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SONNENSTRAHLUNGSBELADENE LATENTWÄRMESPEICHER IN GEBÄUDEFASSADEN

ABHANDLUNG
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DOKTOR DER TECHNISCHEN WISSENSCHAFTEN
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Summary

A translucent external wall system for solar space heating is described here. The passive solar wall is composed of a translucent phase change material (PCM) storage device covered by transparent insulation material (TIM) which decreases the thermal losses to the environment. Because all the system components transmit visible light, this wall type can be used for daylighting purposes as well. Depending on the materials chosen, optical selective transmission of solar radiation can be obtained. This means that visible solar radiation is mainly transmitted, whereas invisible radiation is mainly absorbed and converted into heat, in particular phase change. Therefore, energy is stored and can be used for space heating purposes with a certain time delay. The investigations concentrated on a salt hydrate PCM, $CaCl_2{\cdot}6H_2O$ with additives, which has a heat of fusion of 192J/g. This mixture does not show a sharp, definite melting temperature but rather a melting region between 24 and 29°C. The investigations can be divided in three parts: measurements, modeling and simulations.

In the experimental phase, spectral optical transmittance and reflectance measurements were performed. They showed that slabs of this PCM with thicknesses of a few centimeters are opaque for radiation with a wavelength longer than 1400nm. In another laboratory experiment, melting in a PCM slab was induced by an artificial light source. The thermal state of the storage device was detected by 12 thermo-electric couples and the transmitted and the reflected radiation by optical sensors as a function of time respectively the ratio of melted material to the total amount of material. A prototype wall system was built into an outdoor test facility and exposed to natural weather for five months during winter. In this prototype, the PCM was encapsulated in commercially available glass blocks. A capillary structure made of PMMA was used as transparent insulation. A heating/cooling apparatus controlled the temperature in a narrow air gap behind the prototype wall to 20°C, representing an interior room of a building. Altogether 58 system and climate parameters (temperatures, heat fluxes and irradiances) were measured in time intervals of two minutes. Hourly mean values were used for system analysis.

In order to describe the behaviour of the thermal storage device, a melting/solidification model was used in which continuous thermal properties of the PCM were assumed. Heat conduction was the only energy transport mechanism taken into consideration. A Monte Carlo method was chosen to describe the propagation of light in the storage material. In the model, the spectral dependence of the absorption coefficient and the scattering of light in the bulk of the PCM at low temperatures were taken into account. The results of the Monte Carlo simulations were used in a modular simulation program which was built to describe the overall behaviour of the TIM-PCM wall system.

The system simulation program was validated with the long-term measurements on the prototype wall and used as a tool for sensitivity analysis of system parameters. A south facing façade was assumed and the semi-synthetic climatic data of the design reference year (DRY) for the location Zurich-airport was chosen as the outer boundary condition and a constant temperature of 20°C as the inner. The parameters of the prototype wall were used and a thickness of the PCM layer of 3cm was assumed. If the PCM was in the melting region, typically a heat flux into the room of about 30-40W/m^2 resulted. In December, which is the month with the lowest irradiation, a mean energy flux of 13W/m^2 into the building and a mean system efficiency of 0.27 was obtained. Simulations were performed assuming fictitious PCMs, with the same optical and thermal properties as the salt hydrate PCM used in the experimental investigations but altering the mean melting temperature. The climatic data DRY Zurich-airport from November, December and January were used as the outer boundary condition. These simulations showed that a decrease of the mean melting temperature to 21°C leads to an increase of time in which the building does not lose energy. In this case only during 1% of the time energy losses through the south facing façade occur. Because the ratio of melted material to the total amount of material is higher on the average, a larger amount of light is transmitted into the room. However, at the same time, because of the smaller difference between storage temperature and room temperature, the mean energy flux into the room decreases.

Further parameter studies indicate that with an opaque outer surface of the PCM storage device with a solar absorptance of 0.9 the system efficiency increases in December by 5% (to 0.32). However, such an external wall system would not be able to transmit visible light for daylighting purposes.