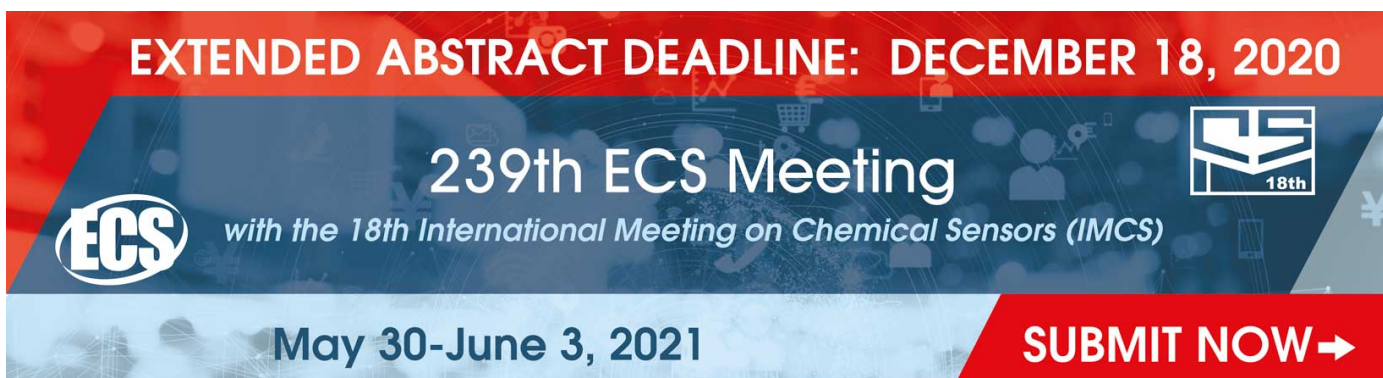


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Analysis of Natural Lighting and Energy Conservation of a University Teaching Building Based on BIM Technology

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Abstract. This paper first collected the design drawings of the second teaching building of the College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, and used Ecotect Analysis software to conduct 1:1 model of the standard floor of the building. The standard layer light environment is analysed from the aspect of natural lighting. According to the simulation analysis results, the window to ground ratio (independent variable) is raised by layers to increase the area of natural lighting. The overall lighting design of the building before and after optimization was compared, and two Chinese national standards, Standard for Daylighting Design of Buildings and Assessment Standard for Green Building, were used to evaluate the lighting capacity of the building through natural lighting coefficient (dependent variable). The analysis indicates that the building meets the requirements of green design. At the same time, it was found that with the increase of the ratio of window to ground, the average value of the lighting coefficient increased steadily, and the area percentage of the lighting coefficient $\geq 3.6\%$ also increased, but the increase gradually decreased and tended to be stable.

1. Introduction

Building information model is called BIM for short. The definition of BIM in American national standard is: BIM is a familiar expression of physical and functional characteristics of a facility; BIM is a shared knowledge resource, a process of sharing information about the facility and providing reliable basis for all decisions in the life cycle of the facility from concept to demolition [1]. BIM has two meanings: information model and the modeling process. Based on this definition, the application of BIM can be divided into two aspects: BIM technology research and BIM information management research. Due to the interdisciplinary nature and complexity of BIM application, in order to further divide the scope, Ji et al. [2] think that Chinese BIM research can be divided into the following four categories: Chinese BIM standard research, BIM application software research, BIM based engineering management, BIM experience summary. The research content of this paper belongs to BIM software application class, which uses BIM Technology to analyse building energy-saving performance and deepen the direction of green design.

There are many research results in the design of BIM Technology and green building. Li et al. [3] used BIM Technology and green analysis software to simulate and analyse the optimal design of solar radiation, natural lighting, natural ventilation and noise; Liu et al. [4] and others discussed the positive significance of BIM for green building; Liang [5] started from the development of BIM technology theory and related applications, and analysed the relationship between the development of BIM



technology and architectural design; PU et al. [6] will compare BIM based energy conservation design with traditional 2D energy conservation design, and find that BIM based energy conservation design has obvious advantages in collaborative design, improving efficiency and accuracy; Abanda et al. [7] used BIM technology to analyse the energy consumption corresponding to different orientations, and found that a building with a good orientation could save a considerable amount of energy in its whole life cycle. Zhang et al. [8] put forward a new green building design approach-integration of BIM technology and building energy efficiency analysis. Bao et al. [9] studied the establishment of green building planning and design software system, so as to increase the number according to the degree of sharing, the efficiency of green building design can be improved; Xu et al. [10] through the energy consumption analysis and cost analysis before and after the scheme energy-saving optimization, the advantages and application value of BIM Technology compared with traditional mode energy-saving optimization in terms of synergy, model accuracy, efficiency, etc.

Building energy systems is defined as the system that consumes energy in the building, including building space, HVAC system, lighting system, occupancy and comfort. Lighting system is an important part of building energy consumption, which consumes 30% of the building's electrical energy, and accounts for a higher proportion in buildings without air conditioning system [11]. More and more scholars think that building lighting system is more and more important for building energy saving. At the same time, it has become a research direction to simulate the building lighting based on Ecotect Analysis software. Wang et al. [12] proposed a design method of lighting control system of industrial building based on sensor network, and proposed the optimal layout and scene control strategy of artificial lighting system by using the simulation analysis of Dialux and Ecotect. Bout et al. [13] optimized the enclosure structure by adjusting the glass area, simulated the thermal environment of a school building in autumn by using software such as Ecotect, and optimized its design, making the spatial distribution and uniformity of natural light higher, and lighting more energy-saving. Ahadi et al. [14] used Ecotect software to simulate the daylighting of the building, and obtained the best layout plan of the patio. Vassiliades et al. [15] used Ecotect to evaluate the environment of the integration of active solar energy system on the building envelope. The research results show that the integration of solar activity system is helpful to reduce the cold and heat loads. In the aspect of natural lighting, the integration of active solar energy system can achieve a high level of natural lighting, while minimizing the glare problem of most systems. Yin et al. [16] used Ecotect and Desktop Radiance to simulate the natural lighting and glare of a public teaching building in a university, and analysed the natural lighting effect of the main classroom on the standard floor of the public teaching building.

In this study, BIM and Ecotect simulation analysis are used to analyse and evaluate the natural lighting of the second teaching building of the College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, in combination with the two Chinese national standards, Standard for Daylighting Design of Buildings (GB 50033-2013) and Assessment Standard for Green Building (GB / T 50378-2019) , and to study the impact of building design optimization on building energy consumption. It provides the basis and reference for the optimal design of building energy consumption.

2. Research methods and content

2.1. Project overview

The teaching building project is located in Chengdu, Sichuan province, with a total construction area of 2848.54 m², total 5 layers, the height 3.9 meters, the teaching building toward for the southwest.

2.2. Independent and dependent variables

The ratio of window to ground is the ratio of window opening area to ground area [17]. Daylight factor rising can increase natural lighting ability, indoor lighting effect and lighting utilization rate.

In the analysis of building lighting, the sky model should be determined in advance. The lighting analysis of Ecotect Analysis was conducted under CIE standard Overcast Sky mode. CIE is the International Lighting Commission. CIE standard cloudy sky refers to the weather when the sky is

completely covered by clouds, and the outdoor natural light is all sky diffused light [18]. The teaching building is located in Chengdu basin and belongs to the southwest region. It is mainly sky diffused light, which is suitable for this model.

In Ecotect Analysis, daylight factor (DF) refers to the ratio between the illumination value generated by the diffuse reflection of the sky at a certain indoor point in the total cloudy day model and the illumination value generated by the diffuse reflection of the sky at the same place and time as that at a certain indoor point in the total cloudy day model, and the outdoor illumination value generated by the diffuse reflection of the sky at an open outdoor level [19].

In Ecotect Analysis, the daylight coefficient is calculated using the Split Flux method. The itemized method assumes that the natural light at any point in the room is composed of three independent components: $DF=SC+ERC+IRC$ [20], as shown in table 1 below.

Table 1. Indoor natural lighting composition.

Designation	Composition
Sky Component (SC)	The part of a room shot directly from the sky through a window
Externally Reflected Component (ERC)	The part that is reflected into the room by the earth, trees, other buildings, etc
Reflected Component (IRC)	Interior reflections of the first two sections on the interior surface

2.3. Standard for design of buildings

In this study, parameters were set according to Standard for Daylighting Design of Buildings and Assessment Standard for Green Building.

The teaching building is located in Chengdu, as part of the V daylight climate zones. On the basis of Standard for Daylighting Design of Buildings, in V daylight climate zones the design illuminance of exterior daylight should be 12000 lx, are shown in table 2. According to Standard for Daylighting Design of Buildings for educational buildings, the standard value of daylight factor of side lighting for special-purpose classrooms, laboratories, staircases, classrooms and offices shall not be lower than 3% [17], as shown in table 3. Because the teaching building is in V daylight climate zones, the standard value of daylight factor should be multiplied by daylight climate coefficient(K), as shown in table 2. The standard value of daylight factor of the teaching building is 3.6%(3% \times 1.2).

Table 2. Light climate coefficient.

Daylight zones	climate I	II	III	IV	V
Daylight coefficient(K)	0.85	0.90	1.00	1.10	1.20
Design illuminance of interior daylight	18000	165000	15000	13500	12000

Table 3. Educational building requirements.

Lighting level	Places	Side lighting
		Standard value of lighting coefficient (%)
III	Permitted use of classroom, laboratory, classroom office	3.0
V	Aisle, bathroom, stairwell	1.0

In Assessment Standard for Green Building, the total evaluation value shall be 12 points with full use of natural light, and shall be scored and accumulated according to the rules, among which the grading rules for public buildings are shown in table 4 below [21].

Table 4. Assessment standard for green building.

Grading rule	Score(points)
1. The daylight factor of the inner area meets the lighting requirements, and the proportion of the area reaches 60%	3
2. The average lighting coefficient of basement space is not less than 0.5%, and the proportion of the first floor area of basement is more than 10%	3

Since there is no basement in the teaching building, the evaluation based on the Assessment Standard for Green Building is mainly to simulate and analyse the daylight factor of article 1 of the scoring rules, among which the daylight factor meeting the requirements according to section 2.2 is 3.6%.

2.4. Research idea

Firstly, BIM 1:1 model was carried out on the teaching building, and the standard layer was selected to calculate the daylight factor. Standard for Daylighting Design of Buildings and Assessment Standard for Green Building are taken as the basis to judge whether they meet the standards and as the basis for the evaluation and optimization of green design. This study mainly solves the following two problems:

- (1) Does the original design meet the requirements of green design?
- (2) Can the window to floor ratio be improved to optimize the design, and what is the optimization effect? Is there any help and inspiration for designers?

3. Result analysis

3.1. Area ratio of window to floor

The original design of the standard floor is 31.2m long and 15.6m wide. There are 36 windows on the northeast and southwest sides, with the size of 1.25 * 2.5 (W x H), and 2 windows on the other two sides, with a size of 1.8 * 2.2 (W x H). Through calculation, the window ground ratio is 22.43%.

3.2. Parameter setting of building materials

For the model material, the exterior wall is set as concrete solid brick, the interior wall is concrete hollow brick, and the window is single-glass. For side lighting, the window opening area above the reference plane shall be used. The reference plane refers to the plane that measures or provides illumination[19]. The reference plane set for this simulation is 0.7m.

3.3. Grid setting and editing

When using Ecotect Analysis software for daylight analysis, the grid should be set first. The number of cells in the grid represents the density of the grid. Different values can be set according to the actual situation, such as dividing the grid size according to the volume size of the building. The standard floor of teaching office building is 31.2m long and 15.6m wide, so a grid of about 0.5mx0.5m is set, i.e. 62 microelements in the X direction and 30 microelements in the Y direction.

3.4. Analysis and calculation of natural daylight coefficient

The critical value of lighting analysis is set. As mentioned above, the standard value of the daylight factor of the window of the education building is not less than 3.6%. Therefore, enter the minimum value of 3.6 in the scale column. There is no requirement for setting the maximum value of the model. Take the maximum value displayed after the initial simulation. For the original design, the maximum value of the first simulated lighting coefficient is 23.6%. Therefore, enter the maximum value of 23.6 in the scale column and the lighting coefficient of the whole model range from 3.6% to 23.6%. Set the class as 2, 10 segments in total. The simulation diagram is shown in Figure 1. From Figure 1 shows the standard layer within the area average daylight factor is 6.28%. On the report page, click the report

generator to generate the percentage analysis report, export it with Excel, and generate the histogram, as shown in Figure 2. According to Figure 2, the cumulative percentage of each bar column is 63.81%, that is, percentage of area with daylight factor $\geq 3.6\%$ is 63.81%, which meets the requirements of more than 60% in Section 3.2 and reaches the level of natural lighting requirements of green buildings.

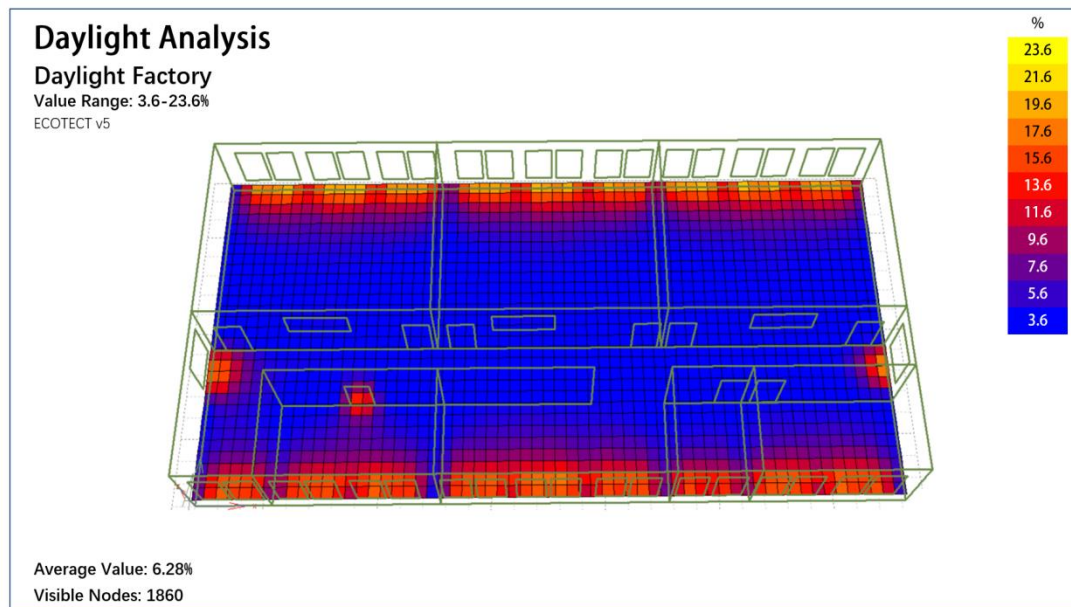


Figure 1. Simulation result.

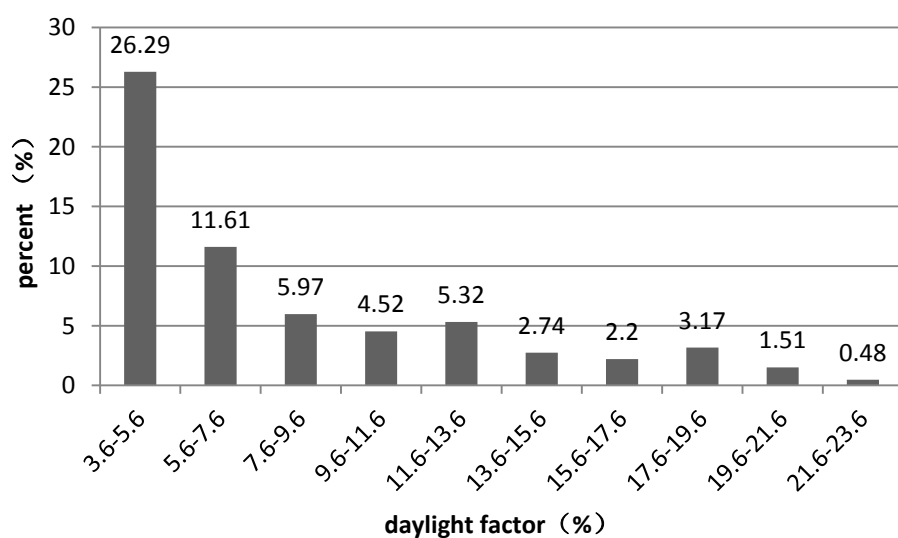


Figure 2. Daylight factor.

4. Optimization analysis

Improve the window to ground ratio by levels, and gradually increase the window to ground ratio from 22.43% to 34.17% by changing the window sizes on both sides of the northeast and southwest, as shown in Figure 3 (a)(b). And then analyze the daylight factor in the standard layer, and the simulation process is exactly the same as that in 4.4, as shown in Table 5.

Figure 4 is the trend of some data column change of Table 5. The research results shows that the average value of daylight factor is increased from 6.28% to 9.20% after the window ground ratio of the original design is increased hierarchically, which shows the significant improvement of the overall lighting level. Percentage of area with daylight factor $\geq 3.6\%$ has increased from 63.81% to 83.07%. At the same time, it is also found that with the increase of the window to ground ratio, 63.81% of the area with the daylight factor $\geq 3.6\%$ has increased from 83.07%, and the growth rate has decreased from 15.03% to 3.27%. At the beginning, it has decreased greatly, and then decreased slowly and gradually stabilized. It can be seen from this that although the percentage of area with daylight factor $\geq 3.6\%$ is rising continuously, its growth rate is gradually decreasing and tends to be stable.

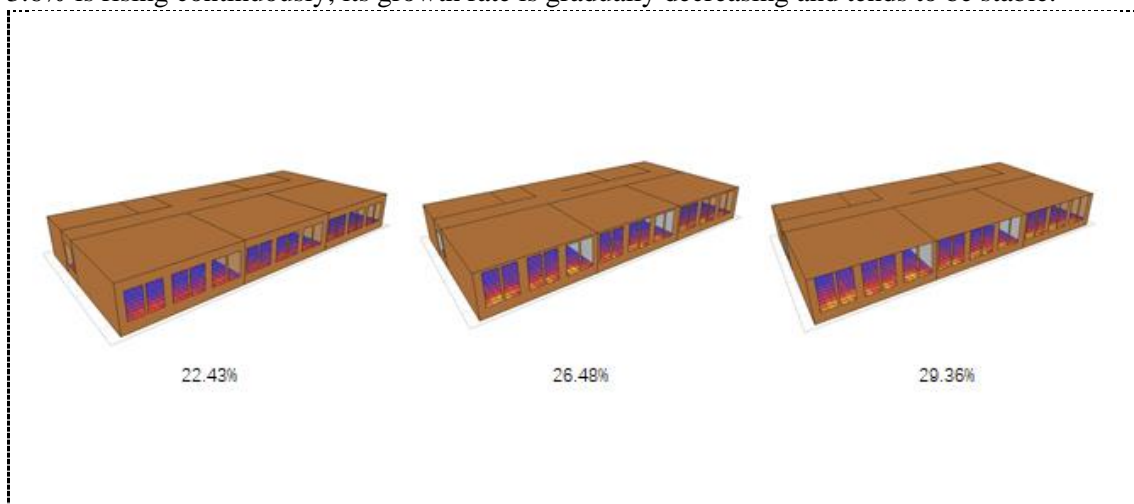


Figure 3. Three dimensional model of different window to ground ratio(a).

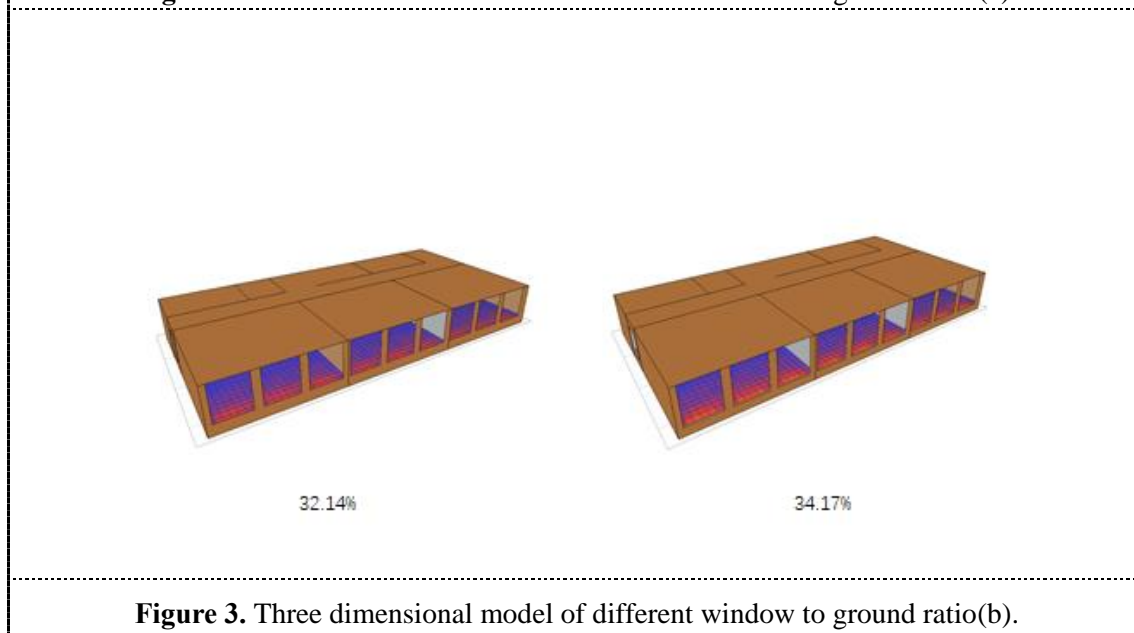
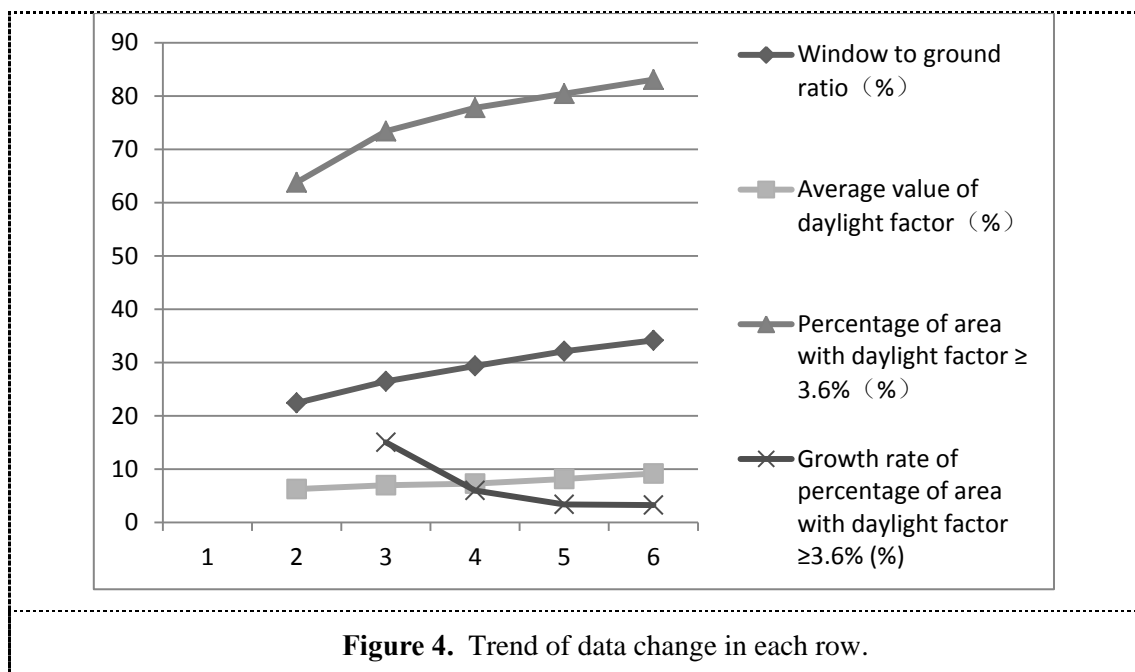


Figure 3. Three dimensional model of different window to ground ratio(b).

**Table 5.** Simulation experiment data.

Window specification (W x H) m ²	Number of windows	Window to ground ratio (%)	Average value of daylight factor (%)	Percentage of area with daylight factor \geq 3.6% (%)	Growth rate of percentage of area with daylight factor $\geq 3.6\%$ (%)
1.25*2.25	36	22.43	6.28	63.81	\
1.20*2.80	36	26.48	6.99	73.40	15.03
1.25*3.00	36	29.36	7.30	77.81	6.01
2.75*3.00	18	32.14	8.16	80.44	3.38
2.75*3.20	18	34.17	9.20	83.07	3.27

5. Conclusion and prospect

The percentage of the area with the daylight factor greater than 3.6% in all designs is greater than 60%, which meets the public building lighting rating standard of Assessment Standard for Green Building. And with the continuous improvement of the window to ground ratio, average value of daylight factor and percentage of area with daylight factor $\geq 3.6\%$ of the optimized model is gradually increased, that is, the larger the window is, the better the natural light can be used to create a good indoor lighting environment and save more energy.

However, there are many deficiencies in this study. Building energy consumption is multifaceted and linked. With the increase of the window to ground ratio, the energy-saving capacity of building lighting can be increased, the energy consumption simulation does not consider other environment of the building, such as the thermal environment of the building. Increasing the window to ground ratio will cause the change of indoor thermal environment and construction cost, which may lead to the increase

of indoor heat consumption and construction cost. Therefore, the resulting thinking: how much will increase the window to ground ratio of 1%, the area percentage with the daylight factor $\geq 3.6\%$, and whether the resulting cost and the energy consumption of indoor thermal environment will increase by more than 1%. Then, when combining this research with the building cost and the building thermal energy consumption, can we get the optimal design result? Next, it will expand the research direction and conduct comprehensive consideration.

Natural lighting analysis of buildings with BIM software is part of energy-saving design, part of green buildings for energy-saving designers, and lighting simulation analysis is only part of the vast architectural knowledge. Green building is the trend of age, the development of BIM is the trend of the future. Simulation software is very efficient and intuitive, and simple to operate, can provide designers with a powerful design reference and save a lot of designer's time, in the architectural design phase of the building visual analysis. It is an inevitable trend to combine BIM with green building design.

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