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Modelling and experimental study of TIM application in passive solar energy buildings

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ABSTRACT

A computer simulation model has been established to describe the behavior of passive solar houses with transparent insulation (TIM) walls. It is used to address the problems of TIM passive solar house performance. The brief descriptions of the model and its results are presented.

This paper also details the method for the TIM wall thermal performance assessment by using a newly built Illuminated Hot Box. The TIM and its absorptive wall can be easily changed. Using a solar simulator, various parameters of a TIM wall can be tested The experimental data were used to drive the simulation model, providing a method to assess the TIM passive solar performance in buildings. The preliminary results for a Polycarbonate Honeycomb TIM without absorber wall are obtained, which shows good agreement with the simulation results.

INTRODUCTION

For the development of TIM applications in passive solar buildings an increased demand for simulation and energy calculations has led to the TIMWAL-2 simulation model. It can be used with given design data to do any calculations of specific parameters, e.g., the absorber surface temperature and the room temperature under certain weather conditions.

In order to obtain actual data for any kind of TIM passive solar building, the Illuminated Hot Box was built. Various kinds of TIMs and combinations of TIM walls can be tested on it. As it is tested using a solar simulator, it can be operated at any time and any weather. It can also be used to do research on TIM or TIM walls, e.g., it is easy to change samples and change the positions of the TIM or walls, so that different data can be obtained.

The experimental results have been used to validate the simulation model. The experimental results for the heat transmission and conduction through a TIM are below.

BRIEF DESCRIPTION OF THE SIMULATION MODEL

A detailed TIM passive solar house simulation model was developed. TIM is treated as a homogeneous material [3] with overall transmittance and absorptance values. Solar energy absorbed by the

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Tim and the absorber and each of the optical layer is calculated by using equation from [2]. Infrared radiation exchange between surfaces is modeled with an effective radiation heat transfer coefficient. The heat conduction under solar radiation is considered [2]. The conduction heat transfer through the absorptive wall is modeled by using a simple unsteady state heat transfer equation:

$$T_i^{p+1} = \frac{\alpha \Delta\tau}{\Delta X^2} (T_{i+1} + T_{i-1} - 2T_i) + T_i$$

where t_i, T_{i-1} and T_{i+1} are the temperatures at nodes i, $i-1$ and $i+1$ in the wall at time p, C;

T_i^{p+1} is the temperature at node i at time p+1, C;
ΔX is the node interval, m;
$\Delta\tau$ is the time increment, s;
α is the thermal conductivity of the wall, W/m.C.

The conduction heat transfer through other building walls including the ceiling and the floor is modelled with the following equations [5], derived from transfer function relations,.

$$q_{s,o} = a_s T_a - b_s T_i + K_{s,o}$$

$$q_{s,i} = b_s T_a - c_s T_i + K_{s,i}$$

where $q_{s,o}$ and $q_{s,i}$ are the conduction heat fluxes into the wall at the outside surface and from the wall at the inside surface, W/sq m;
T_a and T_i are the temperatures of the absorber surface and inside surface, C;
a_s, b_s, $K_{s,o}$, c_s, $K_{s,i}$ are the heat transfer function coefficients, which can be obtained from the data given by [4].

Using the actual situation in China as an example, Fig.1 shows the

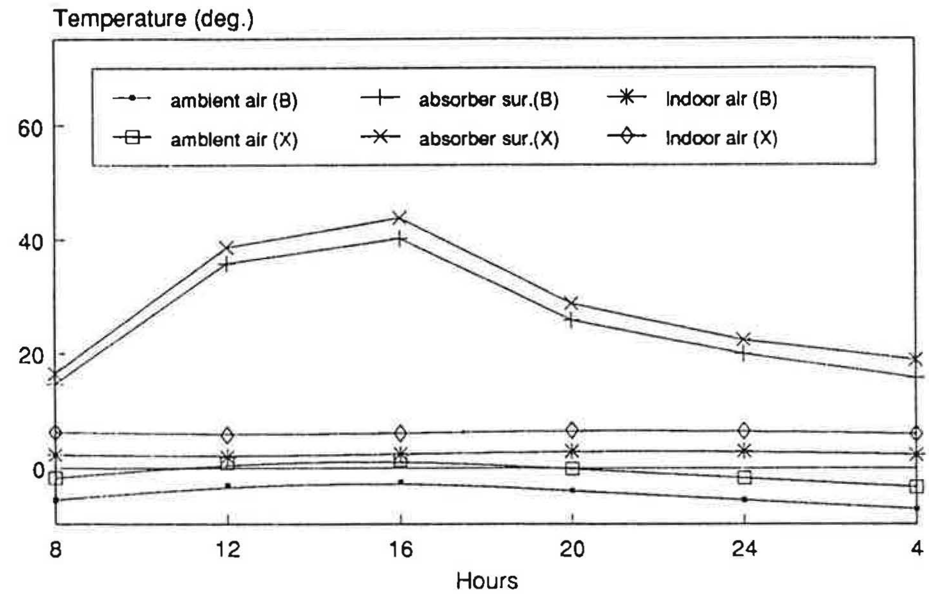

Fig.1 Temperature profiles of monthly days in Beijing (B) and Xian (X) areas

temperature profiles of ambient air, absorber surface and inside room air in the Beijing and Xian areas. The room air temperature can be kept at about 8 degrees in the coldest month - January in Xian area. This result has great significance for southern China [6].

THE ILLUMINATED HOT BOX EXPERIMENT

As shown in Fig.2, solar radiation from the solar simulator passes through a transparent cover to the test sample -- the TIM or TIM wall. Most of the solar energy is transmitted and conducted into the test cell, in which a solar absorber is installed with a selectively-coated surface. The amount of energy absorbed can be measured by a water circulating loop.

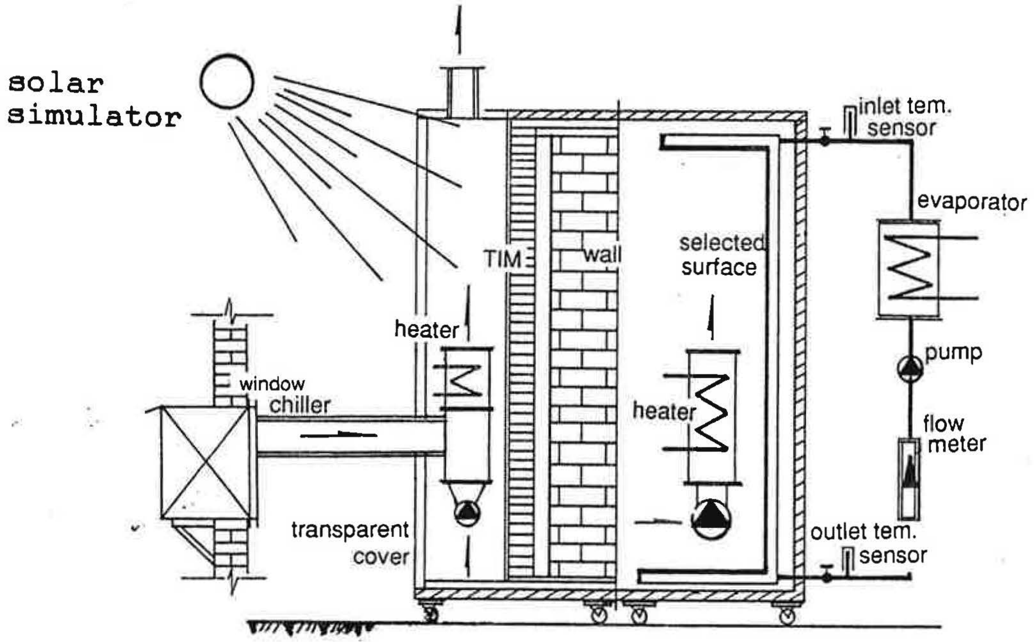

Fig.2 Principle diagram of Illuminated Hot Box Experiment

In order to obtain the transmittance and the heat conduction values through honeycomb TIM and find the parameters necessary to drive the simulation model, the experiment at different radiation levels was done. Fig.3 shows the experimental results for the heat transferred through a honeycomb TIM without a wall under solar simulator. the thermal transmission is dependant on the temperature difference (Tn-Ti) on the both sides of the TIM and the incident radiation flux. The less the incident radiation, the more the heat loss to outside because of heat conduction.

Many other experiments are planned for this apparatus, such as to test TIM walls of other types and to study the influence of some factors on TIM walls, e.g., the air gap, the Trombe wall and so on.

CONCLUSIONS

The dynamic simulation of a TIM passive solar building shows that a TIM wall can greatly reduce the conventional energy heating load, especially in the areas where the ambient temperature is not very

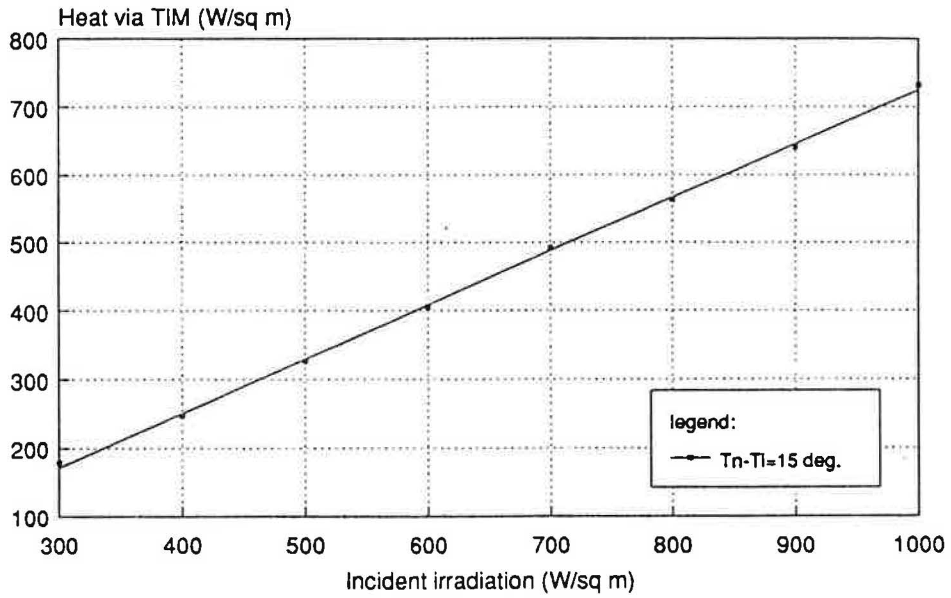

Fig.3 Heat transferred through honeycomb TIM by transmission and conduction

low, e.g., southern China. The simulation model can be used as a tool to analyze the potential benefits of TIM passive solar buildings.

The construction of the Illuminated Hot Box has the advantage of obtaining the experimental data for TIM passive solar houses. Using a solar simulator is easy to perform any experiment and is not affected by bad weather. The results show good agreement with the results from the simulation model and previous experiments [2].

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