

An Investigation of Adjustment of Solar Shading Devices in Office Buildings

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Abstract—The purpose of this paper is to investigate the adjustment of solar shading devices in office buildings in two different seasons by occupants, and its influence on the lighting control and indoor illuminance levels. The results show that occupants take inappropriate measures both in reducing solar radiation in summer and in admitting solar gains in winter, resulting in an increase in lighting energy and a reduction in indoor illuminance. Therefore, movable shading devices, controlled automatically, are suitable for building applications to reduce energy consumption.

Keywords—Solar shading, adjustment, lighting control, indoor illuminance.

I. INTRODUCTION

IN China, the building sector accounts for about 27% of the nation's total energy consumption[1], and thus is one of three key areas for energy reductions. To promote building energy efficiency, China has issued several building energy-saving regulations and standards [2-3]. Among them, a set of prescriptive requirements for roof, wall, and window thermal transmittances is made to ensure that a building will constantly arrive an energy efficiency of 50% from the design stage to construction stage[4]. A variety of studies were carried out to optimize the energy design of building envelope[5-8]. However, solar heat gains through windows have a significant impact on building energy consumption in hot summer and cold winter zone[9], especially for office buildings with movable shading devices that require manual control. Highly glazed office buildings would result in a great increase both in building energy consumption and in indoor thermal discomfort. Since the impact of solar shading devices that rely on manual control on energy and comfort have not been studied, this paper conducted a survey to investigate the relationships among the adjustment of solar shading devices, lighting control and occupant comfort.

II. METHODOLOGY

A survey was conducted on 60 office buildings in three districts of Ningbo city in order to achieve the different adjustment positions of solar shading devices as well as lighting control and indoor illuminance conditions in summer and winter. There are six adjustment positions including: (1) fully open, (2) open <1/3, (3) open 1/3-1/2, (4) open 1/2-2/3, (5) open >2/3 and fully closed. Lighting control falls into three conditions: (1) fully open, (2) partial open, (3) fully closed. There are also three illuminance conditions that are (1) bright, (2) dim and (3) bright at noon.

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III. RESULTS AND DISCUSSION

1) *Summer conditions*: Figures 1-2 present the adjustment positions of solar shading devices during the summer period with and without solar radiation entering indoor spaces, respectively. It can be seen that more than 60% of occupants keep shading devices fully open when solar radiation enters indoor environments, 90% of occupants adjust the shades >2/3, and none of occupants fully closed the shades. When solar radiation is unavailable for indoor spaces, the solar shades remaining fully closed state reach 25% and only about 10% of occupants keep solar shading devices at the state of open >2/3. This means that the adjustment behavior of shading by occupants is not in accordance with the needs for energy savings and overheating protection, leading to a deterioration in indoor thermal conditions and an increase in cooling energy consumption.

The adjustment of shades with solar gains in summer

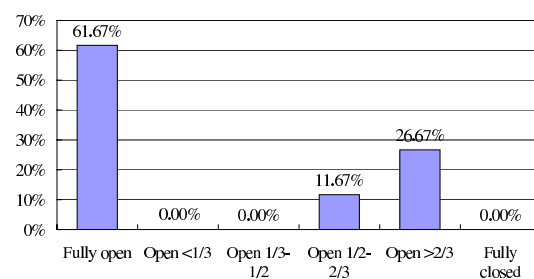


Fig. 1. The adjustment of shades with solar gains in summer.

The adjustment of shades without solar gains in summer

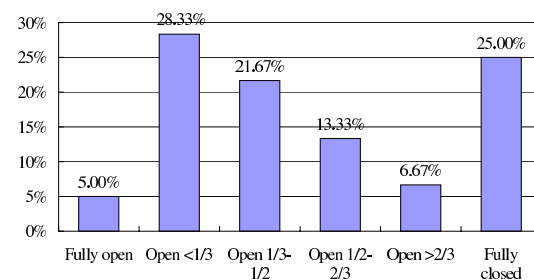


Fig. 2. The adjustment of shades without solar gains in summer.

Figures 3-4 further give occupants' perception of brightness as well as the situation of lighting controls for different adjustment positions of solar shades in summer. Due to a large percentage of the situation of opening shades for existence of solar gains, most of lighting controls are under the situation

of partially switched on, which accounts for over 70%. As a result, the percentage of occupants having the perception of feeling brightness, dim, and brightness at noon is similar. This may attributes to the little difference of feeling brightness among occupants.

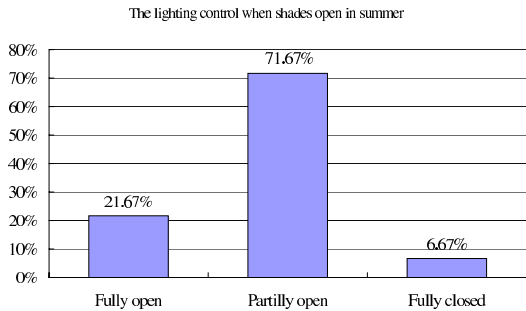


Fig. 3. The lighting control when shades open in summer.

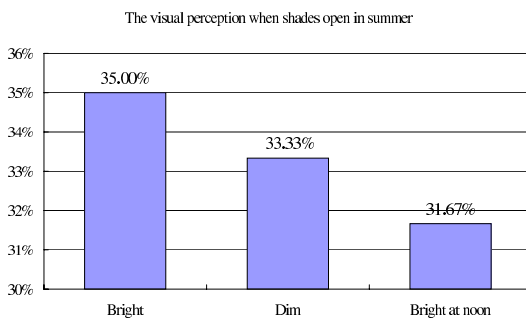


Fig. 4. The visual perception when shades open in summer.

2) *Winter conditions:* Figures 5-6 provide the adjustment positions of solar shading devices during the winter period with and without solar radiation entering indoor spaces, respectively. In both situations, solar shading devices being the fully-closed state reach 70%. For the situation of without solar gains, they are 16.7% much higher than the other one, reaching 86.7%. This means that most occupants close solar shades, whereas only a minor part open shades. This phenomenon reflects that occupants are lack of knowledge about maximization solar application to reduce heating energy requirements by adjusting shades in winter.

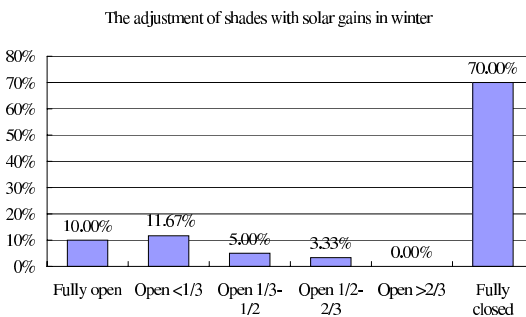


Fig. 5. The adjustment of shades with solar gains in winter.

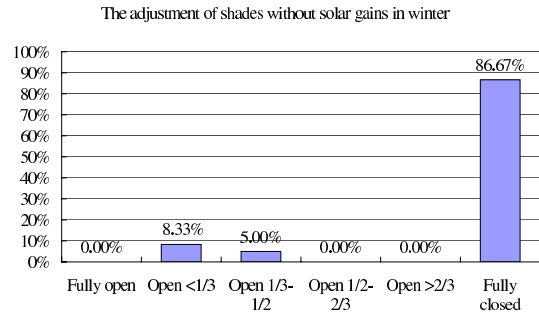


Fig. 6. The adjustment of shades without solar gains in winter.

Figures 7-8 show occupants' perception of brightness as well as the situation of lighting controls for different adjustment positions of solar shades in winter. As the state of fully closed for shades takes the major part, lighting control being fully switched on or partially switched on accounts for a significant percentage of 83.3%. Therefore, most occupants feel dim without artificial lighting according to Fig. 8, with a high percentage of about 60%. Only about 25% of occupants feel brightness, which is less than half of the former.

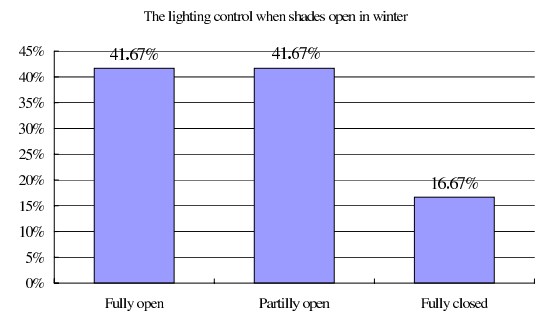


Fig. 7. The lighting control when shades open in winter.

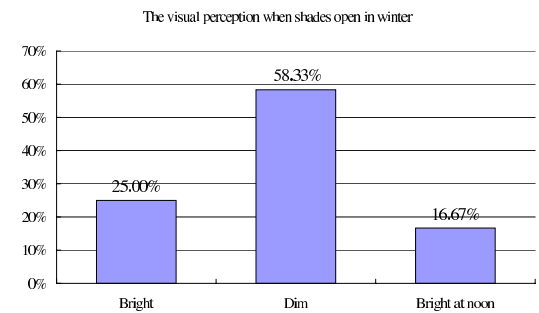


Fig. 8. The visual perception when shades open in winter.

IV. CONCLUSION

Currently, energy efficiency design of the building envelope for office buildings in China has already been taking into account at all stages of building construction. However, optimization of the adjustment of movable solar shades to improve energy and daylighting performance has not been

done. Therefore, this paper aims to investigate the relationships among the adjustment of solar shading devices, lighting control and occupants' perception of feeling brightness by a survey conducted on 60 office buildings in three districts of Ningbo city. The results show that most occupants' behaviour of adjusting movable shades is unreasonable, resulting in overheating problems, insufficient daylighting utilization as well as an increase in cooling, heating and lighting energy consumption. As a conclusion, education should be strengthened to increase occupants' awareness and knowledge about how to optimize the control of movable solar shading devices.

ACKNOWLEDGMENT

This work was sponsored by the Science Foundation of Ningbo University (Grant No. XYL11004).

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