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ScienceDirect

Energy Procedia 70 (2015) 719 – 728

Energy Procedia

International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2014

Lean strategies for window retrofit of Italian office buildings: impact on energy use, thermal and visual comfort

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Abstract

The aim of this paper is to explore lean retrofit strategies for transparent envelope of existing Italian office buildings, to improve their performance and to ensure low energy use and a good thermal and visual comfort. Solar and light control is necessary to prevent overheating in office buildings those generally present high internal loads. The effectiveness of solar window films use in Italian buildings context is here investigated, in comparison with other strategies like the use of internal roller blinds and the substitution of the existing window panes with high performance ones. A sensitivity analysis was assessed to evaluate the office unit primary energy use under different retrofit solution, weather conditions and window to wall ratio. A conventional existing office unit was modeled in EnergyPlus and LBNL Radiance to assess heating, cooling and lighting energy demand coupled with visual comfort parameters. Thermal comfort was evaluated hourly in accordance with ISO 7730. The results are presented with a cost - benefit analysis to understand the best retrofit solution.

Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG

Keywords: Window films, transparent building envelope,human comfort, primary energy demand

1. Introduction

Energy standards and certifications request high performance for transparent and opaque envelopes in new buildings to minimize the energy consumption. Windows are the most important part of the building façade to control solar gain and thermal losses. Their performance are also relevant for visual and thermal comfort. Office

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Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.02.181

buildings, that generally have medium-high WWR (window to wall ratio value), high internal gains due to users, lighting and appliances need a good balance between both thermal and visible performance of transparent facades and between static and dynamic shading control strategies to avoid overheating and to permit optimal use of daylight [1],[2],[3].

In Italy over than the 75% of existing office buildings have more than 25 years and present inadequate or obsolete façades technologies and systems. The opaque part of the envelope is generally with low or no insulation and the transparent façade has single glasses or double pane clear glasses filled with air[4].

Hence is important to elaborate strategies able to improve the transparent envelope performance of existing office buildings that can be easily implemented, without compromising building use and reducing retrofit costs to minimum. We considered and compared lean retrofit alternatives for the transparent part of the envelope i.e.: the substitution of existing window panes with high performance ones, the use of internal shading devices (roller blind with on-off control on solar irradiance) and window films application (Table 1). Each solution permits to optimize, in different ways, several aspects like building consumption during the hot and warm season or to improve thermal and visual conditions in working environments. The analysis was implemented on two office buildings models with different energy needs and located in Milan (Cold Winter – Hot Summers) and Palermo (Warm Winters – Hot Summers). Milan is in the North of Italy (45°27′50″N - 9°11′25″E) and Palermo is in the South (38°07'00"N - 13°22'00"E).

2. Model description

The two conventional representative models of Italian office units were modeled in EnergyPlus to estimate and compare their primary energy use under different weather, and envelope conditions. The dimensions of the units are 3 x 4 x 3 m (W x L x H) and they have only one wall facing outdoors and oriented South, modeled alternatively with different window to wall ratio representative for ribbon window and curtain wall systems. The proposed solutions have a WWR (window to wall ratio) from 50 to 100% (corresponding to a glass area of 42% and 80%). The wall is considered as non-insulated. The standard reference case for transparent surfaces is the double pane clear glass filled with air (DC). The analyzed retrofit alternatives are listed in Table 1-2 and consist in:

- glass substitution with a double pane low-e selective/ solar control glass control filled with air (LowE_X codes, with X from 1 to 3 representative of the three low-e glass alternatives).
- the use of reflective/selective/solar control window films on the existing double clear glass (DC+Y codes)
- The use of an internal automated roller blind with an on- off control based on irradiance and a set point of over 300W/m^2

Table 1. Thermal and optical properties of the double pane clear glass (DC), the double pane Low-e glasses (LowE_X, where X is a number used to identify the LowE glass alternatives) and the Double pane clear glass coupled with window films from type A to type D (DC+Y, where Y is a number used to identify the LowE glass alternatives). Visible transmittance (tvis), Solar Heat Gain Coefficient (SHGC) and Thermal transmittance (U-factor) were calculated and reported in the table.

	DC	**LowE_1**	**LowE_2**	**LowE_3**	**DC+A**	**DC+B**	**DC+C**	**DC+D**
τ_{vis} [-]	0.786	0.698	0.521	0.701	0.686	0.534	0.355	0.176
SHGC [-]	0.704	0.452	0.299	0.382	0.644	0.454	0.320	0.164
U factor [W/m^2K]	2.703	1.674	1.651	1.651	2.733	2.727	2.727	2.727

Table 2. Thermal and optical properties of window films (A clear, B Selective, C and D Solar control) and roller blind.

	τ_{vis}	τ_{sol}	ρ_{vis}	ρ_{sol}
Film A	0.76	0.673	0.09	0.09
Film B	0.59	0.414	0.11	0.12
Film C	0.39	0.29	0.22	0.17
Film D	0.19	0.13	0.57	0.54
Roller blind	0.26	0.28	0.4	0.57