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A Study on Natural Lighting Design Strategies for Teaching Buildings in Hot-summer and Cold-winter Zone of China—A case of the Arts and Sciences Building of Xinyang Normal University

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ABSTRACT

The natural lighting of buildings plays an important role in creating a comfortable indoor light environment and reducing the energy consumption of artificial lighting. Teaching buildings have special requirements for the indoor light environment. Classroom glare, corridor backlit, and low natural illumination in corridor are light pollution problems easily appear in teaching building, which cannot be ignored in the design of teaching building. Regarding the issues above, the paper took the Arts and Sciences Building of Xinyang Normal University as an example, through the architectural modeling, space forms, facade effects and other features, used VELUX simulation software to simulate the illuminance and daylighting parameters of different sunroofs and provided solutions for classroom glare and corridor lighting. Ultimately, the paper analyzed the building lighting energy saving schemes based on regional climate and environment, and found out the best balance point for the energy saving design of lighting and thermal environment, meanwhile, provided valuable and practical reference for lighting design of corridor skylights in the region.

KEYWORDS

Teaching building, Natural lighting, Design strategy, Hot-summer and Cold-winter

INTRODUCTION

The architect Ludwig Mies Van der Rohe said: "The history of architecture is the history of human struggle for light, the history of the window." The lighting discussed in the article refers to the use of direct, reflective or other aids to provide natural light to the interior of a building.

It is an important energy-saving means to optimize the design of lighting and shading for public buildings with different functions. A good architectural light environment can improve the visual comfort of indoor personnel, which also has a very important influence on people's physical and mental health. The teaching buildings have many problems in natural lighting, such as large lighting power consumption and glare which greatly reduce the quality of indoor light environment.

For the study of the top lighting of public buildings, most of them are concentrated in the skylight design for the space with large depth. It also has many research methods and design strategies on indoor glare. In specific climate such as hot-summer and cold-winter area, for the special lighting issues of teaching building including corridor skylight design, glare of side windows and corridors lack of systematic research and solutions. Computer simulation is been used to analyse the influence of inner corridor various factors on the natural lighting (Zhifang Zhang, 2011). Hao Xie summarized several design points of the public building skylight. How to put forward the corresponding design technology strategy for the special needs of education building in light environment is the key to solve the indoor natural lighting problem.

METHODS

Educational building lighting standards

Architectural lighting design standards (GB50033-2013) stipulated that the corridor lighting of the teaching building should not be lower than the standard value of the lighting level V. In this project, the illuminance of the area with roof lighting shall be 75lx, and the lighting factor shall be 0.5%.

Description of project

The comprehensive building for liberal arts and sciences to be built is in Xinyang Normal University, including the roof skylight of Building A1, the corridors of Buildings D and F, and the side windows of the classroom. The Building A1 has 12 floors, and the corridors are illuminated by both sides of the windows. To achieve the Architectural Lighting Standard, increase indoor comfort, 10-12 layers will add the skylight to meet the indoor light environment requirements through the reasonable design of natural lighting. The side windows in classrooms and corridors glare easily when it's sunny. Therefore, effective shading equipment is needed to avoid glare and create a good learning environment for students.

Figure 1. The model of Arts and Sciences Building

Specific design content

Simulation software selection and parameter setting

The solar radiation conditions are determined according to the location of the area. In the corridor lighting simulation, set the height of the reference surface to 1.5m, and the selected weather conditions for the winter solstice cloudy day. VELUX natural lighting simulation software is used to simulate the illuminance, daylighting factor and other parameters of different skylights, in order to compare their lighting effects.

Corridor skylight design

The design of the skylight is based on the building lighting standards in the area, and considering the balance of skylight lighting and heat collecting effects. Through simulation optimization, the skylight design schemes suitable for the teaching corridor of the area are analysed showed in Table 2.

Table 1. Advantages and disadvantages on skylights

Type of top light	Advantages	Disadvanteges
Flat skylight	High lighting efficiency	Easy to glare, higher heating load
Rectangular skylight	Uniform daylighting, easy on ventilation	Complex roof structure
zigzag skylight	No glare	Low lighting efficiency in winter

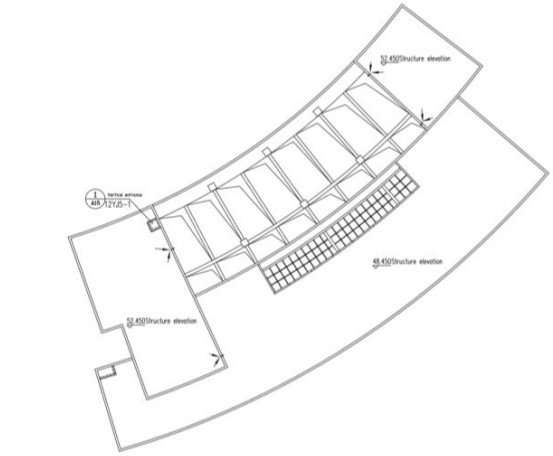
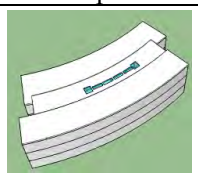
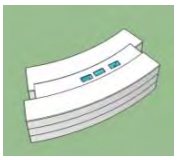
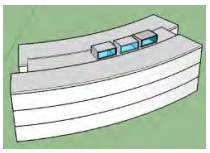
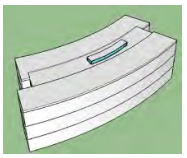
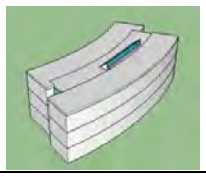
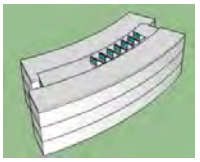


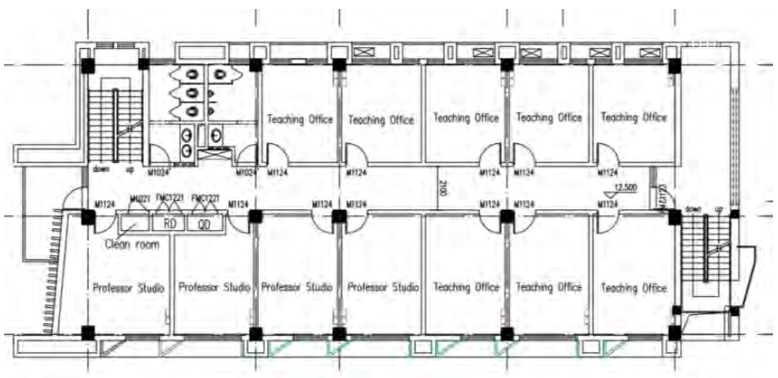
Figure 2. Position of corridor skylight

Table 2. Design of the corridor skylight.

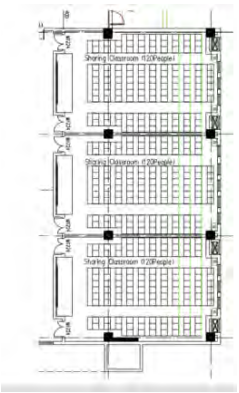
Type of skylight	Design 1		Design 2	
	Graphic	Design parameter	Graphic	Design parameter
Flat skylight		Total area：20 ㎡ Two pieces2×2 ㎡ Four pieces1×3 ㎡ Area ratio of window to floor:1/23		Total area：24 ㎡ Three pieces2×2 ㎡ Area ratio of window to floor:1/19
Rectangular skylight		North and south Total area：52.3 ㎡ Area ratio of window to floor:1/8.8		Window all around Total area：32.42 ㎡ Area ratio of window to floor: 1/14.3
zigzag skylight		Total area：28.42 ㎡ Incline：40° Interior surface: White latex paint		Total area：24.71 ㎡ Incline：40° Interior surface: White latex paint

Corridor glare design research

Due to the climate characteristics of the hot-summer and cold-winter areas, shading facilities are required to not only cover the sun radiation in the summer, but also allow the solar radiation to enter the interior as much as possible in winter. Therefore, The selection of shade strategies should be based on the climate characteristics of the area.



a)



b)

Figure 3. a) Corridor plan in Building D , b) Classroom plan in Building F

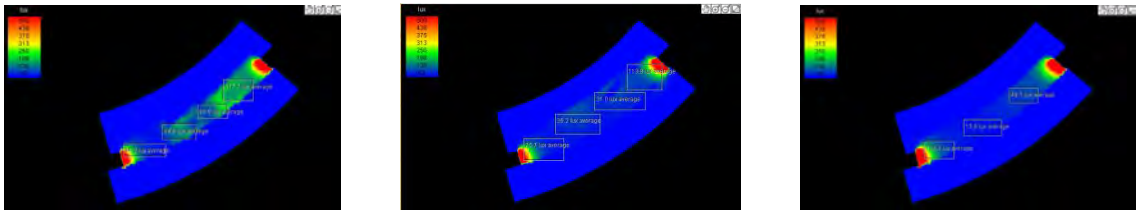
RESULTS

Simulation result of corridor skylight

The VELUX simulation software was used to simulate the mentioned skylight design scheme, and the minimum illuminance during the day and daylighting factor values under different skylight forms were obtained. The simulation results are shown in the Table 3.

Table 3. Corridor skylight lighting parameters simulation results

Type of skylight		Flat skylight	Rectangular skylight	zigzag skylight
Plan 1	Minimum illuminance during the day（lx）	65.1	17.0	31.0
	Lighting factor（%）	1.1	0.2	0.6
Plan 2	Minimum illuminance during the day（lx）	84.6	13.8	21.4
	Lighting factor（%）	1.3	0.2	0.4

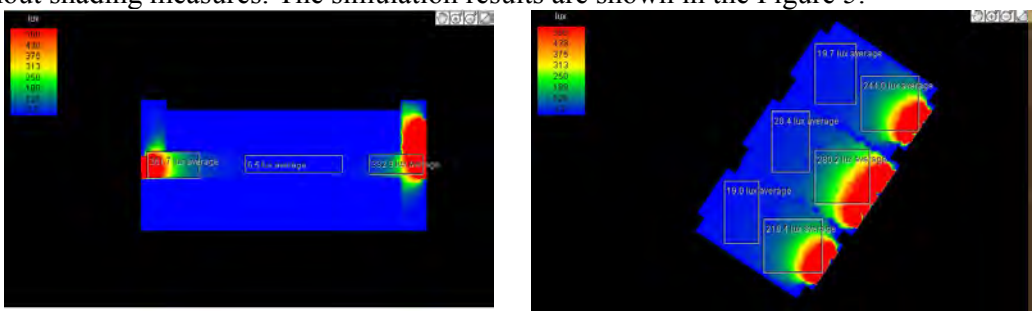


a) b) c)

Figure 4. Illuminance during cloudy winter solstice. a) Plan 2 of Flat skylight, b) Plan 1 of zigzag skylight, c) Plan 2 of Rectangular skylight

Shading measures

After simulating the natural illumination in classrooms and corridors, it is found that the classroom relies on one side window to light has different illuminance values. The area close to side window is brighter. On the contrary, the area farther from the side windows is darker. The indoor light environment is not ideal. It is clear that corridor will generate backlight without shading measures. The simulation results are shown in the Figure 5.



a) b)

Figure 5. Illuminance during summer solstice day.a) Corridor, b) Classroom

According to the characteristics of building space, several applicable shading strategies are selected and optimized.

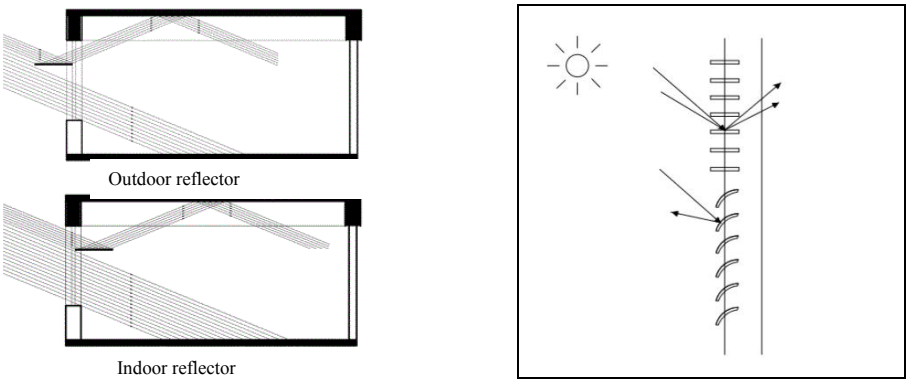
Higher lighting side window

It is the side window set above the sight line that can be used in corridors and classrooms to improve the illumination inside. According to *Architectural lighting design standards(GB50033-2013)*, The total area of the windows on both sides in corridors is

determined to be 6.3 ㎡, The size of each side window is 2m×1.6m, and 1.9 meters above the ground.

Reflector

It can provide more natural light for the interior space while preventing excessive direct light from entering the room which may create glare. The addition of reflectors can significantly improve the uniformity of reference surface illumination. Indoor illumination uniformity from small to large is arranged as: non-reflective plate <internal reflector <external reflector <internal and external reflector.



a) b)

Figure 6. a) The principle of reflector, b) Separately controled venetian blinds.

Venetian blinds

The user adjusts the appropriate blade angle according to different seasons to maximize the sunlight, so that the interior space of the classroom gets sufficient diffuse light. For buildings that do not have separate lighting windows and landscape windows, separately controlled blinds can be used to maximize the advantages of the upper and lower windows. Blinds used for outdoor shading are usually made of galvanized steel, anodized aluminum or colored aluminum and plastic (PVC). For ease of adjustment, the width of the external shading blade is usually about 100mm, and the pitch of the blade is set to 90mm (Wei Yu, 2012).

Venetian blinds are mainly horizontal and vertical. Research test findings shows venetian blinds of different rotation angles can block sunlight at different height angles and directions.

Table 4. The commonly setting method of venetian blinds

Venetian from	Rotation method
Horizontal blinds	Parallel to normal（Level 0°）
	Rotate 45° counterclockwise（Level 45°）
Vertical blinds	Parallel to normal（Vertical 0°）
	Rotate 45° counterclockwise（Vertical 45°）
	Rotate 45° clockwise（Vertical -45°）

DISCUSSIONS

From the above simulation results, it is found that when choosing plan 2 of plat skylight whose area is 24m^2, the natural illumination of the corridor can meet the requirements of the lighting of the whole year. Both rectangular skylight designs are unable to meet the requirements of natural light throughout the year for the three-tier walkway. However, their windows open around to avoid glaring, moreover, they are easy to open that promote natural ventilation and reduce mechanical ventilation and cooling energy consumption. The skylight area used in the two designs of the zigzag skylight is the smallest area, and the simulation

results do not meet the requirements. Due to the limitation of the skylight design position, it is difficult to increase its area. The zigzag skylight design with a window angle of 40° and interior surface of white latex paint is slightly lower than the requirement. The winter illumination may be slightly lower, but the zigzag skylight is easy to open that can improve indoor ventilation.

For some public buildings such as office and teaching buildings, the choice and design of shading measures, if the main consideration is summer shade, an outdoor reflector is generally installed to block the light with high solar elevation angle in summer and reduce building cooling load. At the same time, it reflects light to interior ceiling and enhances secondary reflections. When using a reflector to introduce light, it can also be used together with a reflective ceiling to form a light guide system.

Through the analysis of corridor skylight design and the side window shading measures of the project, the application technology of the teaching building light environment in the hot-summer and cold-winter area can be obtained and is summarized as follows.

a) The flat skylight has the best lighting effect. If the natural ventilation in the corridor is good, the skylight can be selected. The rectangular skylight and the serrated skylight can be selected to improve the natural ventilation in the corridor.
b) It is more suitable to adopt higher side lighting window and vertical blinds in order to solve the problem of backlighting in corridors. For the east side window of the corridor, it can be set with vertical blinds rotated at a certain angle to avoid direct sunlight in the morning which may generate backlighting, and to make the corridor brighter.
c) In order to solve the problem of classroom glare, you can choose high side windows, reflectors and venetian blinds.

CONCLUSIONS

Improve the natural lighting quality of teaching buildings is the key to creating a good learning environment and improving people's visual comfort. Through the rational use of auxiliary equipment for daylight and sunshade, natural light can be effectively used and controlled, which can not only achieve the purpose of energy conservation, but also can produce distinctive architectural lighting effects. The paper took the Arts and Sciences Building of Xinyang Normal University as an example, with the method of computer software simulation, analysed the lighting design strategy of the corridor in teaching building and shading measures applied to avoiding glare of the corridors and classrooms, ultimately concluded the light environment design technology strategy suitable for the teaching building in the hot-summer and cold-winter area which supported the light design of teaching building in that area.

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