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Simulating thermochromic and heat mirror glazing systems in hot and cold climates

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Abstract

This paper investigates the potential energy requirements for heating and cooling when using a thermochromic glazing system on a highly glazed tall office building and comparisons are made with the respective performance of two heat mirror units and a clear triple glazed window. The assessment is done with the ESP-r whole building integrated simulation program in order to account for the dynamic optical properties of thermochromic glass in integrated simulations. The glazing systems are assessed for hot, cold and significantly varying between hot and cold climates. Annual heating and cooling energy requirements were quantified and short-period simulations were also run to assess the effect of the glazing systems on indoor temperatures. It was found that thermochromic glazing could significantly reduce cooling loads in hot climates and where cooling could be a significant building energy load (by approximately 30% in comparison with the other glazing systems). On the other hand, thermochromic glass could have a negative impact in cold climates where the use of heat mirror glazing systems could offer the highest energy savings even when compared with the triple glazed window. In seasonally varying climates and for highly glazed office buildings in which simultaneous high internal and solar heat gains are likely to occur, the use of thermochromic glass is an appropriate technique for saving energy and improving thermal comfort.

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1. Introduction

A wide variety of advanced glazing systems have been produced in recent years with the aim of being more energy efficient than the traditional glazing systems by controlling solar heat gains and limiting heat losses through them. In this paper the thermochromic glazing and heat mirror glazing systems are evaluated for their performance in reducing thermal loads with the use of state-of-the-art whole building

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modelling techniques. Their performance is also compared with simulation results of the same building that uses a triple clear glazing system. The study focuses on highly glazed tall office buildings since they tend to be aesthetically attractive to building developers in urbanised cities and they do also easily overheat due to the high simultaneous occurrence of internal and solar heat gains at daytime. The option of internal or external shading will not be considered in this study since it is not practical or desirable to have, for example, external shading in high rise buildings and it is intended to have a building that maintains maximum visibility and daylight penetration through the windows.

Thermochromic glazing has the ability to control the quantity of light and heat entering the building by changing its optical properties (transmittance, absorptance, etc.) when exposed to heat. Thermochromic systems become darker above specific to their manufacturing characteristics glass temperatures, and therefore they have the potential to reduce cooling loads and the risk of overheating in buildings. Most of the relevant papers in the literature focus on electrochromic glazing, which is a type of glass that has a similar function as the thermochromic but the changes of the optical properties are activated by a small amount of electricity. A thorough review of thermochromic coatings was done by [1]. Only a limited number of whole building energy simulations for thermochromic systems have been reported in the literature. Saeli et al. [2] used the EnergyPlus program to assess the energy savings from thermochromic glazing units across several European and North African climates. Their work focused on thermochromic glass that has one transitional temperature (i.e. optical properties change above one specific temperature) while the work presented in our paper will investigate changes in optical properties at several stages that correspond to more than one transition temperatures. Four thermochromic glass types studied by [2] with their single transition temperatures being between 38.5°C and 59 °C. Xu et al. [3] did use the TRSNSYS simulation tool to compare thermochromic glass that changes optical properties at a single transitional temperature (38.5°C) with traditional white and low-e glass types. The authors report that thermochromic glazing has the potential to offer energy savings only in warm climates where cooling loads are more significant than heating loads. As an extension of the above listed studies, Saeli et al. [4] used EnergyPlus to model the performance of thermochromic glazing for a Southern European climate by using low theoretical single transition temperatures (20°C, 25°C, 30°C and 35°C) for each simulation run. However, the authors have also included a discussion for a potential theoretical hysteresis during the changes of the optical properties between the heating and cooling cycles of the glass (i.e. a different transition pattern during the increase and decrease of the glass temperature). They concluded that the specific type of glazing has a potential to significantly reduce cooling loads if future efforts are focused on reducing the actual transition temperature of the glass.

On the other hand, heat mirror glazing systems have less transient behaviour than the thermochromic systems. When compared with a common double glazing unit, heat mirror units have an additional lightweight heat mirror film between the two glass layers. Placing the heat mirror film in the middle of the window creates two cavities (Fig. 1), which could be filled with a variety of gases. Advanced heat mirror films have now been produced by utilising nano-coatings of metal to reflect heat back to its source. Heat mirror glazing systems can be produced with a wide range of glass types and gas fills that allow flexibility for addressing the heat loss, visible light and solar control requirements of different climates.

The idea of using transparent heat mirror films is not new [5, 6] and the initial studies investigated the optical properties when placing mirror layers that incorporate various coatings in different ways on the glazing system. For example in Lampert's work [6, 7] the use of heat mirrors at different positions in glazing systems has been studied and demonstrated. Placing the mirror in the middle of the glazing system and using it for energy saving purposes has been studied experimentally and with stand-alone (i.e. not whole building) modelling approaches, e.g. [8, 9]. On the other hand, the literature reports only a limited number of whole building energy performance comparisons of these glazing systems with other advanced glazing types (e.g. thermochromic).