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A numerical study of external building walls containing phase change materials (PCM)

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ABSTRACT

Phase Change Materials (PCMs) have been receiving increased attention, due to their capacity to store large amounts of thermal energy in narrow temperature ranges. This property makes them ideal for passive heat storage in the envelopes of buildings. To study the influence of PCMs in external building walls, a one-dimensional transient heat transfer model has been developed and solved numerically using a finite difference technique. Different external building wall configurations were analyzed for a typical building wall by varying the location of the PCM layer, the orientation of the wall, the ambient conditions and the phase transition temperature of the PCM.

The integration of a PCM layer into a building wall diminished the amplitude of the instantaneous heat flux through the wall when the melting temperature of the PCM was properly selected according to the season and wall orientation. Conversely, the results of the work show that there is no significant reduction in the total heat lost during winter regardless of the wall orientation or PCM transition temperature. Higher differences were observed in the heat gained during the summer period, due to the elevated solar radiation fluxes. The high thermal inertia of the wall implies that the inclusion of a PCM layer increases the thermal load during the day while decreasing the thermal load during the night.

1. Introduction

The idea of integrating Phase Change Materials (PCMs hereafter) into building walls has been studied since the early 1980s, although their use has been increasing in the last decade, due to the need to reduce energy consumption and the cost of Heating, Ventilating and Air Conditioning (HVAC) systems [1]. Currently, people spend most of their time in enclosed spaces and demand narrow temperature ranges to live comfortably. Consequently, there has been an increase in both our energy demand, as well as the release of polluting agents into the environment [2].

Traditional building materials store energy in sensible forms, and by varying their temperature, these materials contribute to a decrease in the magnitude of internal air temperature swings. The main drawback of these materials is the heavy masonry walls that are needed to stabilize the temperature swings, due to their limited thermal capacity [3]. An alternative solution is the use of PCMs, which store part of the energy in a latent form (constant temperature) by melting or solidifying, provided that a suitable material is selected [4].

In general, a PCM to be used for thermal energy storage should have a high heat of fusion, high thermal conductivity, high specific heat and density, long-term reliability during repeated cycling and low volume change during phase transition, should be non-corrosive, non-toxic and non-flammable and should exhibit little or no supercooling [5]. Two main PCM groups, organic and inorganic, are differentiated. Inorganic PCMs (salt hydrates and metallics) exhibit supercooling and phase segregation during transitional processes. Organic PCMs, such as paraffins, fatty acids and polyethylene glycol, show little supercooling or segregation, are available over a large temperature range and are compatible with conventional construction materials. However, these materials are flammable and have low thermal conductivity [6].

For this study, the material chosen is the granulate PCM Rubitherm GR, which is commercially available at different melting temperatures. The composition of the granule is 65% ceramic and 35% paraffin wax. This PCM offers the advantage of maintaining its macroscopic solid form during a phase change. The PCM is bound

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