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Experimental study on thermal performance of semi-transparent PV window in winter in Hong Kong

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Abstract

Semi-transparent PV (STPV) windows can provide daylight illuminance and electricity generation simultaneously. The performance of semi-transparent PV in saving cooling energy has been proved in previous studies. This study presents the heating performance of STPV window in winter in Hong Kong. The passive heating effect of STPV was investigated experimentally. The results indicated that space heating is not needed for the room equipped with STPV in work time on sunny days. The SHGC and U-value of the STPV were also calculated. The average values of SHGC and U-value are 0.2 and 5.58 W/(m^2 K), respectively.

Keywords: Building integrated photovoltaic; Semi-transparent PV; PV/thermal; Energy performance; EnergyPlus.

1. Introduction

With rapid development of economic, energy shortage has become a serious problem all over the world. Many efforts have been devoted to combine energy development with conservation. Building integrated photovoltaic is a promising technology which can save energy by replacing conventional building materials with PV material [1]. Semi-transparent PV (STPV) window can provide daylight illuminance and electricity generation simultaneously. Fung and Yang [2] developed a one-dimensional transient heat transfer model for STPV. The thermal performance of STPV under different scenarios were investigated, including the effect of orientation, the solar cell coverage ratio, the efficiency of solar cells and the

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module thickness. Li et al. [3] studied thermal and visual properties, energy performance and financial issues of STPV facades. The results revealed that STPV could produce electricity and cut down electrical lighting and cooling energy requirements. Lu and Law [4] developed an overall methodology to investigate the thermal and power behaviors of STPV windows for office buildings in Hong Kong. Liao and Xu [5] compared the energy performance of STPV with traditional glazings under different architectural conditions in China. The results indicated that the STPV had better energy performance than the single or double glazings in the area where cooling energy consumption is the dominant factor. According to literature review, it was seen that studies related to STPV is mainly in hot climate area, and the effect of decreasing cooling load has been proved. However, the energy performance of STPV in winter was rarely investigated. In winter, the thermal energy generated by the STPV can be used to heat indoor air. Thus, the STPV can be used as a hybrid PV/thermal system in cold areas. In this study, the thermal performance of STPV was investigated experimentally.

2. Methodology

2.1. Structure of the STPV

Fig.1 showed the cross section of the semi-transparent PV window. The tempered glass could protect the thin-film a-Si layers from damaged. Since the a-Si laminate is thin, the STPV window was able to provide outside scene to the people inside the room.

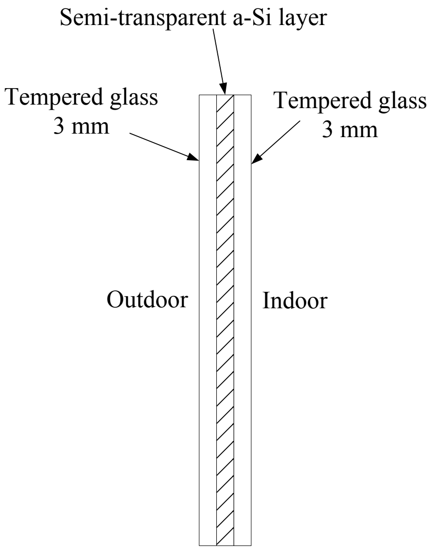

Fig. 1. Cross section of a typical a-Si semi-transparent PV window

2.2. Experiment setup

Experiment was conducted in the campus of Hong Kong Polytechnic University to investigate the thermal performance of STPV window in real environment. As showed in Fig. 2, the STPV was installed on the south facing facade of a small office, which had a shape of 2.32 m wide, 2.3 m long and 2.5m high. The structure parameters of the STPV are showed in Table 1. During the experiment, the weather data were recorded by a weather station, and the ambient air temperature and solar radiation were also recorded. The temperature and the heat flux of the STPV were measured by PT 100 thermocouples and heat flux meters, respectively. The experiment lasted for two weeks, and the experiment data was used to analyze the passive heating effect of the STPV in this paper.

Fig. 2. Experiment setup of the STPV window

Table 1. The structure parameters of the STPV window

Parameters	Value
Width of PV module	1.1 m
Height of PV module	1.3 m
Thickness of PV module	0.006 m

3. Experimental results and discussion

The experiment results are presented in Fig. 3~7. Fig.3 shows the global and diffuse horizontal irradiances. It was found that the experiment period included both sunny days and cloudy days. Fig.4 shows the outdoor and indoor air temperature and the PV module's surface temperature. When the solar irradiance was higher than 700 W/m^2, the temperature of the PV module reached up to 50 ^oC, and the indoor air temperature was as high as 33 ^oC. Considering the thermal comfort temperature in winter, the indoor air temperature should be higher than 20 ^oC in the office. It was found the air temperature can meet the temperature demands in work time on sunny days. It means that there was no need of space heating for the office room on winter sunny days. Fig. 5 shows the incident solar radiation on the STPV and the heat gains through the STPV. The solar heat gain coefficient (SHGC) and U-value of the STPV were calculated with the measured heat flux data which was recorded in an interval of 1 minute. For calculating the SHGC, only the values of solar irradiance higher than 100 W/m^2 were used. The results are showed in Fig.6; the average SHGC was about 0.2. For calculating the U-value, only the temperature differences between the indoor and outdoor air temperature higher than 2 ^oC were considered. The results are showed in Fig. 7; the average U-value was about 5.58 W/(m^2 K). Compared to the thermal performance of PV double skin façade (PV-DSF) [6], the STPV has a higher SHGC, and a lower U-value.

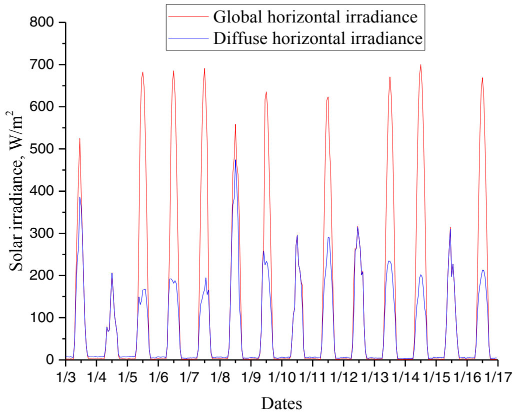

Fig. 3. Global and diffuse solar irradiances on the horizontal surface

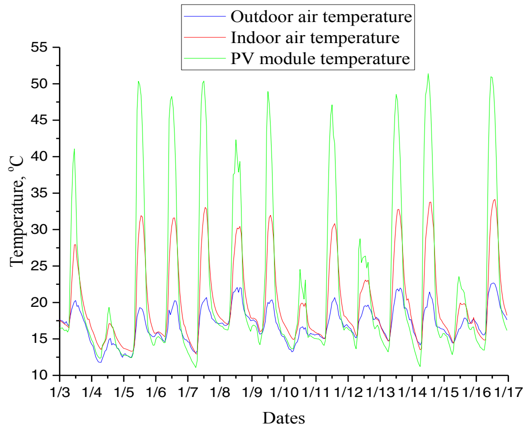

Fig. 4. PV module and air temperatures

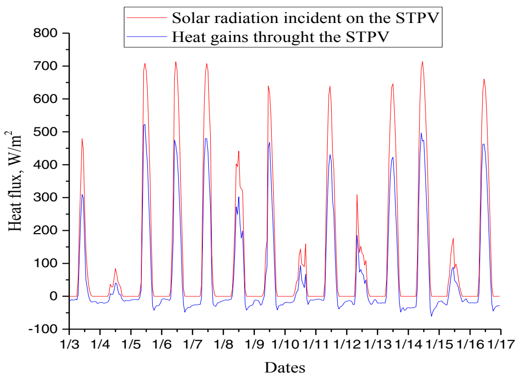

Fig. 5. Heat gains through the STPV

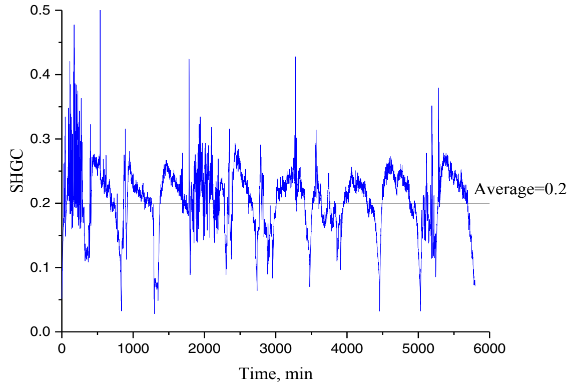

Fig. 6. SHGC of STPV

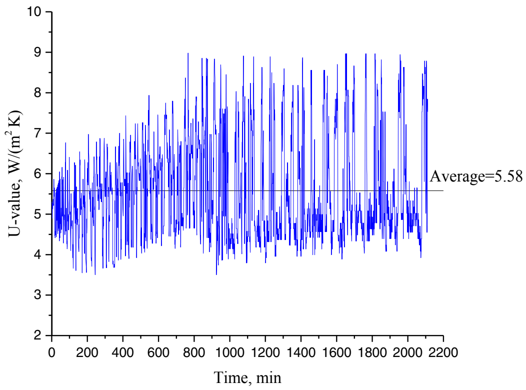

Fig. 7. U-value of STPV

4. Conclusions

In this study, the thermal performance of a STPV window was investigated experimentally. It was found that the temperature of the STPV can reach up to 50 ^{o}C when the solar irradiance exceeds 700 W/m^2 in winter. The indoor air temperature in work time on sunny days are higher than 20 ^{o}C, thus space heating is only necessary on cloudy days in Hong Kong. The average SHGC and U-value of the STPV were 0.2 and 5.58 W/(m^2 K), respectively. The thermal indicators obtained in this study can be used for comparison in further researches.

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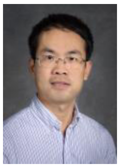

Biography

Jinqing Peng is an associate professor of building services engineering at Hunan University. He received his Ph.D. from Hong Kong Polytechnic University in 2014. Dr. Peng has published more than 50 academic articles in international journals.