

AN EXPERIMENTAL STUDY OF THE ENVIRONMENTAL PERFORMANCE OF THE AUTOMATED BLIND IN SUMMER

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ABSTRACT

Blinds are used widely in numerous buildings to conserve energy and provide for occupants' comfort in the perimeter zone. But manual or motorized blinds are limited in their ability to reduce energy consumption because occupants must control blinds themselves to block glare. Thus the use of automated blinds would more fully take advantage of the full benefits of blinds.

The use of automated blinds is still in the early stages in Korea, and the control algorithm is too rudimentary to satisfy users' full range of comfort needs. Moreover, improvement in environmental performance through the use of automated blinds has not been sufficiently established.

This study aims to evaluate the environmental performance of commercially used automated blinds in the summer season. The environmental performance of automated blinds was evaluated in this study through thermal and visual experiments involving 4 cases of two side-by-side mock-up test cells which were equipped with venetian blinds. The results of the study attest to the ability of automated blinds to enhance environmental performance.

KEYWORDS

Automated Blinds, Manual Blinds, Environmental Performance, Energy Consumption

INTRODUCTION

Recently numerous glass-skin office buildings have been constructed in Korea as the number of high-rise buildings has increased and more interest has been taken in the appearance of the building envelope. While the windows of a building envelope can provide occupants with daylight, visual contact with the outside and a feeling of openness, they also represent a great point of entry for heat. While it is desirable to introduce sunlight for natural lighting over a given constant level, solar radiation caused by introducing the sunlight may not be desired under certain seasonal conditions, and the decision to introduce it must be made based on these conditions. Solar radiation has a positive effect in winter because it reduces the heating load; however, solar radiation increases the cooling load of the building during the summer season. Because sunlight is composed of light and heat, it is difficult to control light and heat separately. In other words, allowing daylight to enter in for greater illumination and isolating excessive heat to lower the cooling load are decisions that must both be considered concurrently. What's more, illuminance that is too high on the workplane can cause a glare problem and should be avoided in an office space. Because glare problem is a major factor that has a great effect on occupants' comfort, it must also be taken into consideration.

Using blinds is a common solution to controlling incoming solar radiation in office buildings. If blinds are controlled properly according to the variations in the external and internal environmental conditions, excessive energy use and occupant discomfort due to direct solar radiation can be greatly reduced. In the case of venetian blinds, more effective environmental performance can be achieved because additional controls for slat angle are available. But previous studies have shown that in reality, occupants rarely change the vertical position of blinds, whether using manual or motorized venetian

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blinds. Manual or motorized venetian blinds are limited in their ability to meet occupants' needs and in reducing energy consumption because occupants tend to change the vertical position only when glare makes conditions uncomfortable.

To overcome these limitations, venetian blinds need to be controlled automatically. In summer, automated blinds can reduce cooling loads and overheating by blocking solar radiation. In winter, they can be opened to allow daylight and needed solar gains, so that the building can reduce its dependence on electric lighting and the heating system. To achieve these outcomes, the blinds must be properly controlled; otherwise, unwanted solar gain may enter the building and increase the cooling load. Also occupants may experience glare from the sun.

This study aims to evaluate the environmental performance of commercially used automated venetian blinds in the summer season. The environmental performance of the automated venetian blinds was evaluated through thermal and visual experiments involving 4 cases in a real-scale experiment in summer.

EXPERIMENT ON ENVIRONMENTAL PERFORMANCE OF AUTOMATED BLINDS

Outline

In this study, the effects of commercially used automated blinds on thermal and visual environmental performance were compared with those of extremely controlled cases, fully opened or fully closed. Internal venetian blinds were used in this experiment and the blind specification was as follows.

- Blinds: Internal venetian blinds (slat material: aluminum, slat width: 50mm)
- Sensor: Sun sensor (sensing outdoor vertical illuminance)
- Operation: Energy saving mode (see Table 1)

Experiments were carried out in two side-by-side mock-up test rooms located on the top floor of a building in Seoul National University, Korea, to measure energy-saving efficiency for the month of August 2006.

Two test rooms with the dimensions of 5.8m (W) x 4.8m (D) x 2.7m (H) with the same heat loss and gain were used to reproduce the same conditions, as shown in Figure 1. Various instruments were installed inside and outside the rooms to measure and analyze environmental conditions, as demonstrated in Table 2.

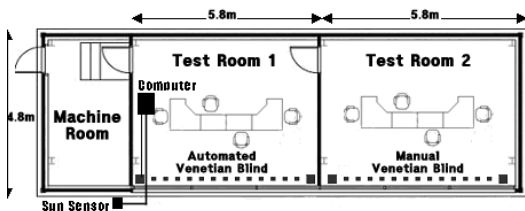


Figure 1 Plan view of test rooms

Table 1 Operation sequence of energy saving mode

Control time	Control conditions				Operation at ON		Operation at OFF	
	ON		OFF		Occlusion index	Slat angle	Occlusion index	Slat angle
	Exterior Illuminance	Delay	Exterior Illuminance	Delay				
09:00 ~ 18:00	≥16 klux	3 min.	≤15 klux	15 min	100%	90°	0%	0°

Table 2 Measuring instruments

	Equipment	Position
Interior illuminance	Interior lux meter Daylight factor meter	Room 1, Room 2
Exterior illuminance	Exterior lux meter	Roof (Outside)
Solar radiation	Exterior irradiance meter	Roof (Outside)
Room temperature	T-type thermocouple	Room 1, Room 2
Outdoor temperature	T-type thermocouple	Outside

Method

Experiments were performed for 4 cases, as presented in Table 3. In test room 1, energy-saving mode was utilized, controlled automatically by an exterior sun sensor. The energy-saving mode was set up to shut out the solar radiation at the maximum level within the control range (see Table 1). In test room 2, for the set up of the compared blinds, two model cases were selected, in which the blinds were fully opened (occlusion index: 0%), and the blinds were fully closed (occlusion index: 100%, slat angle: 90°), respectively. According to previous study, non-automated blinds were mostly located in fully opened or closed (Park et al. 2006).

Through the experiments, the characteristics of automatic control in terms of energy consumption compared with those of the extreme control case were verified by comparing temperature, cooling energy and lighting energy. In cases 1 and 2, how isolating solar radiation according to excessive exterior illuminance changed the room temperature compared to extreme blind position. In cases 3 and 4, cooling and lighting energy were estimated using measured data on the temperature difference between supply air and return air, and interior illuminance. For each case, the experiments were performed from 09:00 AM to 18:00 PM, without artificial lighting. Prior to starting the experiments, the two rooms were air-conditioned to ensure that the same environment prevailed in each.

Table 3 Experiment cases

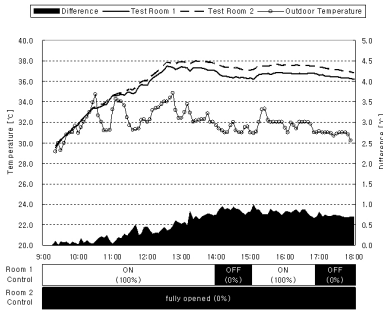
Case	Date	Test room 1	Test room 2	Cooling	Remarks
1	8/12	Energy Saving Mode (see Table 1)	Fully Opened	X	Evaluate temperature difference
2	8/16		Fully Closed		
3	8/19		Fully Opened	○	Evaluate energy consumption
4	8/20		Fully Closed		

RESULTS AND DISCUSSION

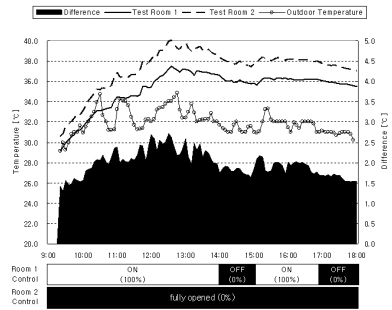
Case 1: energy saving mode vs. fully opened (without cooling)

The temperature of the occupied zone of the test room is shown in Figure 2 a). During the experiment, the temperature in test room 2 where the blinds were fully opened was higher than that of test room 1 where the blinds were controlled automatically. Due to the effective blockage of solar radiation according to the increase of the exterior illuminance in energy-saving mode, the temperature in test room 1 was lower than test room 2 by a maximum of 1.0°C. For the perimeter zone, which was directly subjected to solar radiation, the temperature difference was greater. In Figure 2 b), the perimeter zone temperature of test room 1 was lower than that of test room 2 by a maximum of 2.7°C.

This experiment demonstrated that automated control can more effectively manage increases in room temperature than is possible when blinds are absent. In particular, in the perimeter zone, solar radiation can be effectively shut out by automatic control, thereby reducing the rise in temperature and providing uniform temperature distribution throughout the room.

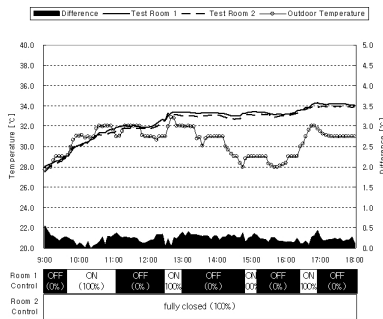


a) Interior zone

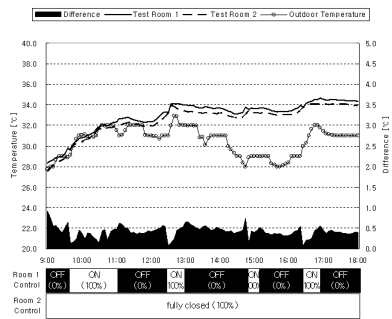


b) Perimeter zone

Figure 2 Temperature profile of case 1



a) Interior zone



b) Perimeter zone

Figure 3 Temperature profile of case 2

Case 2: energy saving mode vs. fully closed (without cooling)

The temperature of both test rooms is shown in Figure 3. Compared with test room 2 where solar radiation was shut out all day, the temperature in test room 1 was about 0.3°C higher in the occupied zone. When comparing the room temperatures in the perimeter zone, the temperature in test room 1 was higher than that recorded in test room 2 by approximately 0.5°C, which is roughly the same as that recorded in the occupied zone.

When compared with the results obtained in Case 1, this shows that the rise in the perimeter zone temperature could be reduced with automatically controlled blinds. Therefore, though the blinds were fully opened sometimes during the experimental period in response to the external weather conditions, the temperature of test room 1 made little difference compared to the temperature of test room 2.

Case 3: energy saving mode vs. fully opened (with cooling)

During the experiment, the supply, return temperature and flow rate through the air conditioning units were measured to calculate the heat removed from the room. On the basis of these measurements, the cooling loads of the test rooms were calculated to be 23.3kWh for test room 1 and 26.4kWh for test room 2; the graph for this data is shown in Figure 4. Therefore, the energy saved by using the automated blinds was 3.1kWh, about 12.0%, compared with the value obtained when fully opened.

Figure 5 shows room depth meeting the required room illuminance of 500lux (IESNA 2001). In test room 1, the required room illuminance could not be met part of the time because the blinds were lowered by automatic operation. Test room 2 was able to meet the required illuminance almost all of the time, since no blinds were used. However, in test room 2, the room illuminance continuously exceeded the upper limit 3,340lux (IESNA 2001), which is the threshold for discomfort caused by glare (see Figure 6). Therefore, in a real situation under these conditions it would be reasonable to assume that, during these times, the blinds would have been fully closed and artificial lighting would have been used.

Assuming that lighting is used where the required illuminance cannot be met, the lighting energy consumption derived from the heat generated from the lighting was calculated by applying the lighting power consumption of 20W/m² in a typical office building (AIK 1994). Consequently, test rooms 1 and 2 were shown to consume 4.12kWh and 2.83kWh of lighting energy, respectively.

On the basis of the experiment's results, it is clear that the automatic control of blinds can reduce cooling load compared with the environment in which no blinds are used. Though additional lighting energy was consumed, the overall consumption was 1.81kWh less when automatically controlled blinds were used.

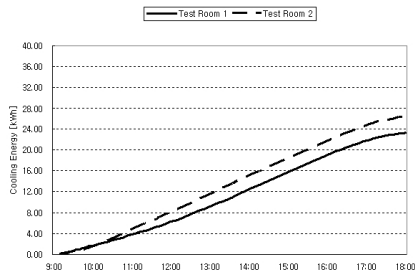


Figure 4 Cooling energy consumption of case 3

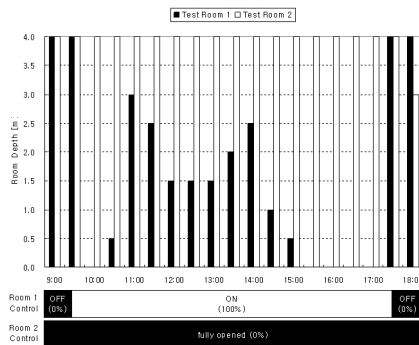


Figure 5 Room depth meeting the required illuminance of case 3

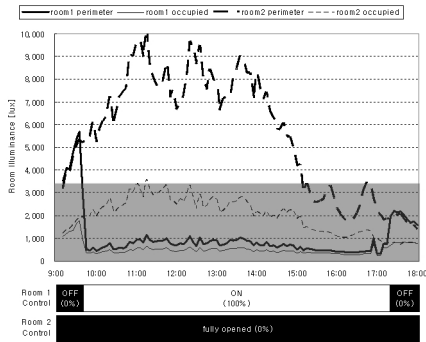


Figure 6 Illuminance change in test rooms of case 3

Case 4: energy saving mode vs. fully closed (with cooling)

Using the same method as that employed for Case 3, the cooling loads of test rooms 1 and 2 were shown to be 16.7kWh and 14.3kWh, respectively (see Figure 7). Consequently, the use of automated blinds in energy-saving mode consumed 2.4kWh (or 16.4%) more energy than when the blinds completely covered the window.

Room depths meeting the required room illuminance in test rooms 1 and 2 are shown in Figure 8. Lighting energy was calculated on the basis of the experiment results using the same method used for Case 3. Test room 1 consumed 3.12kWh and test room 2 consumed 6.59kWh of lighting energy. This experiment, by virtue of the fact that the cooling load was higher than that obtained for the closed blinds, demonstrated that using automated blinds can reduce overall energy consumption, including lighting energy, by 1.07kWh. In addition, the automated blinds provide an open field of vision and a view of outside scenery.

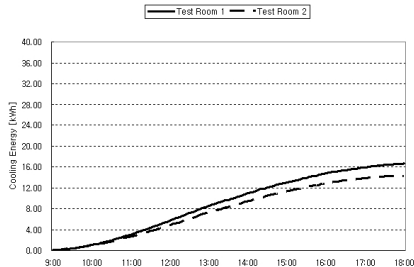


Figure 7 Cooling energy consumption of case 4

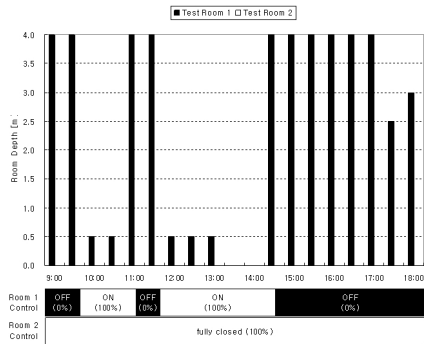


Figure 8 Room depth meeting the required illuminance of case 4

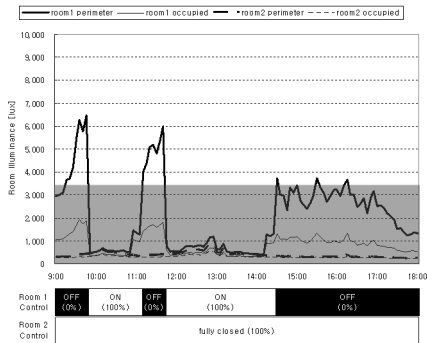


Figure 9 Illuminance change in test rooms of case 4

CONCLUSIONS

In this study, control methods of commercially used automated venetian blinds were analyzed and improved environmental performance was demonstrated through the experiments on energy saving.

From the viewpoint of cooling energy consumption, auto-controlled blinds reduced the cooling load compared to fully opened blinds because the blinds blocked solar radiation according to external weather conditions, but consumed more energy compared to fully closed blinds. However, if additional lighting energy consumption is considered, such as occurs with the interception of sunlight, the overall environmental performance of automated blinds is almost equal to that of fully closed blinds or even a little greater. In addition, selective blind opening according to any detected decrease in external illuminance provides occupants with a view of the exterior.

In the automatic control method employed in these experiments, in which the blinds were either only fully opened or closed, the modification of the occlusion index and slat angle was not considered. Therefore, a control method must be devised that can consider the lighting and cooling energy saving simultaneously by properly controlling the occlusion index and slat angle. Also, the control method discussed in this study was based solely on detecting external weather conditions. But a more effective and enhanced control method, which can also respond to the indoor environment by sensing internal factors such as illuminance and temperature, needs to be developed because the main purpose of blind control is to improve the indoor environment.

REFERENCES

1. A. Guillemin and N. Morel (2001) "An innovative lighting controller integrated in a self-adaptive building control system", *Energy and Buildings*, Vol. 33, 477-487.
2. A. Guillemin and S. Molteni (2002) "An energy-efficient controller for shading devices self-adapting to the user wishes", *Building and Environment*, Vol. 37, 1091-1097.
3. C. F. Reinhart (2004) "Lightswitch-2002: a model for manual and automated control of electric lighting and blinds", *Solar Energy*, Vol. 77, 15-28.
4. E. S. Lee et al. (1998) "Thermal and Daylighting Performance of an Automated Venetian Blind and Lighting System in a Full-Scale Private Office", *Energy and Buildings*, Vol. 29 (1), 47-63.
5. E. S. Lee et al. (1998) "Integrated Performance of an Automated Venetian Blind/Electronic Lighting System in a Full-Scale Private Office", *Proceedings of the ASHRAE/DOE/BTECC Conference*.
6. J. H. Kim et al. (2007) "An Experimental Study for Evaluation of the Environmental Performance by the Application of the Automated Venetian Blind", *Proceedings of Clima 2007 Wellbeing Indoors*, 1678-1685.
7. M. Foster and T. Oreszczyn (2001) "Occupant control of passive systems: the use of Venetian blinds", *Building and Environment*, Vol. 36 (2), 149-155.
8. Y. J. Park et al. (2006) "An Experimental Study on Environmental Performance by the Application of the Automatic Blind in Summer", *Proceedings of the Architectural Institute of Korea*, 605-608.
9. IESNA (2001) "IESNA Lighting Handbook", published by Illuminating Engineering Society of North America.