was adopted in the studies of two research groups in hot climates: Hammad and Abu-Hijleh (2010) from United Arab Emirates (distance of 0.3 m) and Alzoubi and Al-Zoubi (2010) from Jordan (distance of 0.5 m). For both studies the ratio between slats spacing and width is near to 1 (to block sun rays of 45°) and both analyses are focused on the variation of louvers angles. Both studies pointed out that there is an increase of annual total energy consumption and a reduction of daylighting by changing the louver's orientation from horizontal (or nearly horizontal) to inclined. The same unitary value was also adopted by Freewan et al. from UK