Experimental performance of solar chimney window on school building

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Abstract

This paper reports investigation on the natural ventilation of solar chimney window on the school building in Thailand. Both clear glass solar chimney window (CG-SCW) and translucent glass solar chimney window (TG-SCW) were considered. The CG-SCW and TG-SCW composed of different the slat glass on the outer side and the inner side is same glass pane. The slat glasses are clear glass (CG) and translucent glass (TG), and the glass pane is CG. They are openings located at the bottom (room side) and the top (ambient side). The size of openings was 0.0205 m^2. The surface area of each unit was about 0.963 m^2. They were integrated into the southeast facing wall of the small rooms in the school building.

Experimental results were showed that TG-SCW could reduce heat flux by about 3-20 W/m^2. With TG-SCW, velocity field measurement indicated that the induced airflow rate was about 5-15 m^3/hr. However, the proposed configuration of the TG-SCW should be recommended for school building

Keywords: Clear glass; Translucent glass; Heat flux; airflow rate; School building.

1. Introduction

Natural ventilation is one of the important to reduce energy used by air conditioning system and providing thermal comfort in building. The last two decades, the solar chimney can be constructed in one of the building components and it applications. The basic principle of the solar chimney may be understood by considering a rectangular shape with both small ventilation openings. The solar energy incidences on the outer surface through the inside, the air in the space is heated and temperature difference in air, the density gradient between the inside and outside of the solar chimney is obtained that in turn induces a natural ventilation.

Solar chimneys have been traditionally used in building, residential house and it application. Trombe wall is very important to develop the building ventilation. Burek and Habeb [1] reported to the air flow and thermal efficiency of solar chimney and Trombe wall, the experimental presents both correlation equations. (I) mass flow rate as a function of heat input and channel depth, (II) thermal efficiency as a function of the heat input and not dependent on the channel depth. Thermal performances of glazed solar chimney wall (GSCW) were reported by Chantawong et al. [2-3]. The experimental setup of GSCW was 0.74 height, 0.50 m width and 0.10 m air gap. The size of opening was 0.05×0.5 m^2. The experimental and numerical simulation results confirmed that GSCW is highly suitable for tropical climate countries. Zamora and Kaiser [4] have presented numerical results for the natural convection in a solar chimney shape channel. A mathematical model studied on the laminar and turbulent flows induced by natural convection in the channels with solar chimney configuration. A simple mathematical model

of a solar chimney and passive solar cooling were proposed by Ong [5-6]. Chow et al. [7-8] investigated the glazing ventilation technology for application in warm climate provides energy saving. Besides the forementioned research works, solar chimney is applying on building components viz., wall and window configurations during past two decade. The roof solar chimney is one important for building ventilation. Puangsombut et al. [9-10] have presented experimental results the natural ventilation in a rectangular channel established by solar chimney. A rectangular chimney consists of the upper and lower plates. The upper plate is heated plate and insulated on the top side and subjected to a uniform constant heat flux. The lower plate had a radiant barrier (RB) fixed on a thin wood flame. The experimental results were present the heat gain reduction and induced natural ventilation rate, and also heat transfer coefficient for radiant barrier. This article aims to assess the effect of the use of solar chimney windows (SCW) for inducing indoor ventilation and improving heat gain reduction through building component.

2. Experimental set-up

The experimental set-up was built in the fourth floor of the school building, Kasem Bundit University, Bangkok Thailand. Figure 1, two rooms are one test room and another one reference room. The two rooms were built from the plywood (2 mm thick) and partitioned by plywood. The base area of each room was 1.5 m $\times$ 1.0 m and the height was 2.65 m. The double windows faced to the southeast whereas the UPVC door. SCW has 0.963 m^2 surface area (0.9 m $\times$ 1.07 m). The spacing between glass panes was 0.065 m. There were opening the size 0.5 m $\times$ 0.05 m at the top of the outer glass and the bottom of the inner glass. The outer glass is slat glass (thickness 6 mm) and inner is glass pane (thickness 6 mm). Two types of slat glasses pane are clear

glass (CG) and translucent glass (TG). Thermocouples type K (range: 0-1250°C, accuracy $\pm$ 0.5°C) were measured as show in figure 2. The thermocouples were connected to a data logger (Hioki, Model: 8422-52, accuracy ±0.8%). Heat flux (Omega HFS-3, range: 1-1400 W/m^2, Error $\pm$ 0.5%). The inlet and outlet air velocities were measured using a velocity probe (TSI Model 8380, range 0-50 m/s, Error $\pm$ 0.5%) and lux meter (Digicon LX-70: 0-100,000 lux, Error $\pm$ 0.5%) was used to measure indoor illuminance. Experimentation started at 7:00 a.m. and end at 6:00 p.m. by recording data of the two units of windows simultaneously at 30 min intervals.

Figure 1 Testing room

3. Data reduction

The data recorded is conducted to calculate the air volume flow rate in the solar chimney windows for a room with two openings can be estimate as:

$$Q = C_d A_C \sqrt{\frac{2gH\left(\dfrac{T_o - T_i}{T_i}\right)}{\left(1 + A_r^2\right)}} \qquad (1)$$

Where Q is air volume flow rate, C_d is discharge coefficient (0.9), A_C is cross section area, g is acceleration due to gravity,

(a) Clear glass (left hand) and translucent glass (right hand)

(b) Translucent glass solar chimney window, TG-SCW (left hand) and

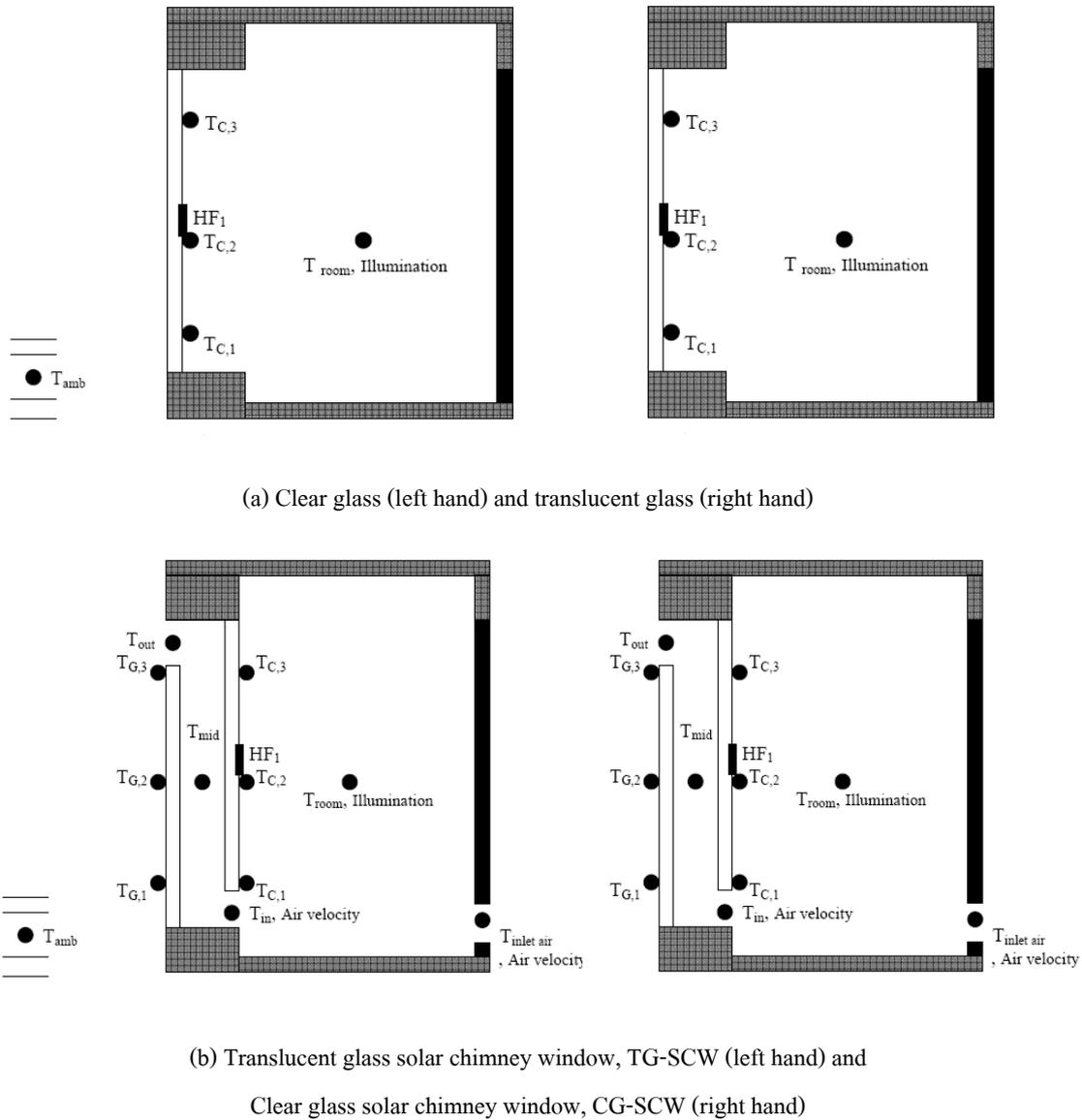Clear glass solar chimney window, CG-SCW (right hand)

Figure 2 Measuring positions of solar chimney window and single glass window

(9.81 m/s^2), H is height of the solar chimney, T_i and T_o are inlet and outlet temperatures. A_r is ratio of outlet and inlet area of openings. An air change of the space room is number of air change per hour (ACH) can be estimate by

$$ACH = \frac{3600Q}{V} \qquad (2)$$

Where ACH is number of air change per hour and V is volume of space room.

4. Results and discussion

4.1 Effect of slat glasses

A preliminary test of non-ventilated single glass window (SGW) was set and carried out in order to investigate temperature; illuminance and heat flux reduction through the windows by two types of slat glasses viz., clear glass (CG) and translucent glass (TG). Fig. 3 shows an example the room temperature variation of the CG and TG windows compared to ambient temperature. It can be seen that both temperatures were practically always lower than ambient. The maximum

temperature of room temperature was observed around 12:30. In the afternoon, after 14:00 the room temperature of CG was closed to ambient temperature.
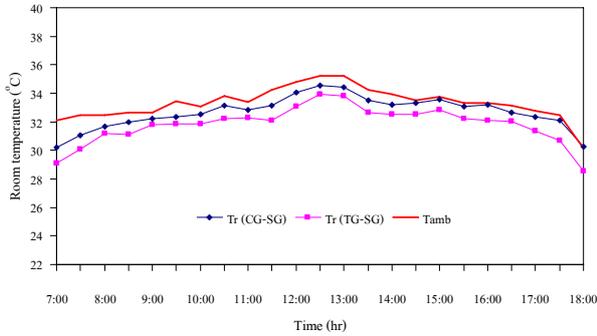

Figure 3 Hourly variations of room and ambient temperatures

Figures 4 and 5 showed the hourly variations of heat flux and illuminance of the two slat glasses. It can be seen that the elevation of heat flux and illuminance were dependant of solar radiation. With global solar radiation of about 880 W/m^2, the heat flux of clear glass was about 20 W/m^2 above the translucent glass. When solar radiation dropped to 50 W/m^2, heat flux of CG was nearly closed to TG. In part of illuminance, it can be seen that the maximum of illuminance was observed around 12:30.

The result suggested that the type of glass has significant effect on room temperature, heat gain reduction and illuminance.

4.2 Effect of natural ventilation on heat gain reduction

This section investigates the different solar chimney window units, namely, CG-SCW and TG-SCW. The CG-SCW composed of the clear slat glass on the outer pane and inner pane is clear glass. The TG-SCW composed of the translucent slat glass and inner glass is clear glass. Figure 6 depicts a comparison between the two solar chimney windows. It could be seen that the heat flux of TG-SCW is lower than that of CG-SCW by about 3-20 W/m^2. Between 10 a.m. to 5 p.m., period during which the natural ventilation

was high, the percentage of heat flux reduction varied between 3-16%. On morning hour, the TG-SCW seems to perform much better than the CG-SCW as heat flux reduction is quite high 25 to 40%.
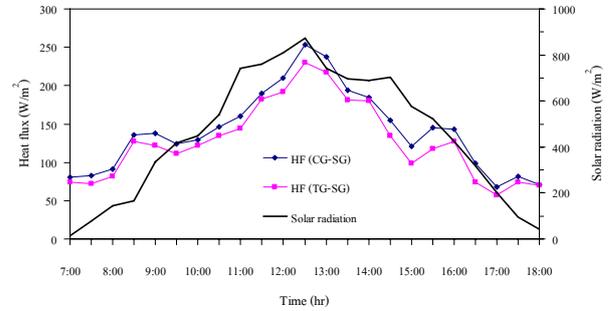

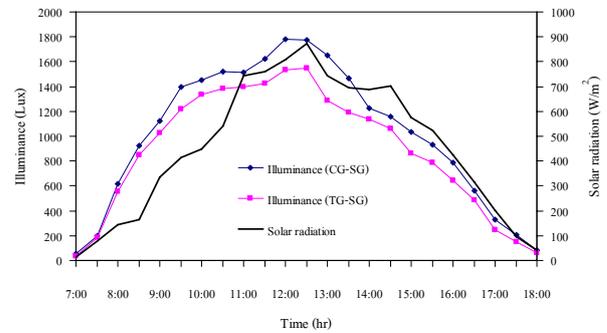Figure 4 Hourly variations of heat flux and solar radiation

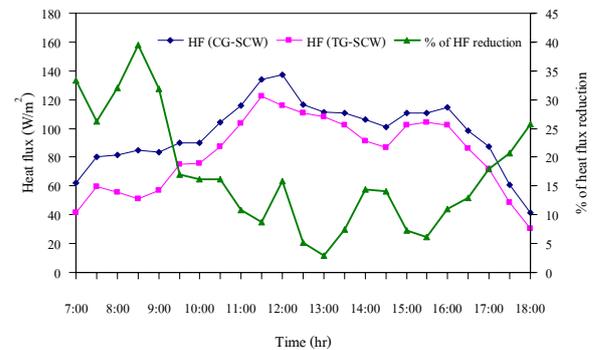Figure 5 Hourly variations of illuminance and solar intensity

Figure 6 Hourly variations of heat flux and percentage heat flux reduction

As a result of heat flux reduction through the solar chimney window, the thermal radiation effect into the room space diminishes and room temperature of TG-SCW is smaller than that of the CG-SCW one as depicted in figure 7. Observe

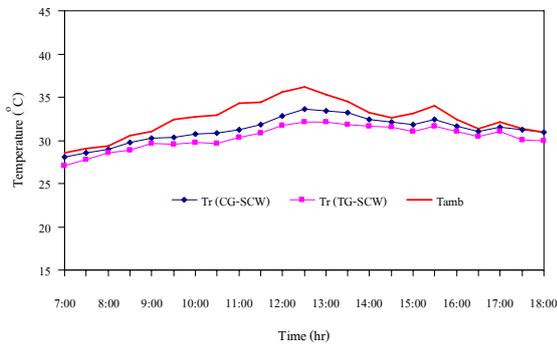that, the room temperature of CG-SCW was above the TG-SCW always.

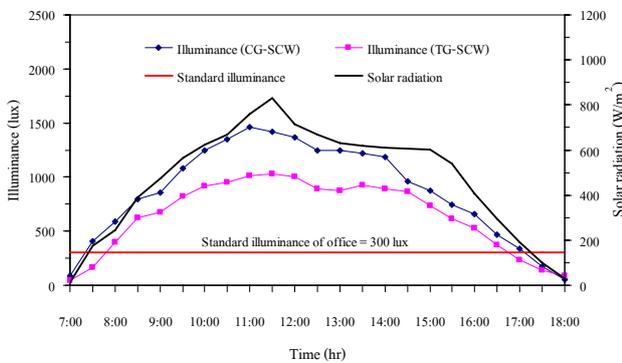Figure 7 Hourly variations of room and ambient temperatures

Figure 8 Hourly variations of Illuminance and Solar radiation

4.3 Daylighting effect

On the day of the experimental, the sky was fairly clear. Figure 8 shows the indoor illuminance compared to the standard indoor illuminance (office = 300 lux) [11]. It can be seen that the amount of indoor illuminance on a horizontal plane at 400 mm from the solar chimney window wall and 750 mm above the floor of the both SCW. During 8 a.m. to 4 p.m., the amount of daylight contribution from the TG-SCW and CG-SCW varied between 400-1000 lux and 800-1800 lux, respectively. However, the illuminance of TG-SCW is higher than the standard illuminance.

4.4 Airflow rate and air change

As the natural ventilation, the airflow rate of each solar chimney window varied following the solar radiation. As

depicted in figure 9, the natural ventilation rate of TG-SCW was smaller than that of CG-SCW ventilation because of the transmission of solar radiation. Figure 10 depicted to the number of air change. It can be seen that the number of air change is much be satisfiable for room space. It varied between 1 to 6 ACH (number of air change).
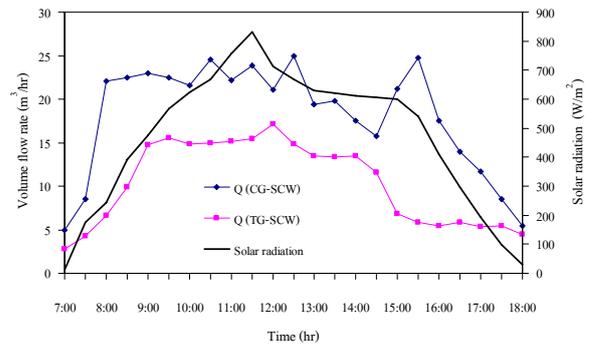

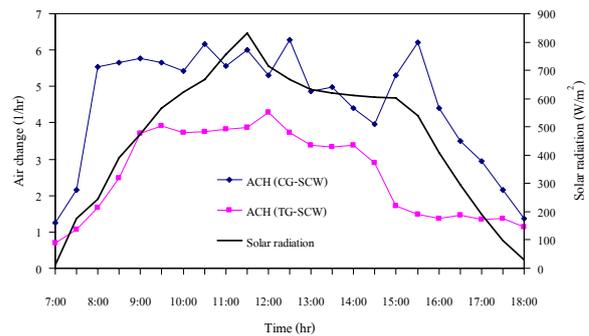Figure 9 Hourly variations of volume flow rate and

solar radiation

Figure 10 Hourly variations of air change and solar radiation

5. Conclusion

The use of SCW to reduce the rate of heat transferred through a window by inducing natural ventilation has been studied experimentally. Both CG-SCW and TG-SCW were considered and two different slat glass (clears glass and translucent glass) using on the outer side and glass pane (clear glass) on the inner. From the experimental results, it was found that TG-SCW could reduce significantly heat transfer through the window by about 3-20 W/m^2 higher than that of CG-SCW. The translucent glass is recommended to be

integrating in outer pane of SCW. Furthermore, the number of air change of space rooms were quite satisfies and varied between 1 to 6 ACH.

In addition, as extra cost of the construction according to the proposed configuration would not increase very significantly; Architects and engineering designer should consider these propositions in their further design.

6. Acknowledgement

7. References

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