行政院國家科學委員會專題研究計畫 成果報告

數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應
研究成果報告(精簡版)

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報 告 附 件 ：赴大陸地區研究心得報告
出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫涉及專利或其他智慧財產權，2 年後可公開查詢

中 華 民 國 99 年 10 月 31 日

附件一

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告 □期中進度報告

數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應

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中　華　民　國 99 年 10 月 25 日

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Numerical HVAC analysis of shape-stabilized phase change material plates coupling an active building envelope system in a building

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Abstract

Effect of shape-stabilized phase change material (SSPCM) plates combined with night ventilation in summer is investigated numerically. A building in Hsinchu, Taiwan without active air-conditioning is considered for analysis, which includes SSPCM plates as inner linings of walls、 the ceiling and floor, and an active building envelope system (ABE) is installed as well in the room becomes the Hybrid system. Unsteady simulation is performed using a verified enthalpy model, with time period covering the summer season. In the present study, a kind of floor with SSPCM is put forward which can absorb the solar radiation energy in the daytime or in summer and release the heat at night or in winter. In the present paper, the thermal performance of a room using such floor、wall and ceiling were numerically studied. Results show that the average indoor air temperature of a room with the SSPCM floor was about 2 K to 4 K higher than that of the room without SSPCM floor, and the indoor air temperature swing range was narrowed greatly. This manifests that applying SSPCM in room suitably can increase the thermal comfort degree and save space heating energy in winter.

Keywords: Shape-stabilized phase change material, active building envelope system, HVAC, renewable energy

I. Introduction

The scientists all over the world are in search of new and renewable energy sources. One of the options is to develop energy storage devices, which are as important as developing new sources of energy. The storage of energy in suitable forms, which can conventionally be converted into the required form, is a present day challenge to the technologists. Energy storage not only reduces the mismatch between supply and demand but also improves the performance and reliability of energy systems and plays an important role in conserving the energy [1, 2]. It leads to saving of premium fuels and makes the system more cost effective by reducing the wastage of energy and capital cost. For example, storage would improve the performance of a power generation plant by load leveling and higher efficiency would lead to energy conservation and lesser generation cost. One of prospective techniques of storing thermal energy is the application of phase change materials (PCMs). Unfortunately, prior to the large-scale practical application of this technology, it is necessary to resolve numerous problems at the research and development stage. One of problems is so called the Stefan problem [3]. The heat transfer characteristics of melting and solidification process arise in the presence of phase change and expressing the energy conservation across the interface. In literature, this solid-liquid interface boundary is known as Stefan or moving boundary problem. It may have low conduction heat transfer.

1. <u>Shape-stabilized PCM (SSPCM)</u>

In recent years, the Stefan problem has been resolved, a kind of novel compound PCM, the, Shape-stabilized PCM (SSPCM) has been attracting the interests of the researchers [4–6]. Fig. 1 shows the picture of this PCM plate. It consists of paraffin as dispersed PCM and high-density polyethylene (HDPE) or other materials as supporting material. Since the mass percentage of paraffin can be as much as 80% or so, the total stored energy is comparable with that of traditional PCMs.

Zhang et al. [7] investigated the influence of additives on thermal conductivity of SSPCM and analyzed the thermal performance of SSPCM floor for passive solar heating. To the authors' knowledge, no research work reported in the literature has made on the performance of shape-stabilized PCM application coupling the active building envelope system (ABE) in buildings combined with night ventilation. Therefore, the purpose of this study is to perform a numerical analysis on the thermal effect of shape-stabilized PCM plates as inner linings on the indoor air temperature under night ventilation conditions in summer, coupling the ABE system in a building, and for overall system of the building based upon a simulated room; a generic enclosure, combined with the climate report of Hsinchu city, Taiwan, 0am~24pm, 1st ~6th July., 2008. [8] to investigate: (1) feasibility study of the hybrid system (2) heating capability analysis (3) cooling capability analysis (4) indoor temperature levels. For the sake of simplification, thermal performance is the only consideration.

2. <u>Active building envelopes:</u>

A brief description of the proposed ABE system is provided here (see Fig. 2). For more details, see [9]. The ABE system is comprised of two basic components: a photovoltaic unit (PV unit) and a thermoelectric heat pump unit (TE unit). The PV unit consists of photovoltaic cells, which are solid-state devices that convert solar radiation energy into electrical energy. The TE unit consists of thermoelectric heaters/coolers (referred to here onwards as TE coolers), which are solid-state devices that convert electrical energy into thermal energy, or the reverse. The PV and the TE units are integrated within the overall ABE enclosure. As shown in Fig. 2, the PV unit forms an envelope surrounding the external wall such that a gap is maintained between the wall and the PV unit. This gap acts as an external heat dissipation zone for the TE unit. The external walls of the proposed ABE system consist of two layers, as shown in Fig. 2. The external layer (facing the PV unit) is made of a thermal insulating material, and the internal layer is made of a material with high heat storage capacity. In Fig. 2, the words ‘‘Thermal insulation’’ and ‘‘Thermal Mass’’ pertain to the external and the internal layers of the ABE wall, respectively. The TE coolers/heaters are dispersed inside the openings that are provided in the insulating layer. Each TE cooler/heater consists of two heat sinks. As shown in Fig. 2, the internal heat sink either absorbs or dissipates heat to the thermal mass layer. The external heat sink either absorbs heat from, or dissipates heat to, the surrounding air; through natural or forced convection.

The author’s team; Tsai BJ [10] just finished a project; In a building installed the ABE system without SSPCM, wind、solar driven, bypass the windmill flow as a air flow (as shown Fig. 3), ambient temperature, To is equal to 308 K and indoor temperature, Ti is 301 K. Numerical results show the Ti will decrease 2 K when the ABE operating with heat sinks, without fan. As fan is opened, strong convective heat transfer, Ti will decrease approximately 4~5 K.

3. Hybrid system:

Zhou et al. [11] in 2009 reported effect of shape-stabilized phase change material (SSPCM) plates in a building (as shown Fig. 4) combined with night ventilation in summer is investigated numerically. Their conclusions show that the SSPCM plates could decrease the daily maximum temperature by up to 2 K due to the cool storage at night. Under the present conditions, the appropriate values for melting temperature, heat of fusion, thermal conductivity and thickness of SSPCM plates are 26 C, 160 kJ kg^{-1}, 0.5Wm^{-1} C^{-1} and 20 mm, respectively. The ACH at night needs to be as high as possible but the ACH at daytime should be controlled.

4. Literature survey of numerical techniques :

During the phase change the solid–liquid interface moves away from the heat transfer surface. The difficulty in solving a phase change problem is the presence of a moving boundary or region on which heat and mass balance conditions have to be met. Generally, two approaches of the finite difference and finite element techniques are used to solve the phase change problems numerically. One of the methods to solve the moving boundary problem is enthalpy formulation [12, 13]. The enthalpy method is used in a particular way so that the only unknown variable is the temperature of the phase change material and the solidification occurs at a uniform temperature. In this work we use the modified enthalpy method treats the enthalpy as a temperature dependent variable and constructs the latent heat flow through the volume integration with the use of the enthalpy of the system [14, 15]. Heat transfer with moving boundary involving phase change is very important in latent heat storage application, i.e., ice formation, freezing of food, castings, metallurgy, crystal growth and various other solidification techniques. The predication of temperature distribution and rate of melting or solidification is very important in order to design such storage device.

II. Analysis method—Physical and Mathematic analysis and modeling

The analysis is designed to examine the indoor thermal comfort level under night ventilation when the SSPCM plates are used or not. A typical south-facing middle room (room A shown in Fig. 5) in a multi-layer building in Hsinchu city, Taiwan, is considered as the model room for analysis, which has only one exterior wall (the south wall) and others are all interior envelopes. The dimension of the room is assumed as 3.9 m (length) x 3.3 m (width) x 2.7 m（height). The south wall is externally insulated with 60-mm-thick expanded polystyrene (EPS) board. There are a 2.1 m x 1.5 m double-glazed window and 1.5 m x 1.5 m ABE system in the south wall and a 0.9 m x 2 m wood door in the north wall which is adjacent to another room or the corridor. The overall heat transfer coefficients of the window and door are 3.01 and 0.875Wm^{-2} C^{-1}, respectively. SSPCM plates are attached to inner surfaces of four walls and the ceiling as linings. Based on a practical consideration, no SSPCM is included in the floor structure. Thermo-physical properties of SSPCM and materials of building envelopes are shown in Table 1. The phase transition temperature range of SSPCM is assumed to be 1 K. Natural ventilation in the day and mechanical ventilation at night are considered. The total indoor heat produced by the equipments, furniture, light and occupants, etc. is assumed to be 50W (average value over the day). The summer climate data is generated by the software Medpha [8]. A verified enthalpy model [16] is applied for this simulation.

1 Heat transfer model of SSPCM wall and ceiling

The schematic of heat transfer through the exterior wall is shown in Fig. 6. The transient enthalpy equation is

$$\rho_j \frac{\partial H}{\partial t} = k_j \frac{\partial^2 T}{\partial x^2} \tag{1}$$

where for SSPCM, $H=\int_{T_0}^{T_1} c_{p,s}dT+\int_{T_1}^{T_2} c_{p,m}dT+\int_{T_2}^{T} c_{p,l}dT$,

for the insulation layer and the hollow brick layer,

$$\begin{cases}\rho_j=\rho_i, & k_j=k_j, & c_{p,j}=c_{p,i} & 0\le x<x_1\\ \rho_j=\rho_b, & k_j=k_b, & c_{p,j}=c_{p,b} & x_1\le x<x_2\\ \rho_j=\rho_p, & k_j=k_p & & x_2\le x<x_3\end{cases}$$

The initial condition is

$$T(x,t)_{t=0}=T_{init} \qquad (2)$$

For the surfaces exposed to the outside and inside air, the boundary conditions are

$$q_{r,out}+h_{out}(T_{out}-T_{i,out})=-k_i\left.\frac{\partial T}{\partial x}\right|_{x=0} \qquad (3)$$

$$q_{r,in}+h_{in}(T_{in}-T_{i,in})=-k_p\left.\frac{\partial T}{\partial x}\right|_{x=x_3} \qquad (4)$$

For the exterior wall, $q_{r,in}$ and $q_{r,out}$ are indoor and outdoor radiation heat flux, respectively (Fig. 6). The convective coefficients h_{out} and h_{in} are calculated according to the ASHRAE Handbook [17].

The above equations are also applicable to interior walls and the ceiling. For the interior walls, h_{out} and $q_{r,out}$ are zero. For the ceiling (Fig. 7), the surface at $x=0$ is assumed insulated and the inner surface corresponds to convective heat transfer coefficient h_c and thermal radiation $q_{r,c}$. Thermal radiations among the internal surfaces of walls, floor and ceiling are calculated by thermal radiation network method [18].

2 Heat transfer model of the SSPCM floor

For floor construction shown in Fig. 8, the transient heat transfer equation is

$$\rho_j c_{p,j}\frac{\partial T}{\partial t}=k_j\frac{\partial^2 T}{\partial y^2} \qquad (5)$$

ρ_j, k_j and $c_{p,j}$ are as follows:

$$\begin{cases}\rho_j=\rho_i, & k_j=k_j, & c_{p,j}=c_{p,i} & 0\le y<y_1\\ \rho_j=\rho_a, & k_j=k_a, & c_{p,j}=c_{p,a} & y_1\le y<y_2\\ \rho_j=\rho_f, & k_j=k_f & c_{p,j}=c_{p,f} & y_2\le y<y_3\end{cases}$$

Again, the initial condition is

$$T(y,t)_{t=0}=T_{init} \qquad (6)$$

The boundary conditions are

$$\begin{cases} k_i\left.\dfrac{\partial T}{\partial y}\right|_{y=0} & y=0\\ -q_{gap}+\varepsilon\sigma(T_{i,un}^4-T_{i,up}^4)=k_i\left.\dfrac{\partial T}{\partial y}\right|_{y=y_1} & y=y_1\\ -q_{gap}+\varepsilon\sigma(T_{i,up}^4-T_{i,un})=k_f\left.\dfrac{\partial T}{\partial y}\right|_{y=y_2} & y=y_2\\ q_{f,up}+h_f(T_{in}-T_{f,up})=k_f\left.\dfrac{\partial T}{\partial y}\right|_{y=y_3} & y=y_3\end{cases} \qquad (7)$$

Where $q_{f,up}$ is the radiation heat flux from the walls and ceiling to the wood floor; for the air gap, heat flux q_{gap} be calculated by the following equation [19]:

$$q_{gap}=N_u\frac{k_a}{L_{gap}}(T_{i,up}-T_{f,un}) \qquad (8)$$

Where $T_{i,up}$, $T_{f,un}$ are the temperature at the upper surface of the insulation layer and at the under surface of the wood floor respectively. And N_u (Nusselt number) is calculated by the following equation:

$$N_u=\begin{cases}0.212(Gr_L P_r)^{1/4}, & Gr_L=1\times10^4-4.6\times10^5\\ 0.061(Gr_L P_r)^{1/3}, & Gr_L>4.6\times10^5\end{cases} \qquad (9)$$

When Gr_L is less than 10^4, only thermal conductivity is considered.

3 Model of the indoor air of hybrid system building

The energy conservation equation fir the indoor air is

$$c_{p,a}\rho_a V_R\frac{dT_a}{dt}=\sum_{i=1}^{N}Q_{w,i}+Q_{s,c}+Q_L+Q_{win}+Q_{ABE} \qquad (10)$$

Where $Q_{S,C}$ is assumed 70% of the total energy from the heat source [20], and $Q_{w,i}$, Q_L and Q_{win} QABE [9,10] are calculated by the following equations:

$$Q_{win}=h_{in}\times(T_{w,i}-T_{in})\times A_{w,i} \qquad (11)$$

$$Q_L=c_{p,a}\rho_a V_R\times ACH\times(T_{out}-T_{in})/3600 \qquad (12)$$

$$Q_{win}=U_{win}\times(T_{out}-T_{in})\times A_{w,i} \qquad (13)$$

$$Q_{ABE}=Q_{ph}=Q_{pc}+IV \qquad (14)$$

4. Model of the SSPCM

The phase change model is based on the enthalpy method as modified by Zivkovic and Fujii [21]. They split the enthalpy as sensible and latent heats and included the melting fraction f in the one-dimensional transient heat equation as given in Eq. (18) below,

$$H=h+L.f_1 \qquad (15)$$

Where, $h=\int_{T_m}^{T} c\,dT$

The local liquid fraction f_1: is given as,

$$f_1=\begin{cases}0 \quad if \quad T<T_m,(Solid)\\ 1 \quad if \quad T>T_m,(Liquid)\\ druing \; melting \; or \; solidification \; of \; the \; CV\\ f_1 \; is \; time \; dependent \; and \; between \; 0 \; and \; 1\end{cases}$$

Substituting in the one dimensional transient heat equation for constant conductivity, density, specific heat gives

$$c\frac{\partial T}{\partial t}=\frac{k}{\rho}\frac{\partial^2 T}{\partial x^2}-L\frac{\partial f_1}{\partial t} \qquad (16)$$

The whole domain of the rectangular storage is partitioned in N equidistant nodes. The control volume

(CV) associated with each node has a thickness Δx, while nodes 1 and N have half-thickness ($\Delta x/2$).

III. Numerical technique

1. Description of the model room

The model room for analysis, which has dimension assumed as 3.9 m (length) x 3.3 m (width) x 2.7 m (height) concrete chamber. The thickness of chamber is 300mm, except the floor and the south wall each wall was installed 50mm thick SSPCM. The south wall is externally insulated with 60-mm-thick expanded polystyrene (EPS) board. There are a 2.1 m x 1.5 m double-glazed window and 1.5 m x 1.5 m ABE system in the south wall and a 0.9 m x 2 m wood door in the north wall which is adjacent to another room or the corridor. Floor is made of the first 30mm thick wood layer, under that the second layer is 40mm SSPCM layer, in between is the air layer with 30mm thick. And the extended computational domain is six times larger than that of the model room. (see Fig. 9, Fig. 10)

2. Input parameters of the model room and applying software

In this study, using the Gambit to construct the solid model and grid mesh, then applying the Fluent as the solver of flow and thermal field. All parameters of the building and material properties of SSPCM were tabulated in Table 1. Regarding conditions of outside environments of the model room were listed in Table 2.

3. Establish grid cells

Cells of grid mesh of this model room as Fig. 11.

Outside environment (7505.784 m^3)：188520 cells
Concrete layer (11.565 m^3)： 285517 cells
SSPCM layer (2.364 m^3)：154989 cells
Inside air of room (18.72 m^3)：149760 cells
Floor-wood layer (0.2673 m^3)：7128 cells
Floor-air gap layer (0.2673 m^3)：7128 cells
Floor-SSPCM layer (0.3564 m^3)：7128 cells
Door-wood (0.09 m^3)：720 cells
Window-glass (0.21 m^3)：1680cells
Air layer front glass window (1.26 m^3)：4320 cells
Air layer front wood door (0.54 m^3)：10,080 cells

4. Settings of the Fluent

Settings of the Fluent software as below:

1. Solver：Segregated
2. Space：3D
3. Velocity Formulation：Absolute
4. Gradient Option：Cell-Based
5. Formulation：Implicit
6. Time：Unsteady
7. Unsteady Formulation：1^{st}-Order Implicit
8. Porous Formulation：Superficial Velocity

5. Initial conditions

The energy stored in cycle is: absorption heat

The ambient temperature is 303 K, 1atm and temperature of SSPCM layer is assuming a constant temperature 293 K, the optimal time (ie. Melting/fusing temperature, and its latent capacity is 265MJ/m^3。The initial condition (t=0) of indoor air temperature is assuming 303 K。 On the contrary,

The energy release in cycle is: removal heat

The ambient temperature is 289 K, 1atm and temperature of SSPCM layer is assuming a constant temperature 303 K, the optimal time (i.e. Melting/fusing temperature, and its latent capacity is 265MJ/m^3。The initial condition (t=0) of indoor air temperature is assuming 289 K。

Each time increment △t is 0.1 sec, then iterations up to the time we set, and need to satisfy the convergence criteria.

6. Boundary conditions

Using the embedding macro files of the Fluent to select our boundary conditions and our case is unsteady. And the maximum of solar radiation on the south wall is 900Wm^{-2} and the Hsin-Chu city in summer wind speed is southern 6 ms^{-1} 、average out door temperature is 302.96 K in winter wind speed is southern 6.6 ms^{-1} 、average out door temperature is 288.9 K (see Table 2）。

7. Convergence criteria

For the purposes of solving any number of flow field changes in the iterative process, Simulation convergence criteria as shown in table 3.

IV. Result and Discussion

1. Simulated temperature results of active ABE

Fig. 12 is the comparison of temperature distribution of active ABE for the fan was on (above) and off (below) in the summer. The gap is between solar panels and the TE wall as the hot side. The temperature can reach 313 to 318 K. Another side of TE produced the cooling effect, and through air-conditioning spread cool air to indoor space. Take the temperature condition at Y = 1.2m. The indoor temperature is 302 to 305 K with fan turning on, or the indoor temperature is about 304 to 307 without turning on the fan. The results show the fan can speed up TE cooling cold-side to spread quickly to the entire room.

2. Simulated PMV results of active ABE

ISO 7730 has recommended the use of the comfort indicators PMV (Predicted Mean Vote):

PMV provides for an average reference, to measure the comfortableness of human body in an environment. PMV index produced from many different testers, in the specific measurement environment, their subjective assessment for a number of environmental conditions. It is divided into seven stages, ranging from -3 (very cold) extends to +3 (extremely warm), neutral point of 0 for moderate heat conditions.

Fig. 13 is the PMV value when turning on and off the fan, i.e., the smaller the value of PMV, the more satisfaction. When the fan was on the indoor PMV value was about 0.69 to 1. When the fan was off the indoor PMV value was about 0.5 to 0.9.

3. Simulated temperature results of passive SSPCM

The energy stored in cycle is: absorption heat

The ambient temperature is 303 K, 1atm and temperature of SSPCM layer is assuming a constant temperature 293 K, the optimal temperature (ie. melting/fusing temperature, and its latent capacity is 265MJ/m^3。The initial condition (t=0) of indoor air temperature is assuming 303 K。Fig. 14 (a~f) simulated indoor air temperature vs. time (YZ plane at middle X) for the SSPCM in an energy stored cycle. At this time, initially t = 0, indoor air temperature is bigger than temperature of SSPCM layer, then all SSPCM layers start to absorb heat, Numerical results show as time increasing and the average indoor temperature will decrease. The average indoor temperature from 303 K drops to 295.93 K within 60 minutes. It produces cooling effect in the daytime or say in the summer. Except the average indoor temperature includes temperatures of wall-concrete、floor-wood、floor-air、door-wood and window-glass were tabulated in Table 4. On the contrary,

The energy release in cycle is: removal heat

The ambient temperature is 289 K, 1atm and temperature of SSPCM layer is assuming a constant temperature 303 K, the optimal time (i.e. Melting/fusing temperature, and its latent capacity is 265MJ/m^3。The initial condition (t=0) of indoor air temperature is assuming 289 K。Fig. 15 (g~l) simulated indoor air temperature vs. time (YZ plane at middle X) for the SSPCM in an energy released cycle. At this time, initially t = 0, indoor air temperature is smaller than temperature of SSPCM layer, then all SSPCM layers start to release heat, Numerical results show as time increasing and the average indoor temperature will increase. The average indoor temperature from 289 K climbs to 298.8 K within 60 minutes. It produces heating effect at night time or say in the winter. Except the average indoor temperature includes temperatures of wall-concrete、floor-wood、floor-air、door-wood and window-glass were tabulated in Table 5.

4. Comparison between numerical and analytical results for hourly variation of outdoor air temperature

Both of above discussions of SSPCM are idealized cases since the temperature of SSPCM was forced as constant, therefore latent heat capacity will be melting or fusing in a short period of time, and the temperature difference of the average indoor temperature will be large around 8 K to 9 K. In fact the average indoor temperature will be sinusoidal cycle with relation to optimal SSPCM temperature. The temperature differences of the average indoor temperature of both energy stored cycle and energy released cycle will around 2 K to 4 K. The analytical results have been reported by Xiao [22]. Therefore we can compare our numerical results with each other based upon hourly variation of outdoor air temperature in Hsin-Chu city on one day of July. (in here, indoor air temperature is simplified equal to outdoor air temperature). From Fig. 16 shows results of numerical and analytical are pretty consistent with each other.

V. Conclusions

The above numerical results coincide with each other. The active ABE system; a building installed the ABE system wind, solar driven, bypass the windmill flow as a air flow, ambient temperature, is equal to 308 K and indoor air temperature, 301 K. Numerical results show the indoor air temperature will decrease 2 K when the ABE operating with heat sinks, without fan. As fan is opened, strong convective heat transfer indoor air temperature will decrease approximately 4 K to 5K. Similarly, the hybrid system integrates the passive SSPCM system. The temperature differences of the average indoor temperature of both energy stored cycle and energy released cycle will around 2 K to 4 K. Hence the hybrid system will increase the function of ventilation. In comparison to natural convection, COP increases significantly, and it is quiet、 clean、 energy-saving and cost-saving. Therefore, this study established a closer to the actual physical situation in Hybrid system as a whole, including sub-systems in this new analysis. Several brief summary as:

(1) The Hybrid system's BIPV、TE、SSPCM heat sink efficiency gains can achieve energy-efficiency and clean. It can also reduce the CO_2 emissions.

(2) The Hybrid system can reduce the total input power and achieve proactive approach to achieve energy saving goals.

(3) SSPCM consists of paraffin as dispersed PCM and high-density polyethylene (HDPE) or other materials as supporting material. The total stored energy is comparable with that of traditional PCMs.

(4) SSPCM of ceiling and floor can use the same material, temperature range between 297 K to 300 K start energy stored cycle, and temperature range between 289 K to 293 K start energy released cycle.

(5) Reduce the temperature gradient between ceiling and floor to under 4 K will increase the comfortableness of humans.

(6) 297 K is the most comfortable temperature.

VI. Acknowledgement

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VII. References

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Figures

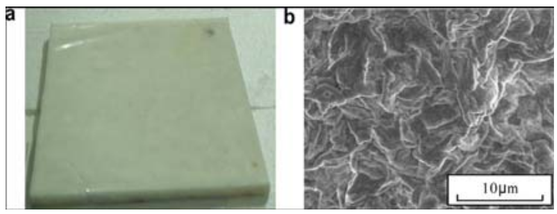


Fig. 1. The photos of the shape-stabilized PCM: (a) photo of the PCM plate; (b) electronic microscopic picture by scanning electric microscope (SEM) [6]

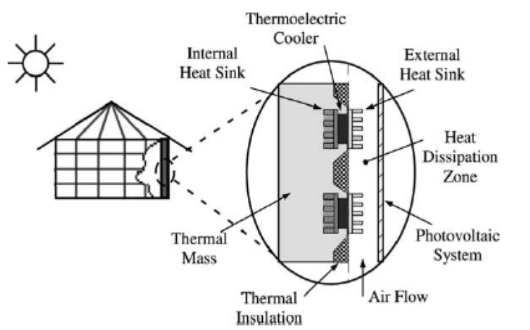


Fig. 2. Active building envelope (ABE) system [9]

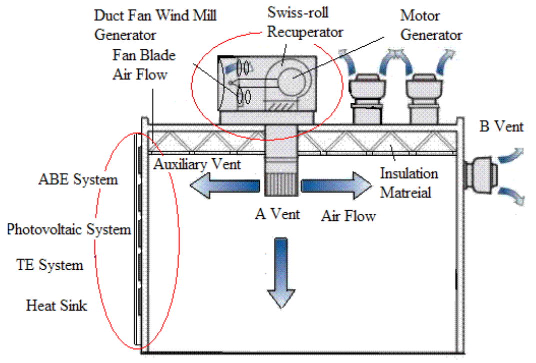


Fig. 3. Active building envelope (ABE) system with ventilation effect (Fan) [10]

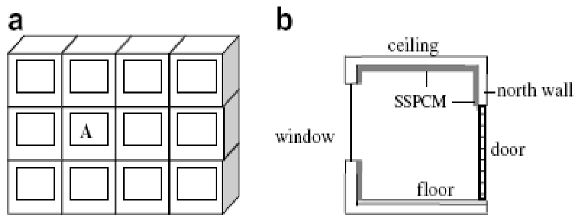


Fig. 4. Schematic of the simulated room: (a) location of the simulated room A in the building and (b) profile of the room A with SSPCM.

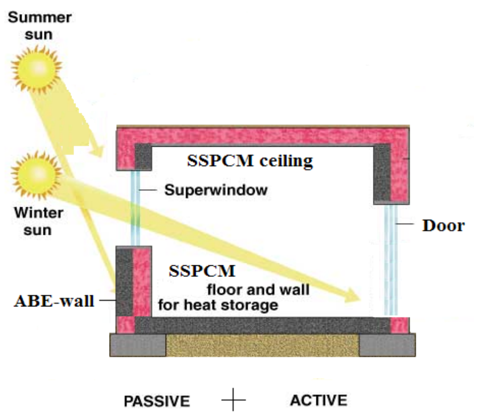


Fig. 5. Schematic of the simulated room with Hybrid system: profile of the room A with SSPCM and ABE wall

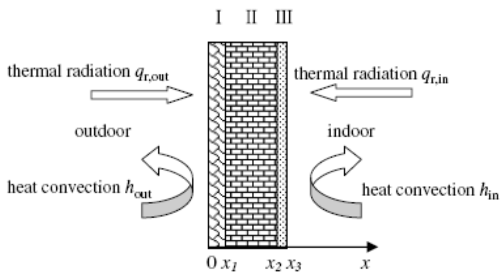


Fig. 6 Exterior wall surface

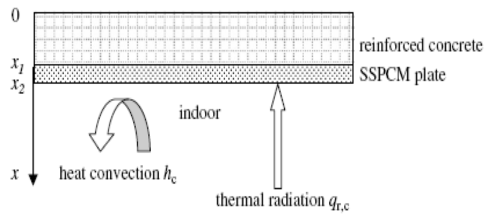


Fig. 7 Schematic of the ceiling heat transfer

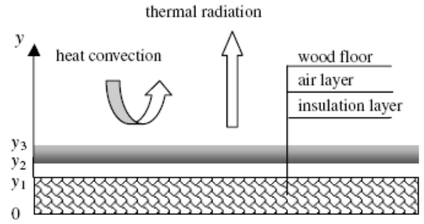


Fig.8 The floor

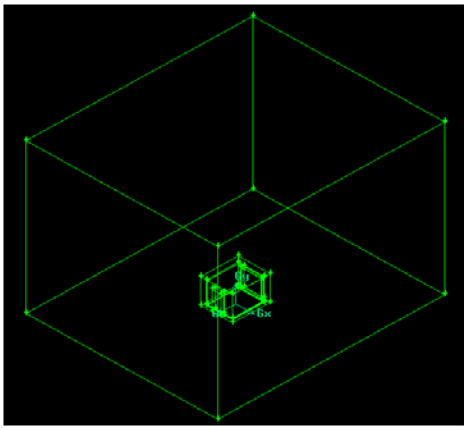


Fig. 9：Schematic diagram of computational domain means environments surrounding the model room。

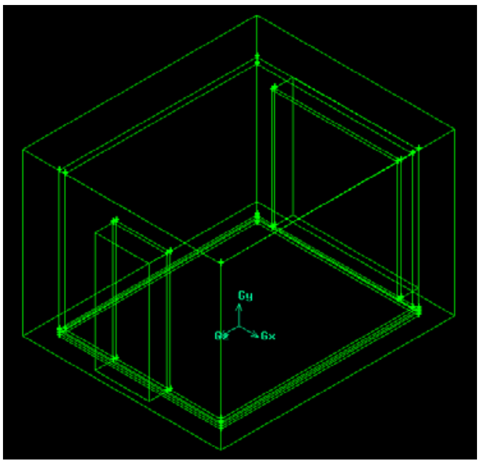


Fig.10：Schematic diagram of the model room for analysis of a building。

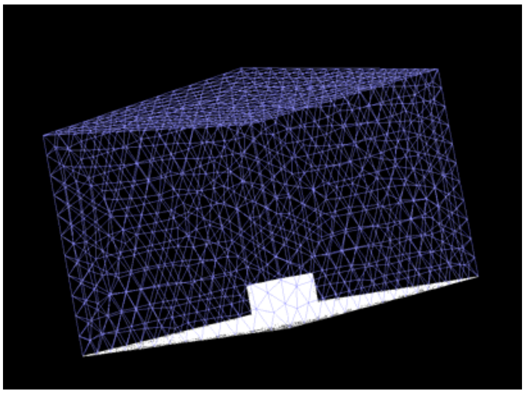


Fig.11：Grid mesh of the model room and environments

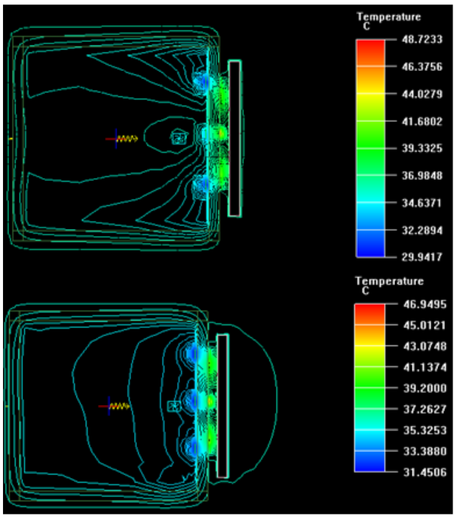


Fig. 12 Comparison of temperature distribution of the active ABE system for the fan was on (above) and off (below)

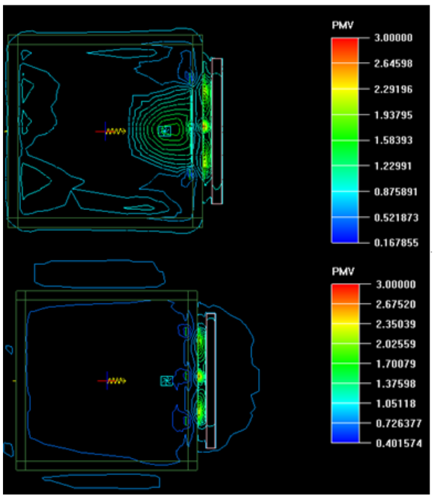
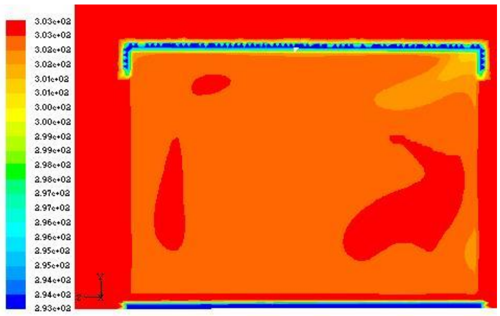
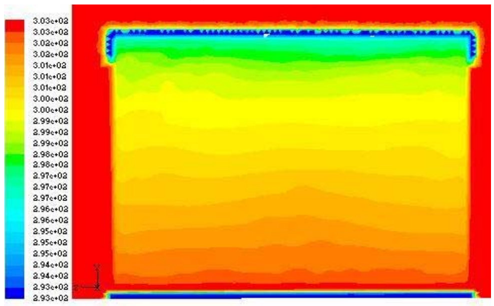


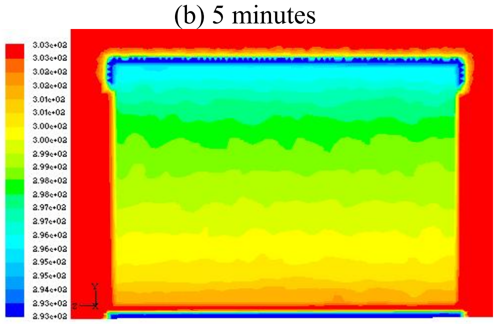
Fig. 13 the PMV value when turning on (above) and off (below) the fan



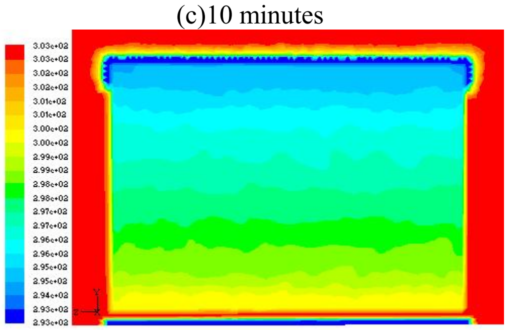
(a) 1 minute



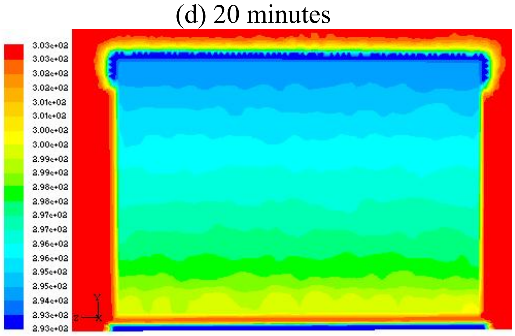
(b) 5 minutes



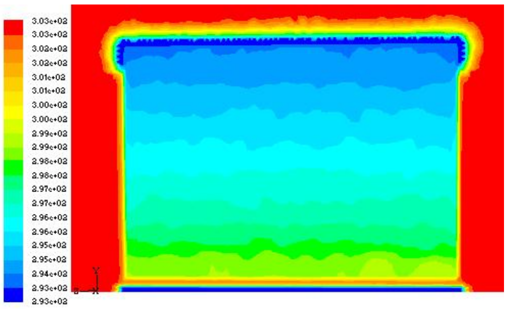
(c)10 minutes



(d) 20 minutes

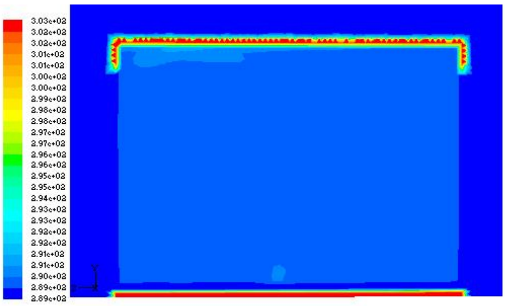


(e) 30 minutes

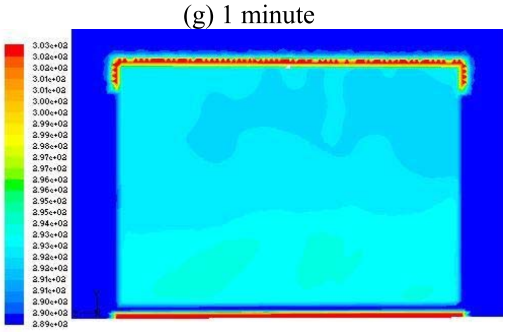


(f) 60 minutes

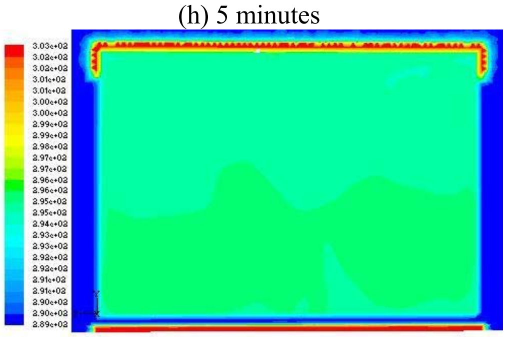
Fig. 14 (a~f) Simulated indoor air temperature vs. time



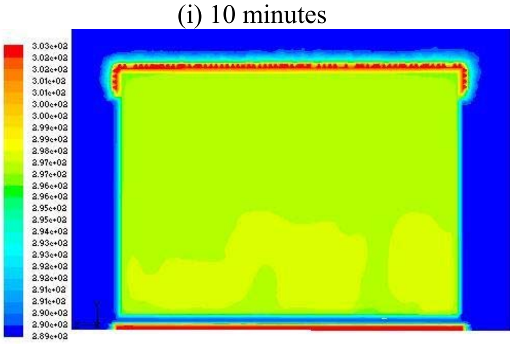
(g) 1 minute



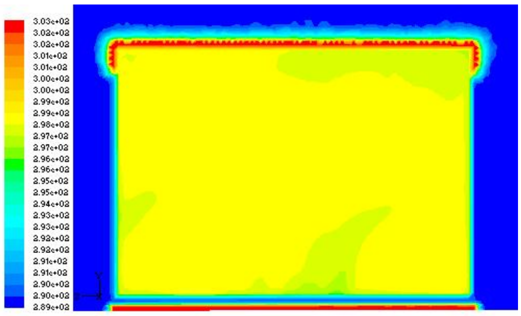
(h) 5 minutes



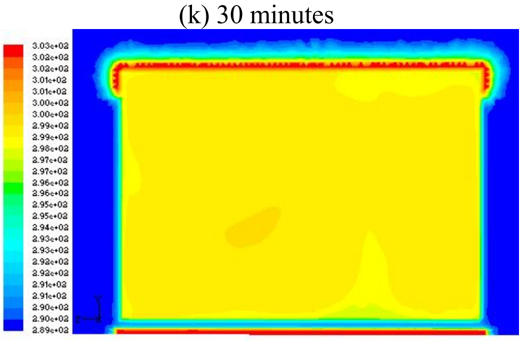
(i) 10 minutes



(j) 20minutes



(k) 30 minutes



(l) 60 minutes

Fig. 15 (g~l) Simulated indoor air temperature vs. time

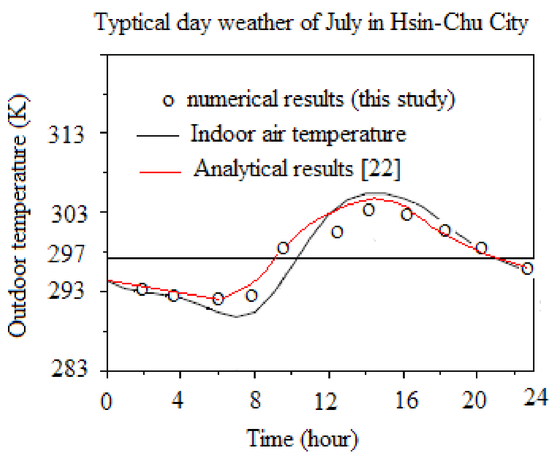


Fig. 16 hourly variation of outdoor air temperature in Hsin-Chu City。

Table 1：Material properties of the building

Materials	P (kgm^{-3})	C_p ($kJkg^{-1}℃^{-1}$)	*K* ($Wm^{-1}℃^{-1}$)	*U* ($Wm^{-2}℃^{-1}$)
SSPCM	850	1.0	0.2	-
Concrete	2500	0.92	1.75	-
Window / Glass	1400	1.05	0.58	3.01
Door /Wood	500	2.5	0.14	0.875

Table 2：Weather data of Hsin-Chu City

Season	Temperature (℃)	Wind speed (ms^{-1})	Pressure (Pa)
Summer	29.6	6 (Southern wind)	1044.8
Winter	15.9	6.6 (Northern wind)	1017

Table 3： Convergence criteria

continuity	x-velocity	y-velocity	z-velocity	energy
0.001	0.001	0.001	0.001	1e-06

Table 4: Average indoor air temperature vs. time for SSPCM storage energy, absorption heat

Time min	concrete	indoor-air	floor-wood	floor-air	door-wood	Window glass
1	302.97	302.35	302.97	298.00	302.99	302.99
5	302.88	300.27	302.85	297.91	302.96	302.95
10	302.78	298.60	302.71	297.82	302.91	302.90
20	302.60	296.99	302.42	297.66	302.81	302.80
30	302.45	296.38	302.14	297.51	302.70	302.69
60	302.08	295.93	301.37	297.12	302.40	302.40

Table 5: Average indoor air temperature vs. time for SSPCM release energy, removal heat

Time min	concrete	inside-air	floor-wood	floor-air	door-wood	Window glass
1	289.03	289.83	289.03	296.00	289.00	289.01
5	289.16	292.78	289.19	296.06	289.05	289.06
10	289.30	295.09	289.40	296.17	289.12	289.13
20	289.55	297.28	289.83	296.41	289.26	289.28
30	289.76	298.12	289.27	296.63	289.40	289.43
60	290.29	298.80	291.47	297.25	289.82	289.84

數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應

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國科會計畫編號. : NSC-98-2221-E-216-047

摘要

建築物在牆壁、天花板及地板鋪設穩態形狀相變材料板(SSPCM)以及整合主動式外表帷幕系統(ABE)形成混成系統，再以一棟位於台灣新竹地區沒有空調的建物為探討對象，來數值分析仲夏夜晚通風及空調情況，為完成對這創新觀念的混成系統可行性作分析評估，以及其在不同操作情況下之空調效能與室內溫度變化進行研究。每一系統及次系統元件都要非常小心的發展其數學模型，並利用數值方法進行求解，利用新竹地區七月份的一天或夏季氣候為條件，使用驗證過的焓模型(verified enthalpy model)暫態模擬進行分析解，同時用 Fluent 準確地計算出具有 SSPCM 與 ABE 系統混成建築物的空調系統之性能，本研究即是在地板、天花板及牆壁安裝 SSPCM，在白天吸收太陽輻射熱及 ABE 的 TE 熱，然後在夜晚或凌晨放熱，而對於被動式熱傳結合主動式熱傳的建築物系統，做出有效預測相變材料成份的溶解/硬化速率及溫度分佈，對普遍使用 PCM 當內能儲存系統(latent heat storage system)都是舉足輕重地重要。提高建築物的空調系統熱效率即是使用白天熱能提供晚上暖氣或提供節能省能的冷氣等本研究成果，相信可促成人們有健康、舒適地居住環境的美夢成真。

關鍵字：穩態形狀相變材料，主動式外表帷幕系統、空調系統、再生能源。

三、參考文獻

本研究所引用之文獻參考已載明於二、報告內容之第七項文獻參考。另本研究成果及參與人員之衍生成果著作於文獻的有:

國際期刊有二:

1. Bor-Jang Tsai 、Koo-David Huang and Chien-Ho Lee , "Hybrid Structural Systems of An Active Building Envelope System(ABE)", *Advanced material research*, in press. NSC-98-2221-E-216-047 (EI: ISTP)
2. Bor-Jang Tsai and Yu-Chun Fu, "Design and aerodynamic analysis of a flapping-wing micro aerial vehicle", *Aerospace science and technology* , Vol. 13, No.7, pp.383-392. NSC-94-2212-E-216-004 (SCI: EI: IF:0.674)

國外研討會有一:

3. Bor-Jang Tsai and Chien-Ho Lee," Active Building Envelope System(ABE)：Wind & Solar driven Ventilation、Electricity、Heat Pump", ESD2010, 2-4 June 2010 at The Empress Hotel, Chiang Mai, Thailand.

國內研討會有三、碩士論文有一:

4. 奈米UV噴墨在螢光薄膜噴塗作業影響之研究, 中華大學機械工程研究所碩士論文,臺灣新竹市,2010.
5. Bor-Jang Tsai(蔡博章)，Pang-Wei Wu(伍邦維), "圓柱型金屬氫化物(MH)儲氫罐系統之模擬研

究”，中國機械工程學會第二十六屆全國學術研討會論文集，中華民國九十八年十一月二十日、二十一日，成功大學 台南市。

6. Peng-Yu Chen(陳鵬宇)、Bor-Jang Tsai(蔡博章)、Chun-Mu Chen(陳俊沐),”摻雜Na與PbI2元素之PbTe材料熱電性質” 中國機械工程學會第二十六屆全國學術研討會論文集，中華民國九十八年十一月二十日、二十一日，成功大學 台南市。

四、計畫成果自評

本研究承蒙國科會經費贊助，非常感謝，也在參與人員努力下，有不錯成果。

研究內容預期達成目標情況為:

預期完成工作項目

(1)Develop physical/ mathematic models for Hybrid system (OK)

(2)Enthalpy formulation, PCM solid-liquid fraction model (OK)

(3)Finite difference-Fortran program code - Hybrid-HVAC programming (OK)

(4)Numerical solutions of building with SSPCM and ABE model (OK)

(5)Heating/cooling, COP, ACH and HVAC performance of the Hybrid system (OK)

本研究之主要成果:

(1) The Hybrid system’s BIPV、TE、SSPCM heat sink efficiency gains can achieve energy-efficiency and clean. It can also reduce the CO_2 emissions.

(2) The Hybrid system can reduce the total input power and achieve proactive approach to achieve energy saving goals.

(3) SSPCM consists of paraffin as dispersed PCM and high-density polyethylene (HDPE) or other materials as supporting material. The total stored energy is comparable with that of traditional PCMs.

(4) SSPCM of ceiling and floor can use the same material, temperature range between 297 K to 300 K start energy stored cycle, and temperature range between 289 K to 293 K start energy released cycle.

(5) Reduce the temperature gradient between ceiling and floor to under 4 K will increase the comfortableness of humans.

(6) 297 K is the most comfortable temperature.

相關成果數據正準備投稿J. of Applied Thermal Engineering or J. of Building and Environments。

合計有研討會4篇，期刊2篇(一篇準備中)，畢業碩士研究生1位。

真實體建造及實驗數據的驗證尚未周全，所以在申請專利過程尚需資源、經費及努力,但太陽能及風力等再生能源分析設計、系統規畫、建物之節能省能技術及熱流分析技術等，應可技轉到建築或營造及節能省能科技，Green Housing等行業上，希望更多資源、經費相信ABE與SSPCM系統會快應用到人類生活。

附件三

國科會補助計畫衍生研發成果推廣資料表

日期：99 年 10 月 25 日

國科會補助計畫	計畫名稱：**數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應** 計畫主持人： 蔡博章 計畫編號：NSC-98-2221-E-216-047 領域：能源科技		
研發成果名稱	建築物系統整合技術：氣、電、熱及綠建材之整合規劃技術 System integrated technique of building		
成果歸屬機構	中華大學	發明人 (創作人)	蔡博章
技術說明	建築物在牆壁、天花板及地板鋪設穩態形狀相變材料板(SSPCM)以及整合主動式外表帷幕系統(ABE)形成混成系統，再以一棟位於台灣新竹地區沒有空調的建物為探討對象，來數值分析仲夏夜晚通風及空調情況，為完成對這創新觀念的混成系統可行性作分析評估，以及其在不同操作情況下之空調效能與室內溫度變化進行研究。每一系統及次系統元件都要非常小心的發展其數學模型，並利用數值方法進行求解，利用新竹地區七月份的一天或夏季氣候為條件，使用驗證過的焓模型(verified enthalpy model)暫態模擬進行分析解，同時用 Fluent 準確地計算出具有 SSPCM 與 ABE 系統混成建築物的空調系統之性能，本研究即是在地板、天花板及牆壁安裝 SSPCM，在白天吸收太陽輻射熱及 ABE 的 TE 熱，然後在夜晚或凌晨放熱，而對於被動式熱傳結合主動式熱傳的建築物系統，做出有效預測相變材料成份的溶解/硬化速率及溫度分佈，對普遍使用 PCM 當內能儲存系統(latent heat storage system)都是舉足輕重地重要。提高建築物的空調系統熱效率即是使用白天熱能提供晚上暖氣或提供節能省能的冷氣等本研究成果，相信可促成人們有健康、舒適地居住環境的美夢成真。 Effect of shape-stabilized phase change material (SSPCM) plates combined with night ventilation in summer is investigated numerically. A building in Hsinchu, Taiwan without active air-conditioning is considered for analysis, which includes SSPCM plates as inner linings of walls、 the ceiling and floor, and an active building envelope system (ABE) is installed as well in the room becomes the Hybrid system. Unsteady simulation is performed using a verified enthalpy model, with time period covering the summer season. In the present study, a kind of floor with SSPCM is put forward which can absorb the solar radiation energy in the daytime or in summer and release the heat at night or in winter. In the present paper, the thermal performance of a room using such floor、wall and ceiling were numerically studied. Results show that the average indoor air temperature of a room with the SSPCM floor was about 2 K to 4 K higher than that of the room without SSPCM floor, and the indoor air temperature swing range was narrowed greatly. This manifests that applying SSPCM in room suitably can increase the thermal comfort degree and save space heating energy in winter.		

產業別	建築營造、房地產、節能省能及能源科技業、建築材料。
技術/產品應用範圍	節能省能 能源材料 環保 氣電熱整合/ 建築物帷幕系統、建築物節能省能系統規畫
技術移轉可行性及預期效益	Green Housing Shape-stabilized Phase Change Materials Save Energy and Protect Environment 技術移轉如是符合上述行業且需有研發能力則效益才能彰顯

註：**本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。**

附件五

國科會補助專題研究計畫項下赴國外(或大陸地區)出差或研習心得報告

日期： 99 年 10 月 01 日

計畫編號	NSC－98－2221－ E － 216－ 047		
計畫名稱	數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動是外表帷幕系統(ABE)之空調效應		
出國人員姓名	蔡博章	服務機構及職稱	中華大學機械工程學系教授
出國時間	2010 年 5 月 6 至 2010 年 5 月 9 日	出國地點	中國大陸,上海市

一、國外(大陸)研究過程

1. 出差行程規畫: 原來計畫書核定;國外或大陸地區差旅費計畫書原來核定(20000 元): 2009/9/24 – 2009/9/30 第五屆魯台科技交流與 2010 年世界太陽能學會, 大陸山東德州市(原因:作業不及), 3 月變更申請為: 2010/04/09 – 2010/04/12 中國低碳經濟論壇-大陸北京市(原因:總費用七萬元,經費不足), 因此才申請第二次變更為:
   2010/05/05 – 2010/05/08 SNEC 4th (2010) International Solar Photovoltaic Power Generation Conference & Exhibition (Expo)及世博會- 大陸上海市. 預計 5/6 出發, 5/9 日返國.
   出差活動日程: 四天三夜
   2010/05/06 桃園國際機場 → 上海市 浦東機場 搭乘長榮航空 BR0702 班機
   2010/05/07 上海市五角場快捷假日酒店 → 上海國際展覽館 上海 SNEC 4th (2010) International Solar Photovoltaic Power Generation Conference & Exhibition 上海 SNEC 第四屆國際太陽能光伏展
   2010/05/08 上海市五角場快捷假日酒店 → 上海世界博覽會
   2010/05/09 上海市五角場快捷假日酒店 → 桃園國際機場 搭乘長榮航空 BR0701 班機

2. 出差預期目標與歷程
   (1) 上海 SNEC 第四屆國際太陽能光電展的預期目標:
      a. 亞洲最大太陽能展—產業概況、展覽規模、參展廠商及重要特色。
      b. 展示之最—最有值得記載或討論事項，最新活動事件和最新研究、技術及應用。
      c. 太陽能光電與綠建築的進展。
      d. 新綠色建築材料，尤其相變化材料 (SSPCM) 的資訊資料收集。
      e. 其他相關研究議題之收集。
   (2) 上海 SNEC 第四屆國際太陽能光電展的歷程:
      由於僅一天行程，為了要有效率參觀，事先整理及研究展訊如下

圖 1. 展場展位圖

比利時、西班牙、瑞士、新加坡及台灣等 66 個國家地區總共 1408 家光電企業廠商參加，展覽的面積達到 8.5 萬平方公尺，總共觀展專業人士達 10 萬人次，為亞洲最大太陽能光電展。參展廠商分類為 A~G 類，展覽會場從W1 ~W4 和 E1 ~ E5共9大區，上千個展覽攤位。

A、生產設備類：矽棒、矽塊、矽錠、矽片晶圓、電池、電池板組件、薄膜電池板等生產設備。

B、電池類：光伏電池、電池組件及電池組件安裝商。

C、相關零配件類：蓄電池、充電器、控制器、轉換器、記錄儀、逆變器、監視器、支架系統、追踪系統、太陽電纜等。

D、光電原材料類：矽料，矽錠/矽塊，矽片，封裝玻璃，封裝薄膜，其他原料。

E、應用產品類：工程及系統應用、太陽能熱水器、太陽能電池、電動車、綠建築節能。

F、光電系統集成類：太陽能空氣調節系統、農村光伏發電系統、太陽能檢測及控制系統、太陽能取暖系統工程、太陽能光伏工程程序控制和工程管理及軟件編制系統。

G、其他。

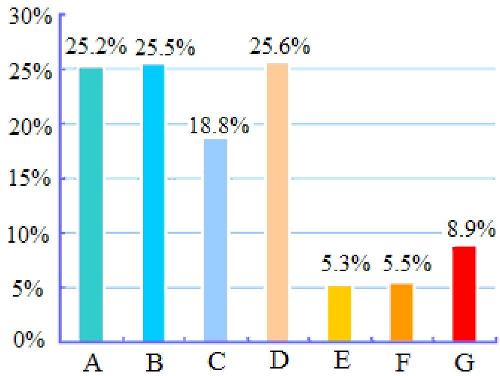


圖 2. 展場廠商類別百分比

2010 年 5 月 7 日--上海新能源行業協會常務副會長米月主持開幕式，中國可再生能源學會副理事長兼光電專業委員會主任趙玉文代表各主辦單位宣讀熱情洋溢的開幕詞；英利綠色能源控股有限公司副總裁趙志恆代表 1400 多家參展單位在會上致辭，十點正，準時上海新能源行業協會會長朱元昊莊重宣布展覽會開幕。

圖 3. 開幕儀式

個人就從 W1 展區進入開始參觀: 尋找展覽之最有特色的地方,以及收集本次參訪預期目標的答案。並且到臺灣投資的攤位拜訪，還有到我國經濟部育成中心聯盟的展場有國內三所大學研究成果。

(3) 2010 年上海世界博覽會的預期目標:

a. 國際大展覽會—展覽規模、參展國家、廠商及其重要特色。

b. 上海世博展示之最—最有值得記載或討論事項。

c. 新綠色建築材料與綠建築的進展。

d. 其他相關研究議題之收集。

(4) 2010 年上海世界博覽會的歷程:

由於僅有一天行程，為了要有效率參訪也是在旅館先收集資訊，一大早即”打的”到另一旅館虹口世紀大酒店與大陸的旅行團併團，其中整輛巴士五、六十人，只有一對香港來的年青人和我，全部都是大陸浙江省來的旅行團，因為 5 月 8 日是上海世博開幕的第一個週末，而且大陸全國總動員，真正讓人體會什麼是”馬蟻雄兵” ，因為當日是很難自行前往的，世博展區是有管制進入，還好我有跟團，於是順利的進入世博會的展區，規模很大，也展開我一天重要而且驚豔的上海世界博覽會的”綠色科技，綠色建築及未來生活”的歷程。因剛開幕所以軟體服務部份就比較薄弱，我就想先到”臺灣館”看看，但一天只開放三千人所以根本排不到票，於是就首先從映入眼簾的是「一軸四館」部份，就先從”世博軸”開始，進入 A 片區，參觀的國家館有: 烏茲別克斯坦館、巴基斯坦館、以色列館、印度館、卡達館及尼泊爾館、亞洲聯合一館六個國家的展覽館、亞洲聯合二館六個國家的展覽館、亞洲聯合三館三個國家的展覽館、朝鮮館、韓國館、安曼館、黎巴嫩館、摩洛哥館及”中國館”是下午 6:00 的梯次。而其中又以阿拉伯館的鯨魚館的經歷最為驚悚，我辛苦排了三個多小時的隊，眼見將可進入阿拉伯館內參觀，確在入口前因為上海副市長的蒞臨，館方人員表演”酋長舞”而造成秩序大亂，有點危險，我的數位相機也不見了，只有沿著大柱旁逃走，放棄參觀，這期中也下起雨來，參觀”中國館”後，本想坐園區電動車到其他 B、 C 、D 片區，確下起大雨來，我雖腳力好、耐性好及觀察力好，但還是得晚上 9:00 回到河邊 3 號的停車場集合。這次能參觀世博是難忘、值得且有收穫的。

上海世博會

上海世博會佔地 5.28 平方公里，大約有永和市這麼大，分為 A、B、C、D、E 五片展區；A、B、C 片在浦東 D、E 片在浦西，園區中有免費的公交車、和 13 號地鐵、及五線渡輪可以連接浦東和浦西；整個世博園區有九處入口，園內近兩百家餐館，各國各省風味的餐廳、料理、簡餐、速食、飲品，應有盡有，是一次建築、文化及科技的饗宴。

一軸四館

「一軸」指的是主要交通軸線「世博軸」，「四館」就是中國館、主題館、世博中心和世博文化中心。也是世博會後唯一不拆除的永久建築。

〔**世博軸**〕長一公里，分為地上、地下兩層，擁有六個形如鐘形的「陽光谷」，由六十九塊巨大的白色膜布拼裝組成，宣稱是世界上最大的繩索布膜結構。可將陽光和空氣引入地下，行人走在底下不感覺熱且有類似「雨水收集器」環保功能是一個高科技與藝術的建築。

〔**中國國家館**〕其建築以倒金字塔造形“東方之冠、鼎盛中華、天下糧 倉、富庶百姓”為構思主題中國館。

〔**主題館**〕上海世博的主題是「城市，讓生活更美好」。呼應這個主題，世博設立五個主題館：城市人館、城市生命館、城市星球館、城市文明館和城市未來館。

〔**世博中心**〕是世博最重要的工作場所，包括新聞中心、演講、論壇都在此舉行。

〔**世博文化中心**〕則是舉行演唱會、音樂會和大型科技秀的主要舞台。很漂亮的飛碟形建築可以隔成可容納 18000 個座位的劇場演藝空間。

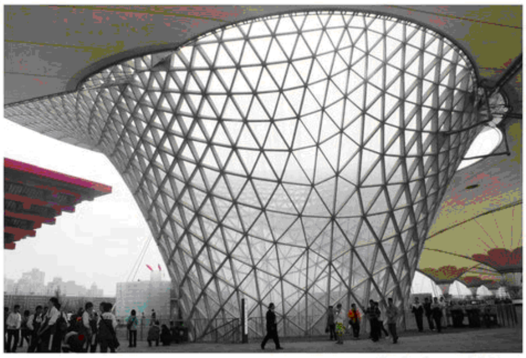


圖 4. 世博軸

圖 5. 中國國家館

圖 6. 主題館

圖 7. 世博中心

圖 8. 世博文化中心

二、研究成果

1. 上海 SNEC 第四屆國際太陽能光電展的研究成果:

(1) 找出商用相變化蓄熱材料的性質與製作廠商

材料	凝固溫度/C	熔化熱/(kJ.kg^{-1})	潛熱/(Mj.m^{-3})
$MgCl_2.6H_2O$	117	168.6	242
石腊	50	265.4	205
$Mg(NO_3)_2.6H_2O$	58	132.2	201

(2) 展示之最—最有值得記載或討論事項，最新活動事件和最新研究、技術及應用。

最大参展廠商——史密德

234 平方米——本屆 SNEC 上海國際光伏展覽會面積最大的“狀元”桂冠，被德國著名的光伏設備生產企業史密德集團奪得。

史密德集團的產品品目繁多，包括矽片、太陽電池、組件等貫穿光電產品全流程的機械設備。該公司德國總部決定，要藉本次中國規模最大的光電展會來擴大影響。 他們不惜成本，從德國總部空運大批專業設備至現場展示，又投重金請名家進行展位設計，還特地派出 15 位資深工程師專門赴上海現場指導。展會期間，他們以最出色的展品，加上最地道的德國啤酒和咖啡，與各路來賓進行互動交流。

效率最高的太陽電池—尚德 Pluto 技術

中國光電產業的龍頭企業——無錫尚德

最大的電池板—美國應用材料公司

應用材料公司是全球領先的奈米製造技術企業。 公司產品包括創新的設備、服務和軟體，它們被應用於半導體芯片、平板顯示器、太陽能電池、柔性電子產品和節能玻璃的製造。 他們製造的太陽能電池組長 2.6 米，寬 2.2 米，總面積 5.7 平方米。是世界最大的太陽能電池模組。

亞洲最大的光電系統集成商--中環光電系統有限公司

中環光電系統有限公司是中國最大的光電系統集成商之一，產量排名亞洲第一、世界第三。據統計，2009 年中環公司生產的原材料在中國市場的佔有率達百分之五十以上。中環公司的生產方式更是企業模範，全程採用全封閉循環模式，確保整個生產過程環保無污染，可謂是中國光電產業名副其實的“綠色生產”第一名。

(3) 探討其他相關研究議題之收集—探討現在技術與組件的水準是否有機會做以下之研究。

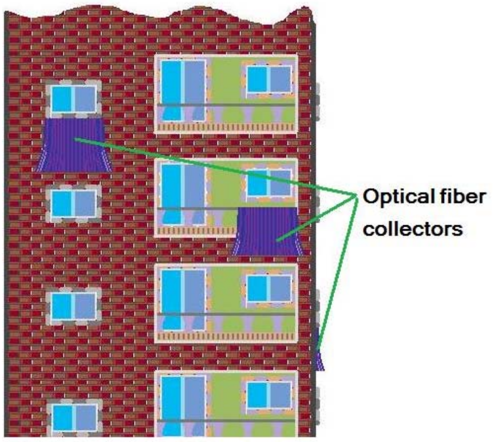
Proposal of a new topic research for the new coming year

Where Do Solar Collectors Be Installed?

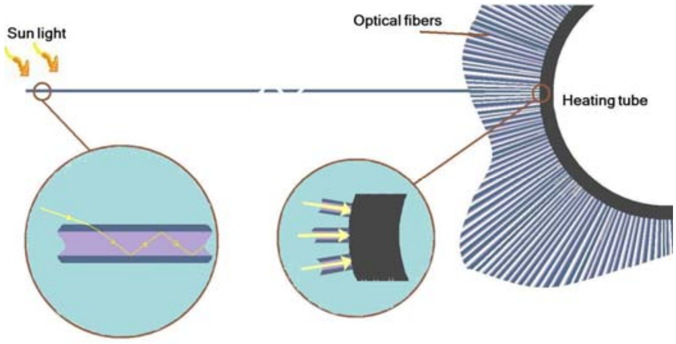
- Panels and solar cells have to face sun light directly.
- They occupy certain areas on roofs and grounds.
- To collect more sun light, panels, mirrors and solar cells need to move to follow sun.

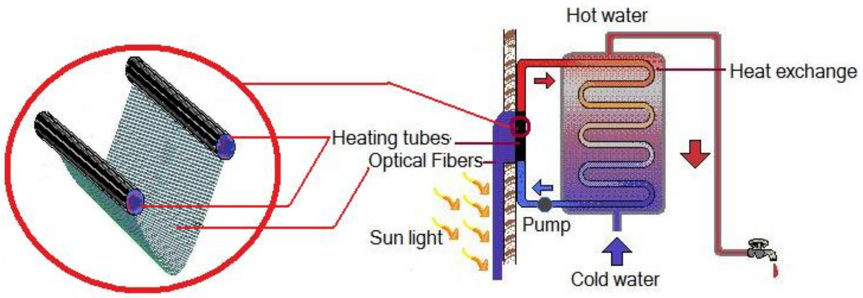
USING OPTICAL FIBERS TO COLLECT SUNLIGHT→ new idea

- In heating systems
- In solar cells



OPTICAL FIBERS SOLAR HEATING SYSTEM (OFSHS)

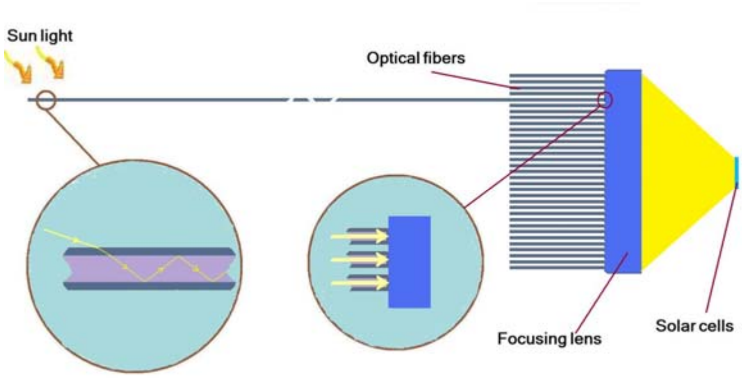




Aims of the study

- Comparing our OFSHS with classic solar water heating system.
- Study the relationship between efficiency of OFSHS with each of length of fibers,
- Fibers density and the angle between fibers and sun rays.

Optical fibers solar cells (OFSC)



Aims of the study:

- Comparing our OFSC with classical solar cells.
- Study the relationship between efficiency of OFSC with each of length of fibers, fibers density and the angle between fibers and sun rays

Discussed with 10 representatives of the 4th SNEC Exhibition companies!

In consideration of proposing new project in the year 2011.

2. 2010 年上海世界博覽會的研究成果:

由於參訪時間有限，但研究成果有三:

(1) 世博軸陽光谷的整個屋頂膜面長約 843 米、最寬處約 97 米，由 69 塊巨大的白色膜布拼裝組成，創造了“世界索膜結構之最”。6 個圓錐型“陽光谷”如同 6 朵盛開的“鮮花”，隨意“飄落”在世博軸上。建工集團攻克了 6 個圓錐型“陽光谷”不規則鋼結構節點安裝和超大面積索膜安裝的世界級難題。

建築使用機械工程上的電腦輔助設計分析與製造 CAD/CAE/CAM 以及三維的量測系統，另人驚豔。

(2) 看了園區採取預鑄工法

圖 9. 預鑄工法

未來建築將會使用大量專用機械和器具應大力推廣研發。

(3) 新綠色建築材料與綠建築的進展—**應儘速建立資料庫與交易平台、另外綠建築雲端建構。**

三、建議

2010 年上海世界博覽會之”台灣館”將搬運回新竹市，建議應結合中央、新竹市、清大與交大、各級學校、工研院及科學園區等多方資源開動一個國際型的綠計畫，將可牽動諸多直接與間接效益。

四、其他

附件一:上海世博會一日票

參考資料:

1. http://tw.group.knowledge.yahoo.com/world-construction/article/view?aid=9
2. http://www.expo2010.cn/
3. http://www.expo2010taiwan.com/TW/index.aspx
4. http://bbs.cn176.com/redirect.php?tid=16530&goto=lastpost
5. http://zh.wikipedia.org/zh/Wikipedia:%E9%A6%96%E9%A1%B5

附件二 電子機票

修改訂單

訂單編號	10TPE12775 完成開票	主行程代碼	上海3天2夜~2010上海世博會
出發日期	2010/05/06	取消期限	
轉入AGENT		訂位人	HSU/SHUYA
保證住房			

旅客資料及機位航次紀錄|新增PNR

CDAPPM |侯補催位 |修改機位紀錄 |選位查詢 |選餐查詢

電腦代碼	編號	姓名/稱謂	出生年月日	會員卡號	聯名認同卡	合作案
CDAPPM	1	TSAI/ BORJANG MR		3319886496GC		

同行嬰兒資料

電腦代碼	姓名/稱謂	出生年月日	同行成人編號

編號	日期	航次	起飛地	目的地	艙等	起飛時間	抵達時間	機位狀態
1	2010/05/06	BR0702	TPE	PVG	S經濟艙	1010	1205	HK1
2	2010/05/09	BR0701	PVG	TPE	S經濟艙	2005	2200	HK1

地面服務紀錄 |新增地面服務 |修改地面服務 |旅客取消/恢復參加 |設定接送機 |分房

定點行程-- 2010上海世博會--上海3天2夜~2010上海世博會 參加人數 1人 TSAI/BORJANG MR

優先選擇	行程資料	訂房狀態
1	EHSHA1022W-- Holiday Inn Express Wujiaochang 五角場快捷假日酒店	HK

住房資料

入住日期	2010/05/06	退房日期	2010/05/09
特殊房型/加價原因	在此期間酒店需加價，每房每晚加價8美元		
備註			

房型	房間數	加床數
單人房(SGLB)	1	0

	房型	間數	2010/5/6	2010/5/7	2010/5/8	小計
Extra Fee	單人房(SGLB)	1	280	280	280	840
			總計			840

使用日	服務名稱	使用說明	備註	LOCAL備註	狀態
2010/05/06	浦東機場至飯店之接機服務				HK
2010/05/08	世博會門票(含規定站點往返接送)		5/8上午9:30虹口世紀大酒店，下午8:30在園區接回飯店		HK
2010/05/09	飯店至浦東機場送機				HK

聯絡人資訊

票務資訊

備註

附件四

國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：99 年 10 月 25 日

計畫編號	NSC－ 98－2221 － E － 216 －047		
計畫名稱	**數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應**		
出國人員姓名	蔡博章	服務機構及職稱	中華大學機械工程系教授
會議時間	99 年 6 月 2 日至 99 年 6 月 4 日	會議地點	**The Empress Hotel, Chiang Mai, Thailand**. 泰國清邁市
會議名稱	(中文)亞洲理工學院 2010 年能源與永續發展國際會議:問題與策略 (英文)PEA-AIT International Conference on Energy and Sustainable Development: Issues and Strategies (ESD 2010)		
發表論文題目	(中文)主動式太陽能帷幕系統(ABE):風力及太陽能驅動氣、電熱整合 (英文) Active Building Envelope System (ABE): Wind and Solar Driven Ventilation, Electricity, Heat Pump		

一、參加會議經過: **適逢泰國紅衫軍事件，旅遊紅色警戒而取消口頭報告**

二、與會心得 **但有註冊沒有出國沒有到泰國**

三、考察參觀活動(無是項活動者略)

四、建議

五、攜回資料名稱及內容

六、其他

Dear B.J. Tsai, C.H. Lee,

Subject: **Notification of Acceptance (Abstract)**

I am pleased to inform you that your abstract titled **"Active Building Envelope System (ABE): Wind and Solar Driven Ventilation, Electricity, Heat Pump"** has been accepted for **oral** presentation at the *PEA-AIT International Conference on **Energy and Sustainable Development: Issues and Strategies (ESD 2010)***. This conference will be held during **2-4 June 2010** at **The Empress Hotel, Chiang Mai, Thailand**.

You may now start preparing your full paper. For inclusion in the proceedings of the conference, we require you to submit your **formatted full paper** not later than **31st March 2010** using our online submission system. You must access our conference website at www.serd.ait.ac.th/esd2010 and upload your paper using the following information:

Paper ID: 52

Password: c56943

Should you encounter problems with submitting your paper online, please don't hesitate to submit it to the ESD Secretariat by email at enreric@ait.ac.th. Please note that the file name of your paper should be your abstract's reference code (in this case **ESD-Online 52**). It would be very appreciated if you could submit at the earliest possible time. Guidelines of paper preparation are attached with this email. You may also download it from our conference website. You are strongly encouraged to use the guideline as template for your paper as it is very important that papers submitted are in the format required for printing with all figures and tables at their correct positions. All papers should be produced using MS Word (version 98 or latest).

Please be informed that only full papers submitted with payment of the registration fee of at least one of the authors will be considered for inclusion in the presentations and the proceedings (note: each author is allowed to present a maximum of two (2) papers only). You may also fill-up the registration form online and submit your proof of payment to us either by email or by fax. When sending your proof of payment it is necessary to indicate your abstract's reference code (*please see above*) and its title. If you require any additional information, please visit our conference website or feel free to contact the ESD 2010 Secretariat at enreric@ait.ac.th.

We envisioned this conference to be a forum for a dynamic international intellectual exchange for all stakeholders to coordinate, promote, and contribute solutions and contribute solutions and strategies to current issues of energy as it impact global sustainable development.

We are looking forward to seeing you at the conference.

Sincerely,

Weerakorn Ongsakul, PhD
Conference Director
ESD 2010

PEA-AIT **International Conference on** *Energy and Sustainable Development: Issues and Strategies (ESD 2010)*
2-4 June 2010, The Empress Hotel, Chiang Mai, Thailand
www.serd.ait.ac.th/esd2010/

Regional Energy Resources Information Center (RERIC)
Energy Field of Study
Asian Institute of Technology
IEJ page: **http://www.rericjournal.ait.ac.th/**

__________ Information from ESET NOD32 Antivirus, version of virus signature database 2740 (20071221) __________

The message was checked by ESET NOD32 Antivirus.

http://www.eset.com

Active Building Envelope System(ABE)：Wind & Solar driven Ventilation、Electricity、Heat Pump

Bor-Jang Tsai*[1] and Chien-Ho Lee*[2]

Abstract--This study takes the ventilation into consideration, making the active building envelope (ABE) system more close to the realistic application conditions. The ABE system is comprised of a photovoltaic unit (PV unit) and a thermoelectric heat pump unit (TE unit). The PV unit consists of photovoltaic cells, which convert solar radiation energy into electrical energy. The TE unit consists of thermoelectric heaters/coolers (referred to here onwards as TE coolers), which convert electrical energy into thermal energy, or the reverse. The PV and the TE units are integrated within the overall ABE enclosure.

The new mechanism of a hybrid system was proposed. A ducted wind turine will be integrated with the ABE system becoming dual core. Then the analytic model of original ABE system has to be revised and analytic solution will be resulted and verified by the numerical solution of CFD. The ducted wind mill will provide air conditioning and power the ABE system, to higher the thermal efficiency of the heat sinks of TE system. Numerical and experimental works will be investigated. a building installed the ABE system wind, solar driven, bypass the windmill flow as a air flow, ambient temperature, T_o is equal to 35 ^oC and indoor temperature, T_i is 28 ^oC. Numerical results show the T_i will decrease 2 ^oC when the ABE operating with heat sinks, without fan. As fan is opened, strong convective heat transfer, T_i will decrease approximately 4 to 5 ^oC. We hope findings of this study can make the dream of healthy living、comfortable room come true。

Key Words: Active building envelope system、Thermoelectric、Solar energy、Wind mill、Photovoltaic

1. INTRODUCTION

In the 1970s, the world's energy crisis occurred twice successively, resulting in globalized affection for obtaining energy. In order to ensure energy is used efficiently, many advanced countries gradually enact legislation to regulate energy management, which also includes the energy conservation management of building. It also has a considerable achievement. However, energy efficiency of each country's building has different standards, such as in the United States and parts of Southeast Asia, Overall Thermal Transfer Value (OTTV) is used as the base line. In Europe and Canada use the building construction envelope heat transfer rate (U value). In Japan, Perimeter Annual Load (PAL) and Co-efficient of energy consumption for air conditioning (CEC) are used as the reference standards, while Taiwan's energy consumption is use both Envelope Load (ENVLOA) and Performance Air Conditioning System (PACS) as the base reference systems.

Taiwan is not a self-produced energy country. 97% of its energy is dependent on imports. As environmental consciousness awakening, development of energy, the use of green energy is growing importance, in 1998 Taiwan government convened a national energy conference and announced that by the year 2020, the total installed capacity of renewable energy power generation to be accounting for 10% of the national power generation system as the goal. In 2002 the government adopted the "Renewable Energy Development Bill" set a renewable energy generating capacity and total volume of 6.5 million kW incentives and further declared to enhance and promote the policies of renewable energy power generation. The government also categorized renewable energy into wind, solar, biomass, geothermal, ocean energy, non-pump storage hydro, biogas, tidal waves, temperature difference, etc, to drive the energy industry and use, followed by "Kyoto Protocol" about the problem of CO2 emissions. Therefore, based on 2006 Thermal and Energy Research Program of government, the guidelines book of the second, third and eight chapters' contents, we conducted related researches about the building energy science and technology.

Building Envelope System (ABE): Active Building Envelope System represents a new thermal control method - to compensate for the building in the surface or other place that has heat transfer and resulted by heat loss and gain. In ABE systems, solar radiation energy by PV cells to convert sun light into electricity. Then, it will provide the electricity needed by thermoelectric power and heat sink system. Put it simply, ABE system consists of two basic components, one for the

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Photovoltaic (PV) systems and another for the Thermoelectric (TE) system. PV system changes the solar radiation energy into electrical energy. TE system's component changes the electrical energy into heat energy, or the reverse to change the heat into electricity. Thermoelectric (TE) components are located in the various openings within the insulating layers, each TE component has two heat sinks – one for heat absorption, and another for heat dissipation. Regardless of the external heat sink for heat absorption or dissipation, both by natural convection or forced convection of heat transfer into the air. The above study was made by Dr. Steve Van Dessel's research team of the United States and assessed the feasibility of ABE systems analysis model. From the total input voltage, we can be observed electricity generated by BiPV is higher than the total input power of TE units, so the ABE system is feasible.
Therefore, this study is under the motivation of 2004 Dr. Steve Van Dessel's [1] proposed Active Building Envelope System (ABE) model and added by a wind mill to drive the Swiss-roll heat exchanger, a new thermal control technology --- trying to compensate for the building envelopes or elsewhere being heat transferred, resulting in heat loss and gain (Fig. 1). This study has the simulation analysis and experimental proof by the reduced size model.

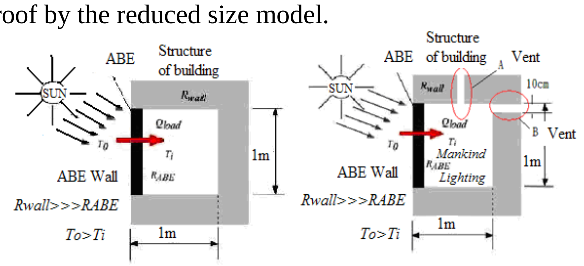


Fig. 1 Schematic diagrams of new (active) and old (passive) model of ABE systems

2. LITERATUR REVIEW

In 2004 Dr. Steve Van Dessel's research team [1] presented Active Building Envelope System (ABE) which included two basic components, one for the Photovoltaic (PV) systems and another for the Thermoelectric (TE) system. PV system is to change the solar radiation energy into electrical energy. TE system device to change the energy into heat energy, or reverse the heat into electrical energy (Fig. 2), which from

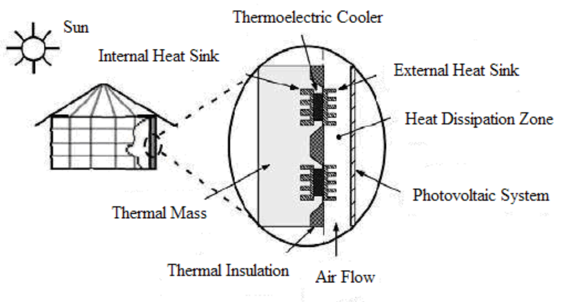


Fig. 2 Schematic diagrams of the PV system and TE system

model analysis we can explicitly calculate the thermal conductivity of the envelope of the Q_{load} = 6 W. In 2004 Buist et al [2] used of numerical software in the TE cooling system and the estimated efficiency of heat sink value was lower than that of Dr. Steve Van Dessel's model, where when I = 8 amps, a model's biggest efficiency difference was about 10%.
On the fan part, firstly in 1999, Fuglsang and Madsen [3] pointed out at the wind turbine rotors to optimize the design with different parameters. In this research we also included Wright and Wood's [4] exploration of the low-speed axial wind turbines design and integration of empirical formula as well. In 2006 Epaarachchi and Clausen [5] proposed a small fan blade to experiment measurement the prediction of the fatigue test under a load mode.
Heat exchanger was firstly applied in 2007 by BJ Tsai [6] to the micro-turbine engine recuperator for preheating combustion to improve engine efficiency. Take advantage of heat-re-circulating or excess enthalpy of combustion technology, the heat generated by burning and through the heat exchanger or other equipment will be recycled and reuse in order to improve system efficiency, or for other purposes . The Swiss roll burner takes advantage of this heat-recycling technology to product high-temperature heat to preheat the reactants to improve combustion efficiency and combustible limit [7]. The above is combination of physical components.
This study considered the actual physical status of the increase in ventilation, so that ABE system is more accurate and closer to the actual physical condition. As described at right side of Figure 1, the so-called new model of the ABE system for home space arrangement clearly stated the innovative ideas of this study - to use air-conditioning aerodynamic mechanisms to achieve the integration of wind & solar driven ventilation, electricity and heat pump.

3. OBJECTIVES AND APPROACHES

3.1 Model Summary

The studied model of author's team could be compared with the model of Dr. Steve Van Dessel's group. We added the return-air inlet (B vent opening) in the x direction. In the y direction it was guided by the wind turbine air flow through the Swiss roll heat exchanger to produce air-conditioning of the forced convection from an A vent opening. This opening could be considered of several kinds of thermal generations and can become the ABE system heat source. Here it was a simplified model. These vent opening only set up for 1 to 2 people and considered only for 1 to 2 people's average heat volume for heating and lighting system. The system's total heat load can better simulate the real buildings in a single unit of about 4m x 4m x 4m of the ventilation, and thermal conditions. The thermal resistance of the analog circuit, such as (Fig. 3) shows, of which the best

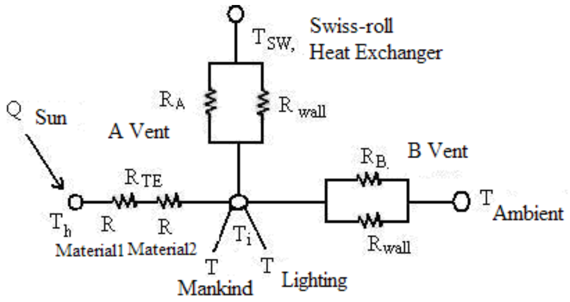


Fig. 3 Thermal resistance-analog circuit of the new ABE model system

insulation R_{wall} setting becomes a dramatically large value to make the calculation of overall thermal resistance easier.

$$T_i = \frac{q_i + \sum j(T_i + R_{ij})}{\sum_j \left(\frac{1}{R_{ij}} \right)} \quad (1)$$

According to Gauss-Seidel iteration method [8] - steps that the form of finite difference equations we can achieve the inside ventilation and heat conditions of active building envelope's global driven. More details of the building equipment configuration are shown in Fig. 4, which indicated the new analytical model of a single dwelling space of ABE system.

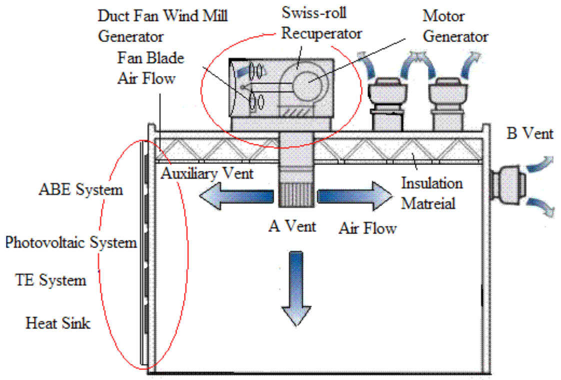


Fig. 4 The new analytical model of a single dwelling space of ABE system

3.2 Software and Model Input Parameters

Use Airpak software [9] to input and establish building's models for analysis.
Model-related input data values are as follows:

1. Air flow volume rate at opening: 1.5m^3/s.
2. Wind speed at opening：10m/s
3. Numbers of opening: 1 set, 1 set for blow downward wind, each of size 0.25 meters long, 0.2 meters wide.
4. Temperature at opening: 14℃, return-air temperature: 24℃.
5. The body heat volume of 1 to 2 people totaling 72 - 144W. Floor heat volume can be neglected. Lighting heat flux is average 100W /m^2
6. The surrounding air wind field can be incompressible. The external flow field should meet the three-dimensional dynamic flow control.
7. When simulate air flow of air conditioning the volume is required to change the maximum load value so the distribution of air flow can meet environmental requirements. Therefore, the air-conditioned environment used air-conditioning designed day peak environmental load as the input values. The model used is in a steady state condition in order to simplify the ABE system air-flow simulation procedure.

3.3 Input Parameters for Analysis of Wind Speed at Opening

According to Nielsen's (1978) [10] test for wind speed at opening, we obtained the relevant data by Grapher software (shown as Fig. 5). Similar curve of wind speed

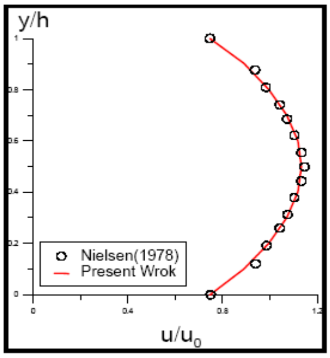


Fig. 5 Nielsen's (1978) [10] test for wind speed at vent opening

distribution obtained, in order to get quadratic regression equation for the analysis as follows:

$$\frac{u}{u_0} = a\left(\frac{y}{h}\right)^2 + b\left(\frac{y}{h}\right) + c \quad (2)$$

a=−1.4287, b=1.4287, c=0.7619

Integration above equation from 0 to 1 yields the average air speed value equal to 1.0.

$$\frac{\bar{u}}{u_0} = \int_0^1 \left[a\left(\frac{y}{h}\right)^2 + b\left(\frac{y}{h}\right) + c \right] d\left(\frac{y}{h}\right)$$
$$= \left[\frac{2}{3}\left(\frac{y}{h}\right)^3 + \frac{b}{2}\left(\frac{y}{h}\right)^2 + c\left(\frac{y}{h}\right) \right]_0^1 = 1.000 \quad (3)$$

That means the above quadratic curve equation of speed distribution integrated in the range of 0 to 1 (y/h) is equivalent to speed with the same average flow speed. In accordance with the wind speed at opening, obtain results of the average wind speed from equation (3) at 10 grid-point locations of opening and then key in the Airpack software.

3.4 Input Parameters

When using the Airpack software the setting values is as follows:
1. Steady
2. Flow model: Turbulent (κ - ε two equation model).
3. Opening:
   Temperature at opening: 14 ℃
   Turbulence intensity: 10%

3.5 Set the Boundary Conditions

By using the Airpak software together with the Central Weather Bureau's meteorological data to calculate and simulate atmospheric wind field as boundary conditions. Input parameters of the external environment are the local wind direction, wind speed, boundary layer thickness and terrain factor. The prediction equation of atmospheric wind field is:

$$U(h)\begin{cases} U_{met} = \left(\dfrac{d_{met}}{H_{met}}\right)^{a_{met}\left(\frac{h}{d}\right)^{a}} & h < d \\ U_{met} = \left(\dfrac{d_{met}}{H_{met}}\right)^{a_{met}} & h \geq d \end{cases} \quad (5)$$

U_{met} = The average wind speed in the vicinity of weather station
H_{met} = Anemometer's height
a_{met} = Weather station terrain factor
d_{met} = Weather station boundary layer thickness
a = Different ground conditions of the terrain factor
d = different ground conditions of the boundary layer thickness

In this paper, we use the Hsinchu area anemometer height of 15.6m, terrain factor of 0.19 and boundary layer thickness of 350m.

3.6 Relaxation Factor

When doing analytical analysis, variables cross effects each other so easily led to divergence of various numbers of flow field data, it is necessary to introduce relaxation factor to increase the number of data values to deliver the stability of the simulation data set, such as the relaxation system shown in Table 1.

Table 1 Under-relaxation coefficients

Pressure	0.7
Momentum	0.3
Temperature	0.9
Viscosity	1.0
Body forces	0.1
Turbulent Kinetic energy	0.5
Turbulent dissipation rate	0.5

3.7 Set of Convergence Value

For the purposes of solving any number of flow field changes in the iterative process, Simulation convergence criteria as shown in table 2.

Table 2 Convergence criteria

Flow	Energy	Turbulent Kinetic energy	Turbulent dissipation rate
0.001	1e-6	0.001	0.001

3.8 Analysis of Independent Grid

Due to coarse or fineness of grid points may lead to different numerical results, thereby affecting the credibility of the results, analysis of independent grid must be used at different set of grid points in the same physical quantity and observe when the grid points increases, whether the physical quantities will be differed. If it were very different, continued to increase grid points until the grid is fine enough did not affect the physical quantities then to stop the increase of grid points. Fig. 6 is this paper's numerical model to solve

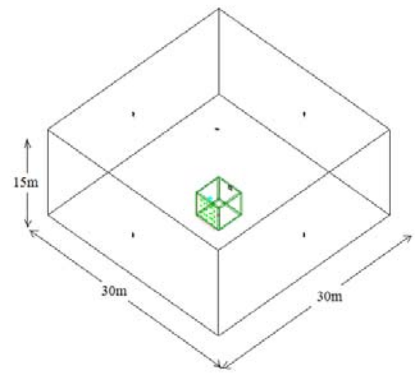


Fig. 6 Numerical model to solve the domain outside the 30m x 30m x 15m volume with a simulated outdoor environment around 4m x 4m x 4m volume within the analog ABE system

the domain outside the 30m x 30m x 15m volume with a simulated outdoor environment around 4m x 4m x 4m volume within the analog ABE system, while the numerical simulation of computational domains as shown in Fig. 7, including 24 thermoelectric cooling module and ventilation of air inlet and opening.

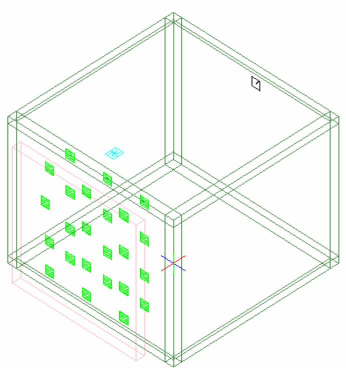


Fig. 7 The numerical simulation of computational domains

Verification of the numerical grids (Fig. 8, Fig. 9): in the same the settings conducted analysis of independent grid. Compared calculation results differences and the results showed that the grid point number of 91,646, 124,892, 132,762, 187,542, etc. different grid numbers generated slight different results. With the best error R is the best set of grid points.

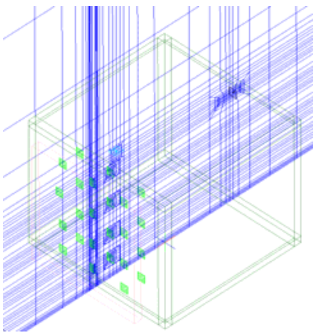


Fig. 8 The cross-sectional planes of 3D numerical grid

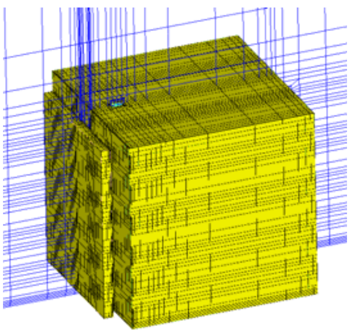


Fig. 9 The 3D numerical grid system

$$R = \frac{\sqrt{\sum_{t=1}^{n} \left(\frac{u_{n+1} - u_n}{u_0} \right)^2}}{N} \tag{4}$$

u_{n+1}: The speeds (m/s) obtained from previous number of grid points

u_n: The speeds (m/s) obtained from current number of grid points

u_0: Speeds of the opening (10m/s)

N: Number of sampling points

Error R results as shown in Table 3. Compared grid 4 and grid 3, u/u_0 error was 7.3E-07 <8.9E-06, both are completely convergent. Namely, the set of grid with grid number of 187,542 is the best grid. Therefore, we use grid 4 to calculate air flow field.

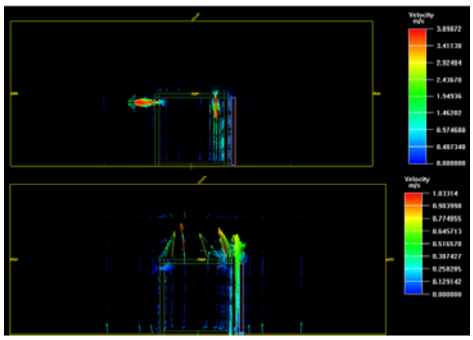
Table 3 Verification of independent grids

Test	Grid 1	Grid 2	Grid 3	Grid 4
Error%	0	3.7e-4	8.9e-6	7.3e-7

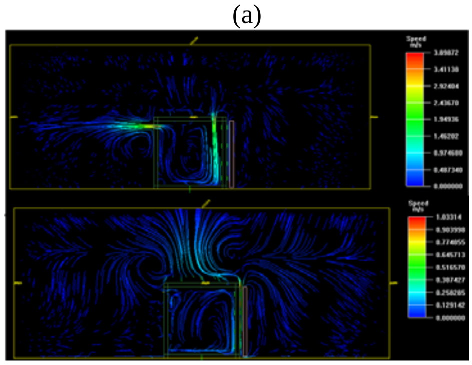
4. RESULTS AND DISCUSSION

4.1 Airflow Simulation Results

Fig. 10 is the ventilation flow distribution with fan turned on and turned off, which is based on the cross-section for the opening where the height of 3.6m. Another plane is for the location of the fan where the height of 4m.



(a)



(b)

Fig. 10 The ventilation flow distribution with fan turned on (a) and turned off (b)

Fig. 10 (a) (b)'s air flow distribution, analysis and comparison of air flow at fan was on (at the top of Fig. 10 a, b) and the fan was off (at the bottom of Fig.10 a, b), we can see from the velocity vector and the flow line, the wind comes from the environment. Path from the upper right corner and then along the right wall TE system, back down to the floor, flow to the left wall outlet and then lastly go out from the upper left corner. When the fan was on, compared with turned off, it has stronger air flow and wind speed. Taking Z = 0m at the air-flow situation. The air flow speed of fan turned on and turned off can be separated as on (u_{max} = 3.9872m / s), off (u_{max} = 1.03314m / s).

4.2 Temperature Simulation Results

Fig. 11 is the comparison of temperature distribution for the fan was on (above) and off (below). The gap is between solar panels and the TE wall as the hot side. The temperature can reach 40 to 45℃. Another side of TE produced the cooling effect, and through air-conditioning spread cool air to indoor space. Take the temperature condition at Y = 1.2m. The indoor temperature is 29 to 32 ℃ with fan turning on, or the indoor temperature is about 31 to 34℃ without turning on the fan. The results show the fan can speed up TE cooling cold-side to spread quickly to the entire room. (Take 6 temperature test points, the ambient temperature is 35℃)

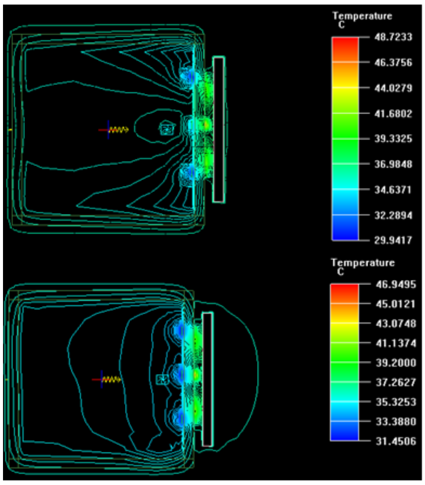


Fig. 11 The comparison of temperature distribution for the fan was on (above) and off (below)

4.3 PMV Value Simulation Results

ISO 7730 has recommended the use of the comfort indicators PMV (Predicted Mean Vote) and PPD (Predicted Percent of Dissatisfied):

PMV provides for an average reference, to measure the comfortableness of human body in an environment. PMV index produced from many different testers, in the specific measurement environment, their subjective assessment for a number of environmental conditions. It is divided into seven stages, ranging from -3 (very cold) extends to +3 (extremely warm), neutral point of 0 for moderate heat conditions.

PPD is used to estimate the extent of dissatisfaction of human body on the environment.

Fig. 12 is the PMV value when turning on and off the fan, *i.e.*, the smaller the value of PMV, the more satisfaction. When the fan was on the indoor PMV value was about 0.69 to 1. When the fan was off the indoor PMV value was about 0.5 to 0.9.

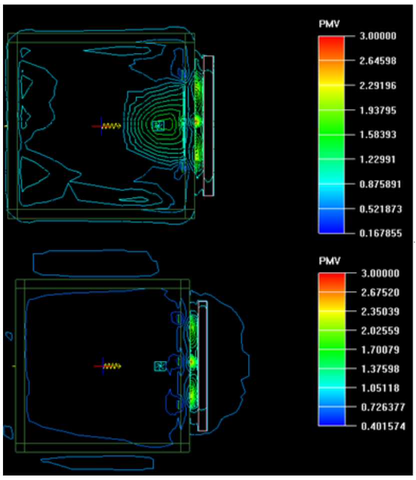


Fig. 12 the PMV value when turning on (above)and off (below) the fan

4.4 The Results of Experimental Verification

According to Fig. 13 measurement from Steve Van Dessel's simple models, instrumentation equipment including: Weather Pro 2317 weather instrument, TM-203-type luminance meter, YK-2005AH-type of hot anemometer and RH520-type of thermometer and

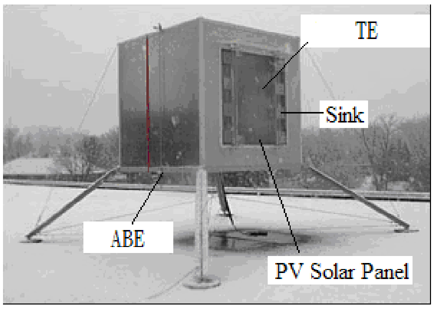


Fig. 13 Setup of the experimental ABE system[1]

hygrometer (show as Fig. 14), solar panels, thermoelectric cooling module, heat sink and ventilation of air inlet and opening… etc. In accordance with experiments of various parameters, uncertainty in this study was about 10%. We took six test points. The ambient temperature is 35℃. We carried out air conditioning and ventilation performance test. The results were shown in Table 4 and Table 5.

Fig. 14 Devices of measurement instrument

Table 4 Measured parameters of environment by numerical and experimental analysis (with fan opened, ambient temperature 35^{o}C)

Test	Temp. ±1℃		Humidity ±5%		Air speed ±0.1m/s	
	Num	Exp	Num	Exp	Num	Exp
Pt1	29.0	29.1	45	45	3.9	3.7
pt2	29.8	29.9	43	46	3.3	3.0
pt3	30.4	30.5	46	45	2.8	2.6
Pt4	31.0	31.2	45	46	2.2	2.1
Pt5	31.5	31.4	47	46	2.0	2.0
Pt6	32.0	32.0	48	46	1.5	1.4

Table 5 Measured parameters of environment by numerical and experimental analysis (without fan opened, ambient temperature 35^{o}C)

Test	Temp. ±1℃		Humidity ±5%		Air speed ±0.1m/s	
	Num	Exp	Num	Exp	Num	Exp
Pt1	31.0	31.1	51	52	1.0	1.0
pt2	31.8	31.9	53	52	0.9	0.9
pt3	32.4	32.5	50	52	0..9	0.9
Pt4	33.0	33.2	51	51	0.8	0.8
Pt5	33.5	33.4	52	51	0.8	0.8
Pt6	34.0	34.0	52	51	0.8.	0.8

5. CONCLUSION

The above numerical results and experimental results coincide with each other and prove that the function of Ventilation driven by wind power is just as turn on the fan. This evidenced that forced convection greatly improved TE and heat sink efficiency in comparison to natural convection, COP increases significantly, and it is quiet, clean, energy-saving and cost-saving. Therefore, this study established a closer to the actual physical situation in ABE system as a whole, including sub-systems in the new analysis model

(1) ABE system's BiPV, BiTE, heat sink efficiency gains can achieve energy-efficiency and clean. It can also reduce the CO2 emissions.

(2) ABE system can reduce the total input power and achieve proactive approach to achieve energy-saving goals

(3) ABE system uses fewer materials to achieve cost reduction targets

(4) Active Building Envelope System (ABE) model and added by a wind mill to drive the Swiss-roll heat exchanger, a new thermal control technology

(5)Completion of the relevant simulation and verification of sub-systems, TE, heat sink, air-conditioning and ventilation system analysis

(6) Fan type wind turbine to provide air-conditioning and electricity and to assist ABE system's input power and to enhance the thermal efficiency of heat sink

(7) The natural convection without turning on the fan is comforter.

ACKNOWLEDGEMENT

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國科會補助計畫衍生研發成果推廣資料表

日期 2010年10月31日

國科會補助計畫	計畫名稱: 數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應 計畫主持人: 蔡博章 計畫編號: 98 -2221-E -216 -047 -　　學門領域: 能源科技		
研發成果名稱	(中文) 建築物系統整合技術：氣、電、熱及綠建材之整合規劃技術 (英文) System integrated technique of building		
成果歸屬機構	中華大學	發明人(創作人)	蔡博章,楊位盛,潘俊良
技術說明	(中文)建築物在牆壁、天花板及地板鋪設穩態形狀相變材料板(SSPCM)以及整合主動式外表帷幕系統(ABE)形成混成系統，再以一棟位於台灣新竹地區沒有空調的建物為探討對象，來數值分析仲夏夜晚通風及空調情況，為完成對這創新觀念的混成系統可行性作分析評估，以及其在不同操作情況下之空調效能與室內溫度變化進行研究。每一系統及次系統元件都要非常小心的發展其數學模型，並利用數值方法進行求解，利用新竹地區七月份的一天或夏季氣候為條件，使用驗證過的焓模型(verified enthalpy model)暫態模擬進行分析解，同時用Fluent準確地計算出具有SSPCM與ABE系統混成建築物的空調系統之性能，本研究即是在地板、天花板及牆壁安裝SSPCM，在白天吸收太陽輻射熱及ABE的TE熱，然後在夜晚或凌晨放熱，而對於被動式熱傳結合主動式熱傳的建築物系統，做出有效預測相變材料成份的溶解/硬化速率及溫度分佈，對普遍使用PCM當內能儲存系統(latent heat storage system)都是舉足輕重地重要。提高建築物的空調系統熱效率即是使用白天熱能提供晚上暖氣或提供節能省能的冷氣等本研究成果，相信可促成人們有健康、舒適地居住環境的美夢成真。 (英文)Effect of SSPCM plates combined with night ventilation in summer is investigated numerically. A building in Hsinchu, Taiwan is considered for analysis, which includes SSPCM plates as inner linings of walls、the ceiling and floor, and ABE is installed as well　Unsteady simulation is performed using a verified enthalpy model, with time period covering the summer season. A kind of floor with SSPCM is put forward which can absorb the solar radiation energy in the daytime or in summer and release the heat at night or in winter. The thermal performance of a room using such floor、wall and ceiling were numerically studied. Results show that the average indoor air temperature of a room with the SSPCM floor was about 2 K to 4 K higher than that of the room without SSPCM floor, and the indoor air temperature swing range was narrowed greatly. This manifests that applying SSPCM in room suitably can increase the thermal comfort		
產業別	營造業、建物裝修及裝潢業、電力供應業、熱能供應業		
技術/產品應用範圍	節能省能 能源材料 環保 氣電熱整合/ 建築物帷幕系統、建築物節能省能系統規畫		
技術移轉可行性及預期效益	Green Housing Shape-stabilized Phase Change Materials Save Energy and Protect Environment 技術移轉如是符合上述行業且需有研發能力則效益才能彰顯		

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

98 年度專題研究計畫研究成果彙整表

計畫主持人：蔡博章 **計畫編號：**98-2221-E-216-047-

計畫名稱：數值分析建築物整合鋪設穩態形狀相變材料板(SSPCM)及主動式外表帷幕系統(ABE)之空調效應

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數(含實際已達成數)	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		NSC-98-2221-E-216-047 國科會一般型研究計畫結案報告
		研討會論文	2	2	80%		中國機械工程學會第二十六屆全國學術研討會論文集二篇
		專書	0	0	100%		
	專利	申請中件數	1	1	50%	件	封閉氣動式混合動力產生裝置 中華民國 2010 年 申請國內發明專利(智財局審查中)
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	2	1	100%	人次	楊位盛未畢業,潘俊良已畢業
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

國外	論文著作	期刊論文	2	2	50%	篇	1. Bor-Jang Tsai 、 Koo-David Huang and Chien-Ho Lee ，' Hybrid Structural Systems of An Active Building Envelope System(ABE)'， Advanced material research, in press. NSC-98-2221-E-216-047 (EI: ISTP) 2. Bor-Jang Tsai and Yu-Chun Fu, ' Design and aerodynamic analysis of a flapping-wing micro aerial vehicle'， Aerospace science and technology , Vol. 13, No.7, pp.383-392. NSC-94-2212-E-216-004 (SCI: EI: IF:0.674)
		研究報告/技術報告	0	0	100%		
		研討會論文	2	2	50%		ICSBM 2011 Call For Papers (EI COMPENDEX) ESD2010
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	1.經濟部技術處 SBIR 機械類技審委員 2.1.International Journal of Energy and Enviroment -Journal Editor (2010) 3.Engineering Applications of Computational Fluid Mechanics -Referee of SCI Journal Paper (2010) 4. Journal of Chinese Society of Mechanical Engineers -Referee of SCI Journal Paper (2010) 5.遠東科技大學 98 學年度課程及工程認證之諮詢委員

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

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□未達成目標（請說明，以 100 字為限）

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說明：

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論文：□已發表 ■未發表之文稿 □撰寫中 □無

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技轉：□已技轉 ■洽談中 □無

其他：（以 100 字為限）

衍生成果著作有:

期刊有二:1. Hybrid Structural Systems of An Active Building Envelope System(ABE)' 2. Design and aerodynamic..,SCI,EI

國內外研討會有四,碩士論文一

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

而本研究相關成果數據正準備投稿 J. of Applied Thermal Engineering or J. of Building and Environments or Applied Energy。而在技術創新上，本研究是建築物在牆壁、天花板及地板鋪設穩態形狀相變材料板(SSPCM)以及整合主動式外表帷幕系統(ABE)形成混成系統(Hybrid system)，再以一棟位於台灣新竹地區沒有空調的建物為探討對象，來數值分析仲夏夜晚通風及空調情況，為完成對這創新觀念的混成系統可行性作分析評估，以及其在不同操作情況下之空調效能與室內溫度變化進行研究。對於建築物系統整合技術：氣、電、熱及綠建材之整合規劃技術，本研究室將會不斷的創新，除此之外，本次研究成果對相變化材料 SSPCM 之數學、物理模型與分析、數值解法做非常有系統的整理及研究。然而真實體建造昂貴及實驗數據的驗證尚未周全，所以在申請專利過程尚需資源、經費及努力,但太陽能及風力等再生能源分析設計、系統規劃、建物之節能省能技術及熱流分析技術等，應可應用到建築或營造及節能省能科技、Green Housing 及綠色建材等行業上，希望 ABE 與 SSPCM 系統會快應用到人類生活。