Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 525, pp 392-396
doi:10.4028/www.scientific.net/AMM.525.392

Online: 2014-02-06

A Study of Cooling and Heating Energy Reduction Effects for Applying of Blind-integrated Window System in Buildings

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Keywords: Blind-integrated window system, Cooling energy consumption, Heating energy consumption, building energy

Abstract. Recently, the window-to-wall ratio in the building envelope has gradually increased. In summer, as a result, cooling load significantly increases because of a large amount of sunlight coming through the windows. And in winter, thermal comfort can decrease at night because of heat loss and cold radiation which take place through the windows which have relatively low thermal resistance. To evaluate on characteristics of cooling and heating energy consumption under the blind-integrated window system which can fundamentally block this kind of cooling and heating load, this study has measured inner & outer surface temperature of glazing, electricity consumption and heat flux after installing the general and blind-integrated window systems in the test bed. According to the inner & outer surface temperature of glazing, the blind-integrated window system was 20.4℃ while the general one was 14.4℃ in summer. And in winter, the blind-integrated window system was 2.1℃ while the general one was 0.8℃. Under the blind-integrated window system, in other words, electricity consumption was saved by up to 26% (about 11% daily), and heat flux decreased by approximately 34%. In addition, it's been confirmed that heater electricity consumption in winter could be saved up to 17%.

Introduction

The window-to-wall ratio in the building envelope has gradually increased. In summer, cooling load significantly increases because of a large amount of sunlight coming through the windows in the daytime. In winter, thermal comfort can decrease at night because of heat loss and cold radiation which take place through the windows which have relatively low thermal resistance. In Korea, with the amendment of design criteria for building energy saving in March 2013, the insulation standards for windows and doors have become more rigorous by about 30%[1]. However, this measure has concentrated on heat loss by heater. Therefore, it is not effective in reducing solar heat gain loads which have dramatically increased recently.

This study has attempted to evaluate on characteristics of cooling energy consumption in an objective and quantitative method after installing a blind-integrated window system which can fundamentally block solar heat gain loads around the windows in the test room and assessing its performance as a part of developing practical technology[2,3]. In addition, this study has evaluated the heating energy consumption of the blind-integrated window system by operating a heater in winter.

Test methods for evaluating on the cooling and heating energy consumption

2.1 Test overview To evaluate the cooling and heating energy consumption of the blind-integrated window system, both blind-integrated window system and general window system were installed in two test rooms with the same window and room size in Korea Institute of Construction Technology

(KICT). The two window systems had the same specifications. Because of the thickness of the blind, the blind-integrated window system was thicker than the general window system in terms of intermediate space. The glazing specification is stated in Table 1, and the indoor view of the test rooms is shown in Fig. 1. A list of measurement items and equipment is summarized in Table 2.

Table 1 General description and specification

Classification		Room 1	Room 2
Room area		8㎡	8㎡
Composition		Blind-integrated window system	General window system
Glazing specification	outside	5CL+27Air+5CL	6CL+12Air+5CL
	inside	5CL+12Air+5CL	5CL+12Air+5CL

Fig. 1 Indoor appearance of test room 1 and room 2

Table 2 Measured items and device

Measured items	Measurement device	Use
Temperature	T-type thermocouple sensor	Indoor temperature
		Glazing surface temperature
	Data logger	Data Logging
Energy consumption	Watt-hour meter	Electricity consumption
Load	heat flow sensor	Heat flux
indoor temp. maintenance	Air-conditioner / Heater	Maintaining indoor temperature

2.2 Test methods To measure the cooling energy consumption of the blind-integrated window system in summer, an air conditioner was installed in each test room. By keeping indoor temperature at 24˚C, electricity consumption by indoor temperature was measured using the Watt Hour Meter (WHM). In the blind-integrated window system-installed room, the blind was set to roll down automatically when ambient temperature hit 31˚C, using the detection sensor on the outside of the window. To measure inner & outer surface temperature of glazing, indoor walls and indoor and outdoor spaces, T-type sensor was attached to each part, and changes in surface temperature by outdoor air were measured. The surface temperature was measured at places as shown in Figures 2 and 3.

To evaluate the heating energy consumption of the blind-integrated window system in winter, moreover, a convector heater has been installed, and indoor temperature was kept at 20˚C. If indoor temperature exceeds 20˚C, the heating system stops. It is designed to be operated when the temperature is 20˚C or below. Using the WHM, the consumption of heating energy and inner & outer surface temperature of glazing have been measured. When the heating system is operated, they were measured with the blind rolled up to increase the amount of solar radiance coming through the window.

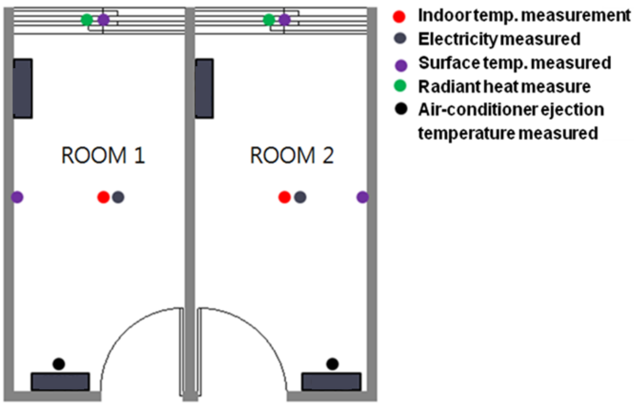

Fig. 2 Indoor temperature-measured position in prototype

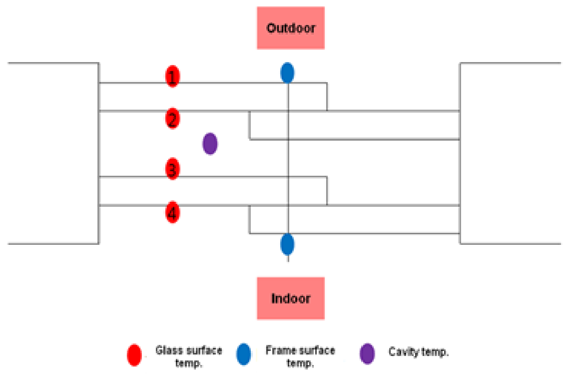

Fig. 3 Indoor/outdoor surface temperature-measured position in window

Results of evaluation on the characteristics of cooling energy consumption

3.1 Results of measurement of surface temperature To analyze differences of inner & outer surface temperature of glazing between the general and blinded-integrated window systems, data collected at the maximum load (14:00-16:00) and minimum load (02:00-04:00) have been analyzed. According to the analysis, the blind-integrated window system was 20.4˚C while the general window system was 14.4˚C in terms of glazing surface temperature at maximum load. In other words, if the blind-integrated window system was applied, the inner & outer surface temperature of glazing was higher by about 6˚C. At minimum load, on the contrary, the inner & outer surface temperature was nearly same between the two window systems. Under the blind-integrated window system, the amount of solar radiance coming through the window dramatically declines because of the blind. Therefore, it is effective in reducing solar heat gain loads. At maximum load, inner & outer surface temperature of glazing is shown in Fig. 4.

3.2 Electricity consumption and heat flux

3.2.1 Electricity consumption To analyze indoor electricity consumption after the installation of bind-integrated and general widow systems, it was measured in the daytime and at night. Then, the following results were obtained: electricity consumption was 3,000Wh and 3,780Wh in the blind-integrated window system and in the general window system respectively. Compared to the latter, the former system was able to save electricity by up to 26% (about 11% daily). In addition, it's been confirmed that the blind-integrated window system is effective in reducing cooling energy consumption by blocking solar heat gain loads in summer. The indoor electricity consumption under the general and blind-integrated window systems is shown in Fig. 5.

3.2.2 Heat flux The total accumulated heat flux under the general and blind-integrated window systems was 471.39 W/㎡ and 719.2 W/㎡ respectively. Compared to the general window system, it was able to reduce solar heat gain by about 34% in summer under the blind-integrated window system.

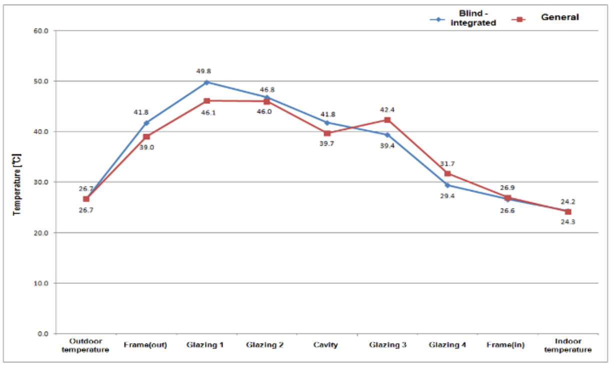

Fig. 4 The measurement of results of indoor/ outdoor surface temperature in summer

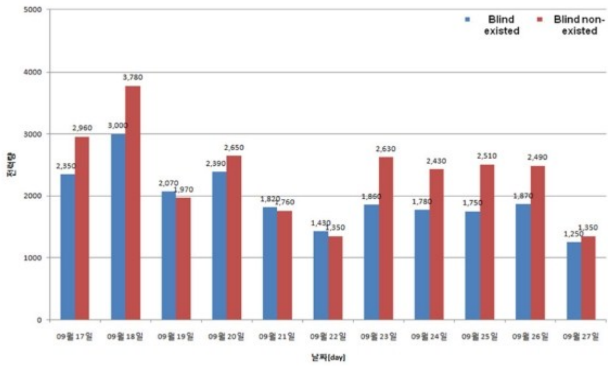

Fig. 5 Date-specific electricity consumption in summer

Results of evaluation on the characteristics of heating energy consumption

4.1 Results of measurement of surface temperature To analyze differences of inner & outer surface temperature of glazing between the general and blinded-integrated window systems, data collected at the maximum load (14:00-16:00) and minimum load (02:00-04:00) have been analyzed. According to the analysis, the blind-integrated window system was 2.1˚C while the general window system was 0.8˚C in terms of glazing surface temperature at maximum load. In other words, if the blind-integrated window system was applied, the inner & outer surface temperature of glazing window was higher by about 1.3˚C. It appears that temperature difference has occurred depending on the gap of intermediate space because the blind was rolled up to allow solar radiation to flow into a room in winter. The inner and outer surface temperature of glazing in winter is shown in Fig. 6.

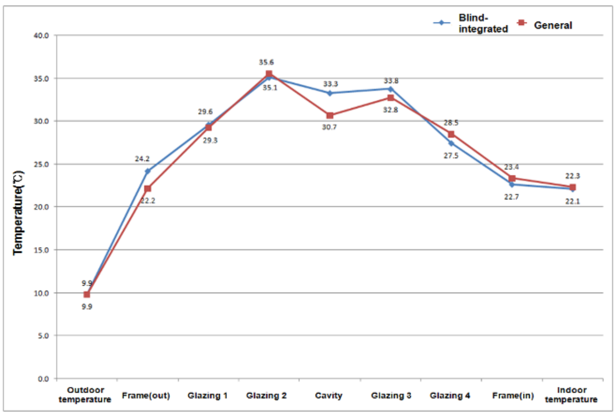

Fig. 6 The measurement of results of indoor/ outdoor surface temperature in winter

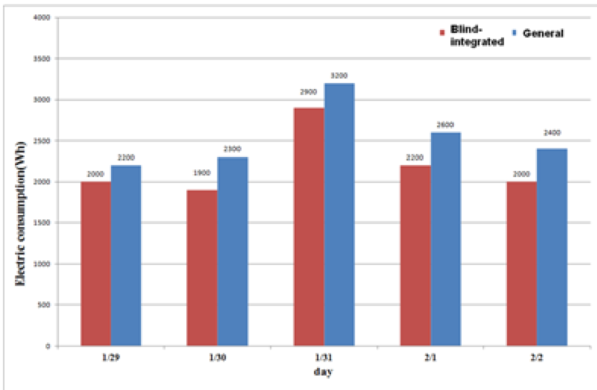

Fig. 7 Date-specific electricity consumption in winter

4.2 Results of electricity consumption To analyze indoor electricity consumption after the installation of bind-integrated and general widow systems, it was measured in the daytime and at night. Then, the following results were obtained: electricity consumption was 1,900Wh and 2,300Wh in the blind-integrated window system and in the general window system respectively. Compared to the latter, the former system was able to save electricity by up to 17%. At night, in addition, 5,100Wh and 4,300Wh of electricity was consumed in the blind-integrated window system and general window system respectively, which means that the former can save electricity up to 16%, compared to the latter. It's been also confirmed that the blind-integrated window system is effective in reducing heating energy consumption even in winter. The indoor electricity consumption under the general and blind-integrated window systems is shown in Fig. 7.

Conclusions

Recently, the window-to-wall ratio in the building envelope has gradually increased. In summer, as a result, cooling load significantly increases because of a large amount of sunlight coming through the windows. And in winter, thermal comfort can decrease at night because of heat loss and cold radiation which take place through the windows which have relatively low thermal resistance. To evaluate cooling and heating energy consumption under the blind-integrated window system which can fundamentally block this kind of cooling and heating load, this study has measured inner & outer surface temperature of glazing, electricity consumption and heat flux after installing the general and blind-integrated window systems in the test rooms. According to the inner & outer surface temperature of glazing, the blind-integrated window system was 20.4˚C while the general one was 14.4˚C in summer. And in winter, the blind-integrated window system was 2.1˚C while the general one was 0.8˚C. Under the blind-integrated window system, in other words, electricity consumption was saved by up to 26% (about 11% daily), and heat flux decreased by approximately 34%. In addition, it's been confirmed that heater electricity consumption in winter could be saved up to 17%.

Acknowledgements

This work was financially supported by a grant (08 Building Technology Research and Development A01) from High-tech Urban Development Program (HUDP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

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