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PHASE CHANGE MATERIALS FOR DAY LIGHTING AND GLAZED INSULATION IN BUILDINGS

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Abstract

This paper presents the experimental solar transmittance measurements of commercial grade Phase Change Material (PCM). The effects of ambient temperature, solar radiation and thickness on transmittance have been studied. The study indicates that the PCM has higher transmittance than water. High transmittance, low thermal conductivity and high latent heat of fusion make it suitable transparent insulating building material (i.e. Window, sky roof etc.).

Keywords: Phase change material, Latent heat, Solar transmittance, Thermal conductivity.

1. Introduction

Low energy consumption in buildings can be achieved by control of passive solar heat gains. In the hot climate, solar heat gain is main load for cooling systems where as in cold climate, enhancement of the passive solar heat gain can reduce the heater load. Exterior glass windows in buildings can provide the necessary day lighting but have adverse effect on energy consumption. Transparent insulating phase change materials can be one of the ways to achieve this objective. They can store solar thermal energy and has the advantages of high storage density and the isothermal nature of the storage process. The information on the latent heat thermal energy storage (LHTES) materials and systems is enormous and published widely in the literature but very limited efforts have been made to utilize these as transparent day lighting medium in windows [1].

LHTES materials usually have low thermal conductivity, and these materials can act as self insulators. Because of the poor thermal conductivity and good optical

Abbreviations

ADAM	Advantech Data Acquisition Modules
LHTES	Latent Heat Thermal Energy Storage
PCM	Phase Change Material
RTD	Resistance Temperature Detector

transmittance, these materials can be used as transparent insulation and can also trap the heat. Many PCMs are highly transparent for the visible part of solar spectrum where as the infrared part is absorbed within the PCM [2]. But no efforts have been made to study the optical transmittance of these materials [3]. Such materials can be useful for trombe walls, solar windows and shutters [4]. When the sun is shining, the heat can be stored by the PCM, and this stored heat can be transmitted to the living space when the sun is not shining.

The main objective of the present study is to measure the solar transmittance of a PCM in the liquid phases experimentally for different thickness under natural solar radiation and ambient conditions.

2. Experimental Set-up and Measurements

The experimental set up consists of a cuboidal shape glass box of dimensions of 560 mm in length, 460 mm in width and 48 mm in height for the PCM. The glass used to make the box is 4 mm toughened glass. The top portion of the box slides and the inside is divided into two equal compartments of 280 mm of length by a vertical glass divider and it is made leak proof so that experiments with two materials can be run simultaneously. The experimental set up is shown in Fig. 1.

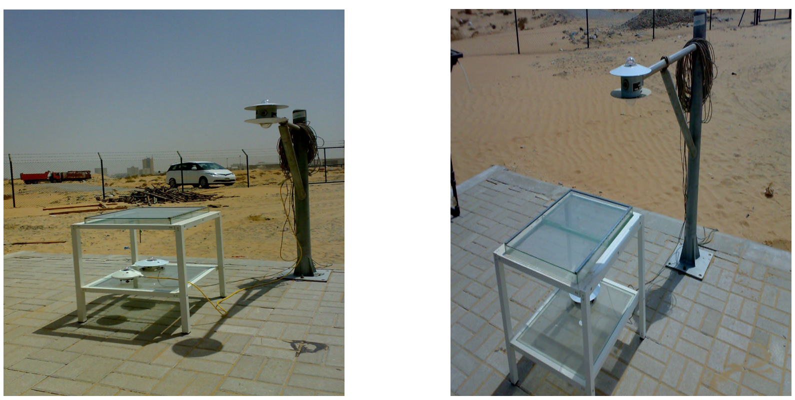

Fig. 1. Experimental Set-up.

Three pyranometers have been used for measurements of global solar radiation and transmitted solar radiation through the two materials placed in different compartments of the set up. The ambient temperature is also measured using a Pt 100 RTD (Platinum resistance temperature detector). Measurements from pyranometers and ambient temperature were recorded at an interval of 1 s using Advantech Data Acquisition modules (ADAM) with an accuracy of ±0.1% or better. High precision pyranometers were used for measurements. Two Eppley laboratory Pyranometers with calibration factors of 7.99×10^{-6} and 7.89×10^{-6} $V/W/m^2$ were used. A third Pyranometer from Kipp and Zonen with a calibration factor of 8.85×10^{-6} $V/W/m^2$ was also used.

Experiments were conducted at the test site of CSEM UAE Innovation Center LLC, Ras Al Khaimah (latitude 25.62°N, longitude 55.93°E), United Arab Emirates. Experiments were conducted between 11:15 am to 1:15 pm. This duration has been selected because it is almost symmetrical about the solar noon for the location, to avoid the effect of shading of the container on the PCM and to have the smaller angle of incidence of the solar radiation.

Commercial grade PCM (purity 99.3%) has been chosen for solar transmittance testing. Thermo physical properties are given in Table 1. The PCM was selected on the basis of adequate melting point, high latent heat of fusion and low thermal conductivity. The melting point was chosen to be near to the average ambient temperature as this is suitable for PCM in a glazing application. As sun rises, PCM will become liquid, so the user will gain the advantage of natural daylight through the PCM glass window. Its low conductivity will act as thermal barrier between the outside and inside of the building and will not allow the heat to flow in either direction. Simultaneously it will store the heat due to its heat capacity. Thus the PCM can act as a transparent insulating material.

Table 1. Thermo-Physical Properties of PCM.

Melting point [b]	31.98°C
Heat of fusion [b]	236.17 kJ/kg°C
Solid specific heat [a]	2.15 kJ/kg.K
Liquid specific heat [a]	2.18 kJ/kg.K
Solid thermal conductivity [a]	0.34 W/m.K
Liquid thermal conductivity [a]	0.15 W/m.K
Density [a]	777 kg/m^3 @ 25°C

a: From literature [1] b: From differential scanning calorimeter measurement

3. Results and Discussions

A number of experiments were conducted to measure the solar transmittance of the PCM. Measurements of the average PCM solar transmittance for thicknesses in the range of 4 to 30 mm, the average solar radiation and average ambient temperature are tabulated in Table 2. Variation of the PCM average solar transmittance as a function of the thickness of the PCM is shown in Fig. 2. A linear regression shows a best curve fit with the experimental results. The coefficient of determination, R^2, was found to be 0.992, which indicates the goodness of fit.

Table 2. Solar Transmittance Measurements for Various Thicknesses under Outdoor Conditions.

PCM thickness (mm)	Global solar radiation (W/m^2)$^+$	Ambient temperature (°C)$^+$	PCM transmittance (%)$^{+,*}$
4	744.2	38.7	67.6
10	775.3	40.1	65.3
15	786.6	40.6	63.9
20	771.8	38.9	62.9
30	698.8	38.6	59.9

+ These values are averaged values during the different days of measurements
*** This value is system transmittance values with PCM layer between two glass covers.**

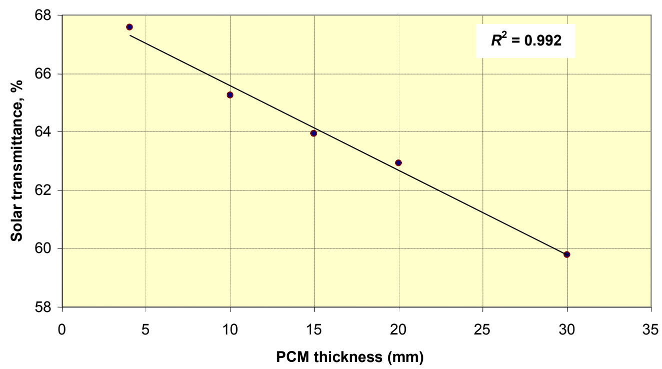

Fig. 2. Variation of Average PCM Solar Transmittance with PCM Thickness.

A trend of solar transmittance of PCM for the thickness of 4 mm and 30 mm for experimental duration on typical day is shown in Fig. 3. It shows that there is significant drop (around 7.7%) in PCM transmittance. Therefore, melting point and thickness of PCM seems to play an important role in the selection of PCM as a transparent insulating material for variety of applications.

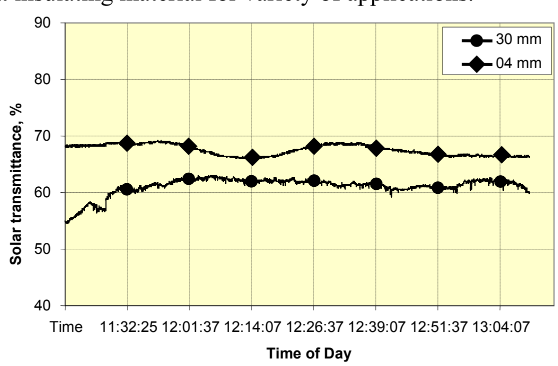

Fig. 3. Variation of Average PCM Solar Transmittance over a Day.

Experiments with air and water were also conducted and a comparison for solar transmittance of PCM, water and air is shown in Table 3. Results show that PCM has higher transmittance (63.9%) than water (60.4%) for the thickness of 15 mm.

Table 3. Comparison of Solar Transmittance of PCM with Water and Air.

Material	Transmittance @15 mm
PCM	63.9
Water	60.4
Air	74.6

Transmittance of PCM alone is given in Table 4 for different thickness, which varies 90.6% (for 4 mm) to 80.2% (30 mm) respectively. Therefore, transmittance of PCM (85.6%) alone is higher than water (80.9%) for 15 mm thickness. PCM transmittance is almost in the same range of toughened glass with low iron content for 4 mm thickness.

Tab. 4. Transmittance of PCM Alone.

PCM thickness (mm)	4	10	15	20	30
PCM alone transmittance (%)	90.7	87.5	85.7	84.4	80.3

4. Conclusion

In the present study, the solar transmittance of PCM for different thicknesses were measured and presented. The transmittance of the liquid phase PCM is higher than the water for the same thickness. High transmittance and low thermal conductivity makes it suitable transparent insulating medium for building material (i.e. Window, sky roof etc.). Melting point and thickness of PCM plays an important role in the selection of PCM as a transparent insulating material for variety of applications. Transparent insulating PCM could be suitable to save energy on one side and reduction of CO_2 gas emissions on another side.

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