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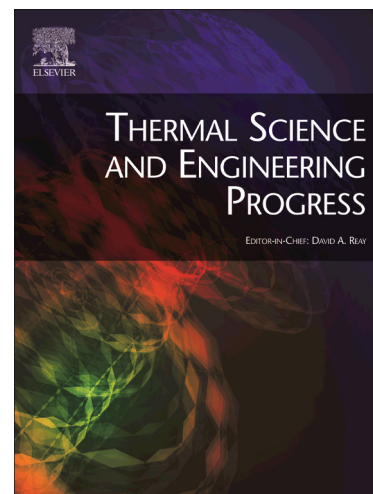
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Amirreza Fateh, Davide Borelli, Francesco Devia, Helmut Weinläder

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Summer thermal performances of PCM-integrated insulation layers for light-weight building walls: effect of orientation and melting point temperature

Amirreza Fateh¹, Davide Borelli¹, Francesco Devia^{1*}, Helmut Weinläder²

¹DIME, Università degli Studi di Genova, Genoa, ITALY

²Bavarian Center for Applied Energy Research (ZAE Bayern), Würzburg, Germany

*Corresponding author. E-mail: francesco.devia@unige.it

ABSTRACT

Phase change materials (PCMs) as insulation layers constitute a novel application of this kind of heat storage materials, which could be profitably used in buildings for energy saving because they can shave the peak heating load during the day. PCMs exploit the capability of storing and releasing the latent heat of phase change with minor or even no variation of temperature. In this condition, they show an apparent increase of their thermal capacity, per unit of mass or volume, which can be particularly useful in lightweight walls. This paper deals with the effect of solar radiation on a light-wall with PCM-integrated.

In addition, a dynamic model of a wall is developed considering the different conditions such as position of PCM and different orientation of the wall. The results show that utilizing PCMs integrated insulation layers could provide major reductions of heat loads when their intensity is fluctuating and variable, and that this solution is more effective when the temperature variations are close to the phase change temperature, leading to energy savings up to 75% of the heat load through opaque walls.

Keywords: light-wall, PCMs, Solar, Dynamic modelling.

1. INTRODUCTION

Nowadays, more than 40 percent of energy is used in buildings [1]. Such a large slice of energy consumption leads to the necessity of defining new proposals aimed at its reduction. This aspect is so essential that the European Commission has established to reduce 20% of energy consumption by 2020 and a 30% reduction in energy consumption by 2030 [2-3].

In addition, the advancements of technology have made the design and construction of buildings with lighter walls possible. This leads to the necessity to apply lighter and more efficient insulators in this new kind of light-weight buildings. One of the new and most promising methods of increasing their energy efficiency is using new construction materials such as phase change materials (PCMs). The use of PCMs is largely widespread in storages, thanks to their apparent thermal capacities. For this reason, in the last decade they have been considered for building insulation because they can act as a distributed, passive, storage that helps the management of variable heat loads.

The reduction of energy consumption in light-wall buildings can be obtained from a proper analysis of the transient thermal behaviour [4] aimed at two tasks:

- peak-shaving of the thermal loads
- exploitation of the occurrence of the daily reversals of heat flow rate, which takes place in some climatic conditions [5-9]

For this purpose, especially in summer and intermediate seasons, any model aimed at describing the transient behaviour of a building must adopt a precise model for hourly solar radiation as well as an hourly variation of environmental temperature, since this parameter represents the major heat load and is subject to the highest fluctuations.

The smoothing and delaying of heat wave effect depends on the capability of the building structure to act as thermal storage, and this attribute is particularly low in light-weight buildings [10, 11].

This represents an interesting alternative to the use of conventional storages and it could be a valid possibility for enhancing the distribute storage capability of the building without using more complex systems that exploit the integration of inverse cycle, electric storages, and thermal storages, well described in [12-13].

In addition, the application of light insulation with apparently high thermal capacity could be very useful for this kind of construction.

Climatic data are usually available as total solar radiation, but for this kind of study, the separate contributions of direct and diffuse solar radiation are needed. For this reason, it is important to use a reliable model, which infers the fraction of the direct component of solar radiation and the diffuse one, separately, starting from data about the total radiation on a horizontal plane. Several papers describe the calculation of the sun angle that is needed for the successive calculation of the detailed solar radiation. Bivona et al. obtained a common expression to evaluate the global and diffuse radiations on horizontal surfaces. They found that a Gaussian distribution with two parameters, which takes into account the asymmetries between morning and afternoon hours, properly fits experimental data of six actinometrical stations with different geographical location and climatic conditions. This method is accurate for both the diffuse and global radiation [14].

Boland et al. developed a model in order to determine the influence that the smoothing due to the use of hourly data (instead of 15-minute data) has on the results. The model was carried out utilising data from Australian locations, to explain some of the substantial scatter by adding apparent solar time as a predictor, which showed to be significantly better than solar altitude [15].

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