Simplified on-site method for evaluating solar shading performance of advanced windows

Takashi INOUE, Masashi MOMOTA

Tokyo University of Science, 2641 Yamazaki, Noda-shi, Chiba, JAPAN

ABSTRACT: A simple measuring system has been developed in order to determine the solar shading performance of various novel complicated windows, such as airflow windows, windows with exterior blinds or double skin using low-E glass, electro-chromic glass and so on. An experimental set-up (approx. 350 x 350 x 350mm) with heat flow sensor panels, a Peltier device, and an insulation box was completed and tested for some window units, and it was then applied to advanced window systems in actual office buildings in Tokyo. The results showed that this compact system provided a simple method to evaluate solar shading performance of various windows under the actual conditions of buildings with practical accuracy.

Keywords: measurement, solar shading performance, SHGC, window

1. INTRODUCTION

Recent architecture tends to feature a facade mostly comprising of glass. Such architecture might be extremely influenced by solar intrusion and deterioration of thermal environment due to expansion of glass surfaces. Therefore, various window systems have been proposed and developed for the purpose of improving energy-saving properties and comfort. Solar heat gain coefficient has been recognized as an evaluation index of the solar shading performance of a window. While its computational estimation procedure has been defined by the standard such as ISO, its experimental estimation procedure has not been well established, compared with the case of insulation properties. The measurement procedure of solar shading performance of a window with indoor measurement using artificial light sources concerns a large-scale apparatus and different wavelength distribution and directivity from sunlight. Our study aims to evaluate the solar shading performance of an actual window. This report addresses the development of a simple on-site measurement procedure of solar shading performance using sunlight.

2. Profile of Measuring Instrument

As shown in Fig. 1, the measurement box comprises large-size heat flow meters (300 x 300 x 0.4 mm) on all five surfaces of its cubical inside, and detects heat gain from its aperture with these heat flow meters. The profile of the measurement system is shown in Fig. 2. Since the temperature inside the measurement box rises by solar radiation, the measurement box is cooled from the outside of the heat flow meters so that the temperature inside is adjusted to room temperature. Aluminium fins installed at the heat flow meter improve cooling capacity in the measurement box. In addition, a double-skin outer case covered by aluminium foil

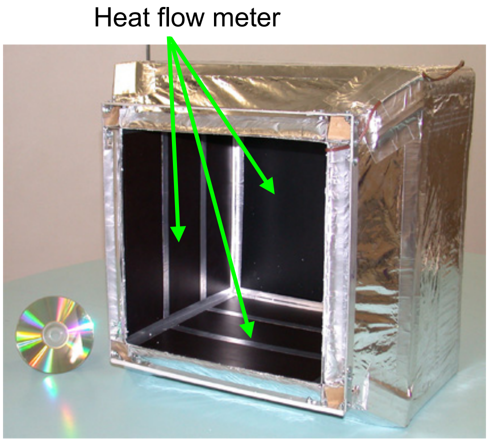

Fig 1: Measurement box

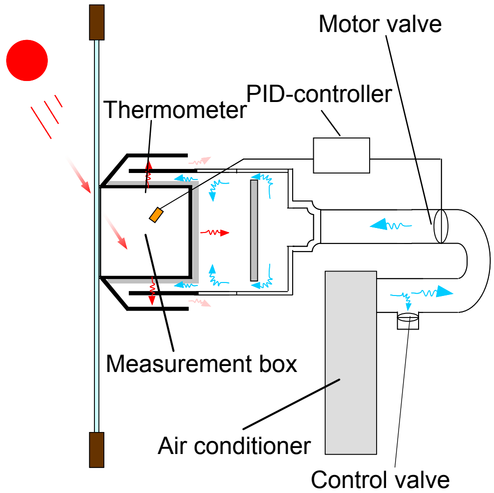

Fig 2: Schematic of system

suppresses the influence of solar radiation on the exterior of the measurement box. Temperature control is performed as follows: temperature in the measurement box is detected with thermometer; a motor valve installed in the air duct opens and closes by PID control; and the flow rate of cooling air is automatically controlled. A compact air conditioner and duct system is adopted. Solar heat gain coefficient is computed with heat detected by the heat flow meter, from which caused by temperature difference through the glass is subtracted.

3. Accuracy Evaluation of Measurement Box

Detection accuracy of the measurement box was verified as preliminary measurement. The aperture of the measurement box was sealed with heat insulating materials. Measuring conditions on window surfaces being simulated, the measurement box was heated with 4 types of virtual heat sources: electric bulbs of 10 W, 20 W, 40 W, and 60 W. Then the external surfaces of the heat flow meters were cooled with cold air, so that the interior of the box approached room condition and temperature in the measurement box was stabilized. Measurement was carried out after maintaining this condition for 20 minutes. Figure 3 indicates the correlation between input energy and detected value at measurement. The overall detection rate averages about 101%, which demonstrates its detectability of relatively high accuracy. It was also confirmed that the detection rate is rather constant with respect to input energy that is, constant measurement accuracy is expected regardless of solar radiation.

4. Examination of Automatic Control Response to Solar Fluctuation

It was verified whether the overall heat transfer coefficient could be measured stably, by flow rate control of cold air corresponding to fluctuation of solar radiation with a double-glazing window (FL 3 + A 6 + FL 3 mm) in our university. Fig. 4 indicates that excellent detection is assured in general, even if the influence of ambient conditions at detection is taken into consideration. Fig. 5 shows almost constant temperature in the box in the time span for the measurement, which demonstrates that automatic control responds properly to the fluctuation of solar radiation. Also solar heat gain coefficients(i.e.SHGC), measured and computed, are comparable, which shows that they are measured in relatively high accuracy.

5. Verification of Accuracy of Measurement Box in Offices

As mentioned above, the controllability and accuracy of this measurement procedure over actual windows have been verified. Therefore, thermal performance of airflow windows (Fig. 6) of an office building under actual use was evaluated based on this result. As shown in Fig. 7, temperature in the box has been kept properly under excellent control. Stable

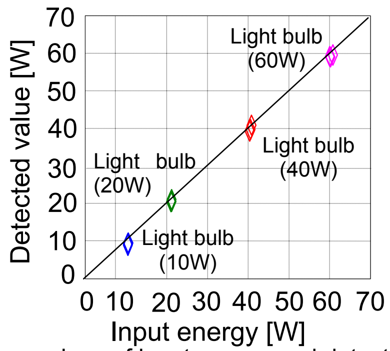

Fig 3: Comparison of input energy and detected value

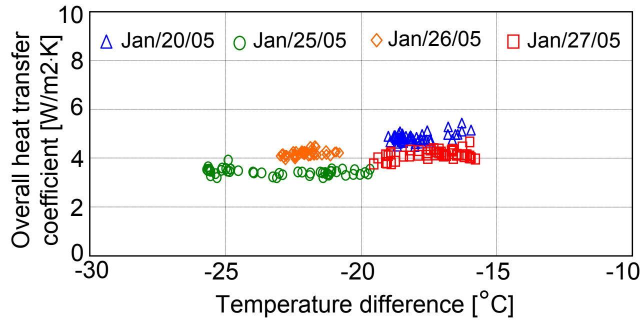

Fig 4: Relationship between temperature difference and overall heat transfer coefficients

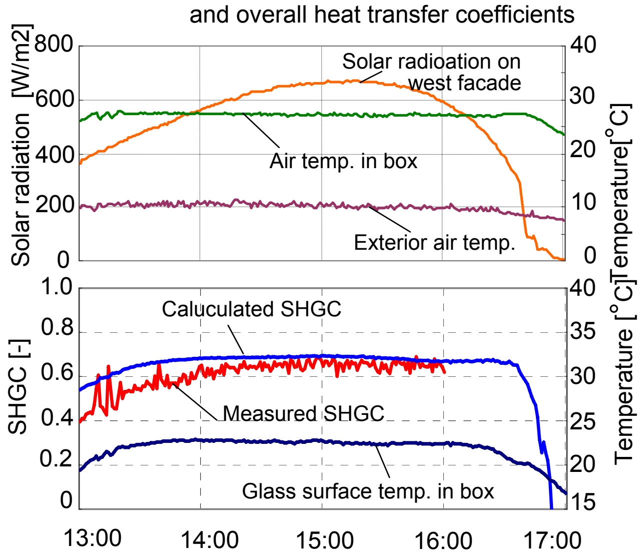

Fig 5: Measured SHGC for double-glazing (22/Jan/05)
(SHGC; Solar Heat Gain Coefficient)

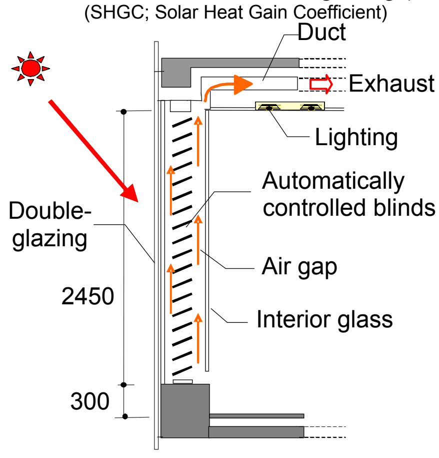

Fig 6: Schematic of airflow window

temperature in the box assures stable measurement. Solar heat gain coefficient and glass surface temperature in the box have a similar upward tendency, which suggests that fluctuation in inflow heat from the window glass can be detected with accuracy. Next, taking the specification difference into consideration, we have compared this simplified measuring method with the laboratory measurement procedure in our previous report that captures the heat balance of the whole laboratory precisely (Fig. 8). Both provide mostly agreeable values; it is considered that the result reflects difference in ventilation flow rate and variation in sun elevation under actual use conditions.

6. Examination of More Simplified Measuring Method Using Peltier Device

We also have developed and proposed a procedure, described below and shown in Fig. 9 and Fig 10 using a Peltier device aiming at measuring solar shading performance more easily in buildings under actual use. A heat flow meter and a Peltier device of the same dimension were laminated and installed on one surface of the measurement box. Other four surfaces were composed of vacuum insulation panels and highly thermal-insulating rigid polyurethane, and the aperture surface was closely attached to the window. Hence the measurement box detects heat inflow from the window as indicated values of the heat flow meter. Also in this case, temperature in the measurement box was measured, the Peltier device was turned on and off with PID control, so that temperature in the box was controlled to become the same as room temperature. This configuration requires no air conditioner or duct system, and allows us to improve workability in on-site measurement remarkably.

Detection accuracy was verified according to the above-mentioned measuring method as shown in Fig.11, and detectability was verified for double-glazing according to fluctuation of solar radiation. The result is summarized in Fig. 12. Compared with the above-mentioned whole surface heat flowmeter method, this method provides somewhat greater values. It is supposed that the Peltier device causes fluctuation due to its switching. However, this procedure turns out to have detection accuracy almost comparable to the above-mentioned method.

This measuring method was applied to an office window system with exterior blinds and heat-generating double-glazing glass (Fig. 13, 14). The result is shown in Fig. 15 and Fig. 16. This procedure provides a little greater solar heat gain coefficients compared with the whole surface heat flow meter method. However, as both values ranges 0.07-0.10, the present method proves that this window system has excellent solar shading performance.

7. Conclusion

We have proposed a simplified measuring method of the solar shading performance of a window using large-size heat flow meters or a Peltier device. It is

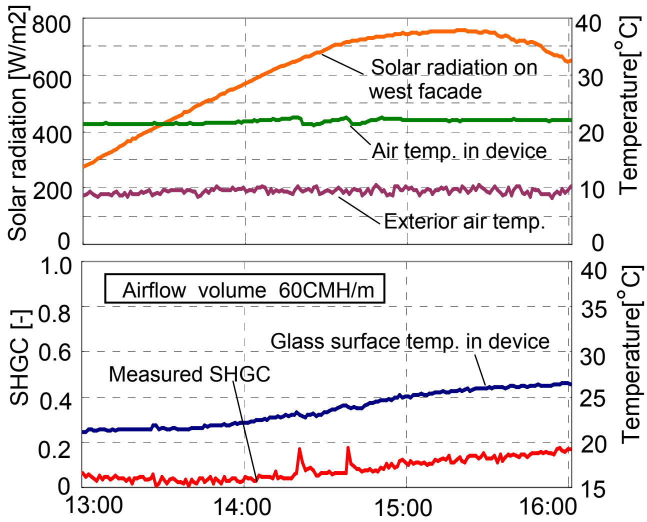

Fig 7: Measured SHGC for airflow window (30/Jan/05)

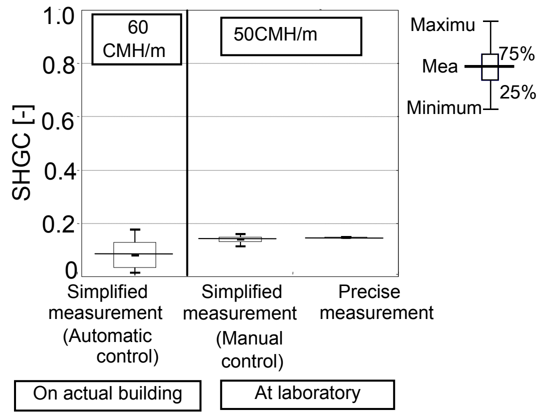

Fig 8: Comparison of SHGC of airflow window

Fig 9: Measuring device with Peltier unit

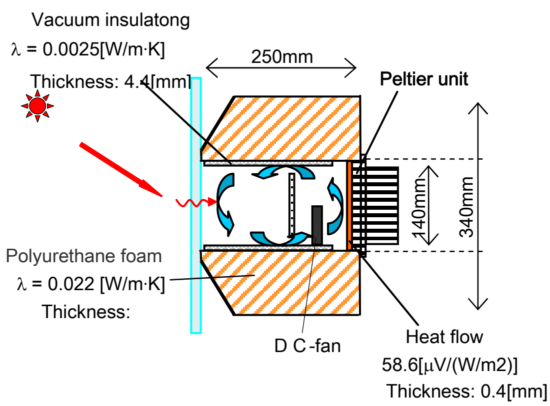

Fig 10: Cross-section of system with Peltier unit

verified that the proposed method could measure solar shading performance in practically sufficient accuracy for windows with excellent solar shading performances, such as airflow windows and windows with exterior blinds and heat-generating glass.

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REFERENCES

[1]T.Inoue, T.Kawase et.al., The Development of an Optimal Control System for Window Shading Devices based on Investigation in Office Buildings, ASHRAE TRANSACTION Vol.94 Part 2(1988), P1034-1049
[2]P.Baker, D.Saelens, M.Grace and T.Inoue, Advanced Envelopes - Methodology Evaluation and Design Tools, - Laboratorium bouwfysica K.U.Leuven
[3] T.Inoue, Solar shading and daylighting by means of autonomous responsive dimming glass: practical application, Energy and Buildings Volume35, Issue5, June 2003, P463-471
[4] T.Inoue, T.Kawase, Effects of Exterior Blinds and Heat-generating Double-glazing in an Office Building, PLEA 2004-Eindhoven, Sep, 2004,


Fig.13: West façade of building

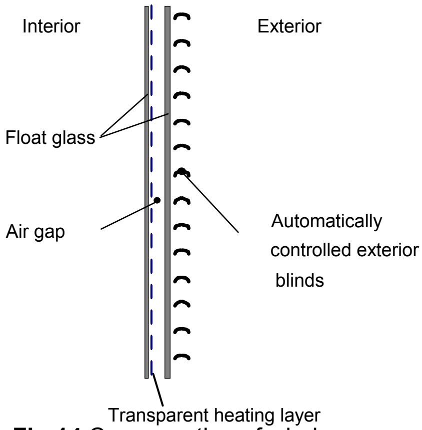

Fig 14:Cross-section of window

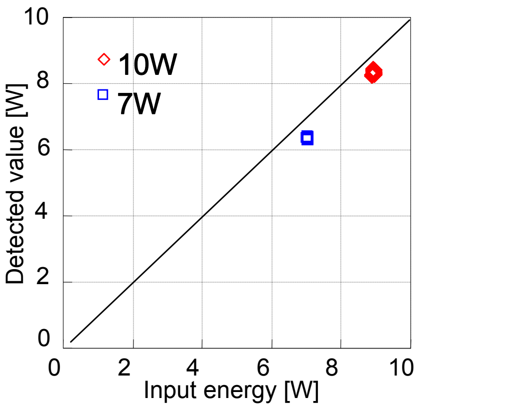

Fig 11: Comparison of input energy and detected value

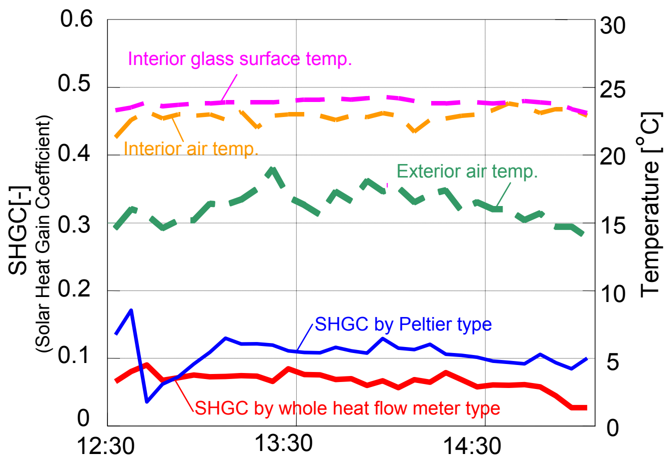

Fig 15: Measured SHGC for exterior blinds (17/Dec/2005)

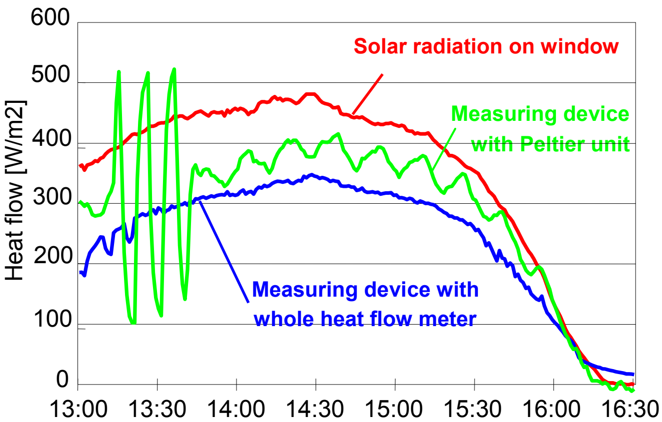

Fig 12: Comparison of detected heat flow for double-glazing (8/Dec/2005)

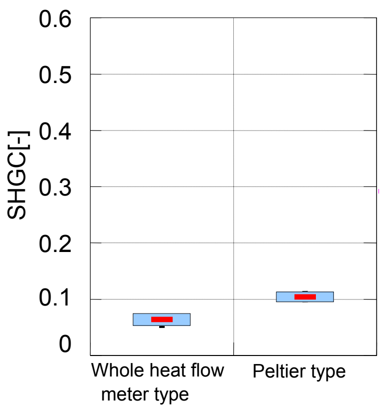

Fig 16: Comparison of SHGC of whole heat flow type and Peltier type