International Journal of Sustainable Built Environment (2013) 2, 56–64

Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

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Possibilities for characterization of a PCM window system using large scale measurements

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Received 19 December 2012; accepted 24 September 2013

Abstract

The introduction of dynamic envelope components and systems can have a significant reduction effect on heating and cooling demands. In addition, it can contribute to reduce the energy demand for artificial lighting by better utilization of daylight.

One of these promising technologies is Phase Change Materials (PCM). Here, the latent heat storage potential of the transition between solid and liquid state of a material is exploited to increase the thermal mass of the component. A PCM layer incorporated in a transparent component can increase the possibilities to harvest energy from solar radiation by reducing the heating/cooling demand and still allowing the utilization of daylight.

Measurements have been performed on a state-of-the-art, commercially available window that integrates PCM using a large scale climate simulator. The glazing unit consists of a four-pane glazing with an integrated layer that dynamically controls the solar transmittance (prismatic glass) in the outer glazing cavity. The innermost cavity is filled with a PCM, contained in transparent plastic containers.

When dynamic components are incorporated in the building envelope, it makes the characterization of static performance (e.g. the thermal transmittance, *U*-value; the solar heat gain coefficient) insufficient in giving the full picture regarding the performance of the component in question.

This article presents a series of preliminary measurements, and the related methodologies, carried out on a window with incorporated PCM. The tests have been carried out using several test cycles comprised of temperature and solar radiation cycling, where the aim has been to delve deeper into the possibilities for the characterization of dynamic building envelope components by full scale testing in a climate simulator, showing potentials and limitations of this approach and measurement facility.

It was found that even for temperatures similar to a warm day in Nordic climate, the potential latent heat storage capacity of the PCM was fully activated. Long periods of sun combined with high exterior temperatures are needed.

Keywords: Window; Façade; Phase change; PCM; Experimental

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Peer-review under responsibility of The Gulf Organisation for Research and Development.

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1. Introduction

1.1. Technology overview

Based on the recommendations given in IEA ECBCS Annex 44 and the “Kyoto Pyramid” (IEA, 2011), combined with the fact that windows contribute to a substantial part of

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the heat losses and gains, a further investigation on the possibilities of reducing the energy demand related to glazed and/or translucent parts of the facades is necessary.

In recent years there has been an increasing interest in and amount of research carried out regarding fairly new technologies like Phase Change Materials (PCM). A PCM in a building context is a material that has a melting point in the region close to the comfort or operational temperature in the building where it is adopted. The latent heat storage potential in the phase transition between liquid and solid state can thus be utilized as heat storage and shows a favorable behavior in terms of increasing the thermal inertia of the system. The raw materials used to produce PCM's can be divided in three main groups, eutectic, organic and in-organic materials (Baetens et al., 2010). For the use of PCM in windows, paraffin based, organic materials are the most interesting, since they are transparent in the liquid state and translucent in the solid state.

Some studies concerning PCM in combination with glazing have previously been performed. These range back to 1997, with a study of the PCM layer coupled with a transparent insulated material (Manz et al., 1997). The aim of including a PCM layer into a transparent system is to collect (a large part of) the NIR solar radiation (that does not contribute to daylight) within the PCM layer itself and letting (the largest part of) the visible solar radiation enter the indoor environment, thus still allowing natural light exploitation for daylighting purposes. This behavior is achieved thanks to the highly selective optical properties of some PCM, e.g. paraffin wax. An investigation of the optical properties of PCM layers in combination with glazed layers was carried out, by means of a Large Integrating Sphere facility, by Goia et al. (2012), who characterized different thicknesses of the PCM and the angular-dependence of the coefficients.

The use of PCM as moveable shutters was studied by Ismail and Henriquez (2001). Here, PCM are pumped to and from a storage tank underneath the window. The authors conclude that a PCM filled window is thermally more effective than an air-filled window as it filters out thermal radiation which in term reduces heat gains or losses. Weinläder et al. (2005) performed measurements on a double glazing with a PCM acting as a third (internal) layer to the glazing unit. The authors found that a reduced heat loss compared to the double-glazing unit is mainly due to the additional cavity behind the PCM. There was also found a slight shift in peak energy flows when using the PCM, but the authors concluded that if the heat gains of a double glazing (higher during mid-day) can be stored it might overcompensate the high heat losses of this system. However, the addition of PCM has a positive effect on thermal comfort by dampening the extreme temperatures during mid-day and night.

A study where PCM was used for latent heat storage in an internal slat-blind shading device (Weinlaeder et al., 2011), concludes that there is a substantial cooling potential during summer, and also some benefits during wintertime, compared to a conventional material blind. Whereas, the PCM used here are not transparent, it is used in combination with a window, thus making it part of a transparent component. Likewise, a numerical simulation study for externally placed shutters with PCM (Alawadhi, 2012), conclude that the heat gain through the window can be significantly reduced when mounting shutters with PCM compared to an un-shaded window. A comparison of two-pane windows with a gas-filled cavity and a PCM filled cavity was performed by Ismail et al. (2008). Goia et al. performed an experimental analysis on a double glazing system with paraffin wax, by means of an outdoor test cell facility located in a temperate sub-continental climate (2010). Implications of this system on thermal comfort condition were also investigated starting from experimental data (Goia et al., 2013), and physical–mathematical models (Goia et al. 2012) for simulating PCM glazing systems were developed too. Recently, Gowreesunker et al. (2013) analyzed the optical and thermal properties of a small scale PCM-glazed unit, assessing its performance by a combined experimental–numerical analysis. The investigation focused on the relationships that describe the extinction, scattering and absorption coefficients within the phase change region, validated in a numerical CFD model.

1.2. Scope of work and possible outcome

Performing measurements on dynamic systems, like the PCM glazing, is extremely relevant. The complex interaction of solar radiation and phase change has a complicating effect on the physical behavior of such a system. Characterizations that make use of only analytical and numerical tools are well known to be difficult and subject to experimental validation. Full scale testing can thus serve as validation support for the theoretical models that are being developed. An example of this procedure can be found in Cao et al. (2010). The measurements carried out for an opaque wall incorporating PCM presented in this article have been used for validation of a numerical model (Tabares-Velasco et al., 2012). The use of a full scale climate simulator, where temperatures and solar irradiance levels can be dynamically regulated and controlled, increases the possibilities to deepen the investigation on the behavior of a translucent component under defined environmental conditions.

1.3. The PCM glazing

Measurements have been carried out on a commercially available glazing system with an integrated prismatic solar reflector and a PCM filled cavity. The producers have not stated the amount of PCM in the window, but the thickness of the PCM encasings were measured to be approximately 23 mm thick. The type of glazing system has been used in several existing buildings, primarily in Switzerland. The PCM glazing is often combined with standard windows in the façade, as shown in Fig. 1. The window is a 1.2 by 1.2 m large window which consists of a four-pane