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OPTIMAL DESIGN OF CLASSROOM LIGHTING BASED ON OPTICAL SIMULATION

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Abstract: In the context of the rapidly expanding lighting market and constantly evolving light source technology, in the field of educational lighting for elementary school students,optimize the layout of the elementary school classroom light environment, use lighting design software for optical simulation and rendering, through scientific design analysis, study the reasonable configuration relationship between overall lighting and key lighting to achieve the best classroom lighting effect.

Keywords: Optical Simulation;Classroom Lighting;Optimization Design

0 Introduction

Due to the heavy academic pressure on students, frequent use of electronic devices, and insufficient outdoor exercise time, the detection rate of visual impairment among students worldwide is increasing year by year and the trend towards younger is significant. As the main venue for students' study, the quality of the classroom's lighting environment directly affects students' vision, and educational lighting related to eye health has become a research hotspot. At the same time, the International Commission on Illumination has put forward the concept of health lighting, focusing on the visual and non visual effects of lighting. Health education light environment needs to be constructed. Provide a higher quality lighting environment for primary school students' learning and working in the classroom, and protect the growth and development of children's eyes during the peak period of hyperopia reserve.

1 Theoretical Research on Educational Lighting Design

Traditional educational lighting generally has some problems, such as low uniformity of illumination, high glare, low color rendering index, severe flicker, and blue light hazards. These lighting issues will directly affect the quality of teaching, and in the long run, they will threaten the physical and mental health of students. At present, a large number of researches on the light environment of educational space focus on classroom space, and explore the influence of spectrum, illuminance, color temperature, explicit

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indication and other factors of classroom lighting on students' vision and physiology.

The lighting quality of primary school classrooms directly affects the visual comfort and health of teachers and students, and is closely related to students' concentration and learning efficiency. Therefore, the following requirements are proposed for the lighting fixtures and lighting environment in primary school classrooms: excellent illumination, high visibility, moderate color temperature, no glare, no flicker, and no blue light. *The GB 7793-2010 Hygienic Standard for Daylighting and Lighting in Primary and Secondary School Classrooms* [1] stipulates the following provisions for classroom lighting design: desk illumination>300lx, blackboard illumination>500lx; Illumination uniformity $\geqslant$ 0.7; Unified glare value UGR $\leqslant$ 19; Power density<11W/m; The relevant color temperature of the light source ranges from 3300 K to 5300 K; Color rendering index $\geqslant$ 80.

Extensive exploration has been conducted in the research and application of lighting design software both domestically and internationally. Mistrick et al. [2] systematically introduced and evaluated the development process of lighting design software, and analyzed the specific characteristics and functions of lighting design software. Stockmar, H. [3]introduced the lighting design software DIALux, elaborated on its characteristics, functions, and usage methods, and evaluated and analyzed its role in lighting design. This article conducts optical simulation using DIALux evo lighting design software.

2 The spatial scale and lighting arrangement of ordinary classrooms in primary schools

The classroom can be divided into three areas based on the different functions of each area, namely the teacher operation area, student seat area, and transportation corridor area. The teacher operation area is an area where teachers write on the blackboard, display teaching materials on electronic screens, and conduct teaching activities on the podium; The student seat area is the main area where students study in the classroom, including desks and chairs for placing books, stationery, and other items; The traffic corridor area is a functional area that meets the needs of classroom corridors and student evacuation.

The lighting of primary school classrooms should adopt a uniform distribution of lights on the ceiling. While ensuring the illumination and uniformity requirements of educational lighting, it is advisable to minimize the installation height and hanging position height and density of lighting fixtures as much as possible. At the same time, specific plans are made based on the spatial area of different classrooms to create a healthy and comfortable classroom lighting environment. Draw a table based on relevant research and information, showing the lighting arrangement methods for different classroom areas.

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According to the latest regulations of the *Construction Standards for Urban Ordinary Primary and Secondary School Buildings* [4], the usable area of each newly built ordinary classroom in primary schools shall not be less than 61 ㎡. The classroom is 9.200m long, 7.800m wide, and 3.600m high, requiring 12 classroom lights and 3 blackboard lights.

classroom area /㎡	number of classroom lights	blackboard size /m	number of blackboard lights	lamp arrangement method
≤45	≤6	≤3.6	2or3	6+2
>45and≤65	≤6	>3.6	3	9+3
>65	≤12	≤3.6	3	12+3

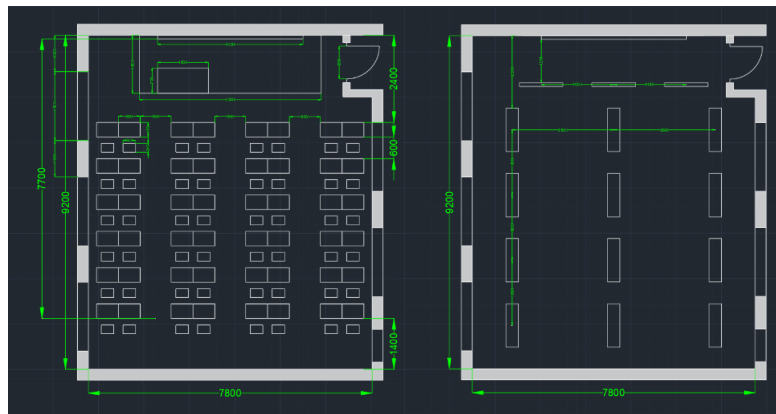Fig 1. Primary school general classroom lighting enumeration

Fig 2.The floor plan and light position of the general classroom in elementary school

3 Classroom Lighting Simulation and Rendering Based on DIALux evo

Based on the lighting design software DIALux evo, optical simulation is conducted on the lighting environment of primary school classrooms. Draw a floor plan of a primary school regular classroom in Auto CAD; Import the sketch into DIALux evo and adjust the 2D model as needed; Edit the spatial parameters of the 2D model to create a simple 3D classroom model; Adjust the spatial parameters and environment of the 3D model, place doors and windows, draw ceilings and roofs, create and select components such as blackboards, desks, chairs, and podiums, and arrange them in the 3D model; Provide a more comprehensive decoration of the 3D model, including the reflectivity and coating color of materials such as ceilings, walls, and floors, to make the model scene closer to the actual classroom environment; According to the light bitmap, arrange lighting fixtures for scene lighting rendering, and group and control classroom lights and blackboard lights; Insert calculation components into the spatial workspace,

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including the class desktop, blackboard surface, and ceiling, and define the photometric parameters to be calculated; Activate the lighting scene for lighting calculation; Generate lighting design reports, output ray tracing legends, including grid diagrams, pseudo color diagrams, renderings, etc., obtain data and distribution maps of horizontal illumination, right angle illumination, unified glare values, etc. for each working surface; Compare and analyze the results to evaluate the design scheme of lighting fixtures and lighting environment in primary school classrooms.
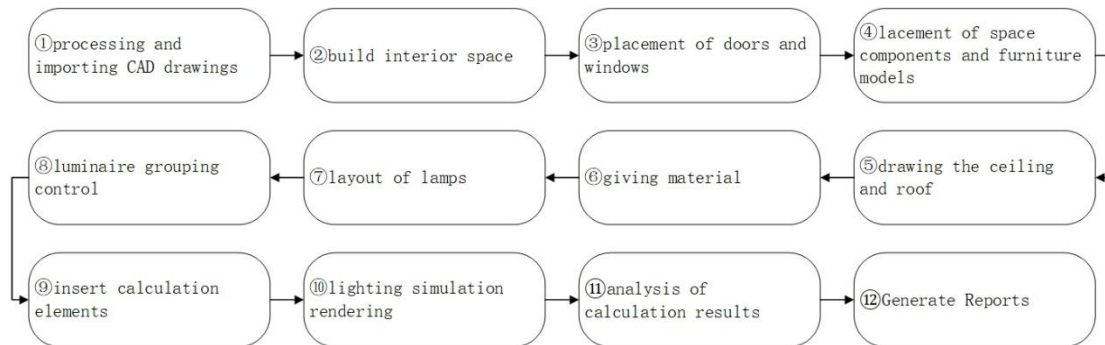

Fig 3.Flowchart of general classroom lighting simulation in elementary school

Fig 4.Panoramic view of classroom lighting scene

4 Analysis and Comparison of Classroom Lighting Calculation Results

(1) Horizontal illumination of class desktop

In the lighting design of the ordinary classroom in this elementary school, 9 * 7 illumination sampling points were arranged on the classroom desktop, with an average illumination value of 443Ix. The minimum illumination value of the classroom desktop was 357lx, and the maximum illumination value was 535Ix. The average value of horizontal illuminance on the class desk meets the standard limit of classroom lighting level illuminance (not less than 300lx), which is 143lx higher. The value and distribution of horizontal illuminance on the class desk perform well, both in accordance with national standards and experimental requirements. It can provide good illuminance for primary school students' homework in the classroom, and even students sitting in corners can have bright lighting.
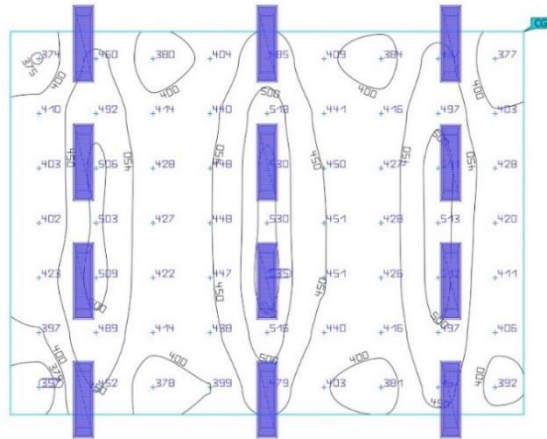
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Fig 5.Horizontal Illumination Distribution Diagram of Class Desktop

(2) Right angle illumination of blackboard surface

20 * 5 illumination sampling points were arranged on the blackboard surface of the classroom, with an average illumination value of 684Ix. The minimum illumination value on the blackboard surface was 471lx, and the maximum illumination value was 888Ix. The average value of right angle illuminance on the blackboard surface meets the standard limit of vertical illuminance on the blackboard surface for classroom lighting (not less than 500lx), which is 184lx higher. The installation position and light angle of the blackboard light optimize the attenuation of the blackboard surface illumination from top to bottom. According to the isoilluminance curve, the bottom right angle illuminance on the blackboard surface is all above 500lx, and the value and distribution of right angle illuminance on the blackboard surface are good, meeting the requirements of national standards.
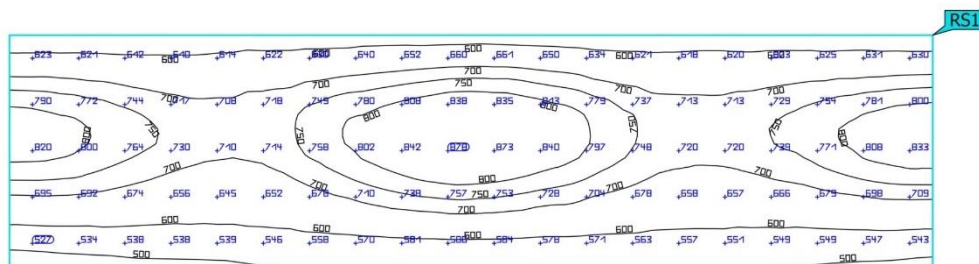

Fig 6.Right angle illumination distribution on blackboard surface

In the national standards *GB 50034-2013 Building Lighting Design Standard* [5] and *GB 7793-2010 Hygienic Standard for Daylighting and Lighting in Primary and Secondary School Classrooms* [1], the unified glare value UGR limit for classrooms is 19, and currently the limit value for some local standards is 16. In the lighting design of this classroom, a calculation surface is set with a desktop distance of 0.800m from the ground, and 9 * 7 UGR observation points are evenly set. Each observation point is from a horizontal perspective of 15°, and the observation is parallel to the calculation surface within the range of 0°~360°. The figure shows the

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glare value data table. The simulation results show that the glare value in the working area gradually increases from 10 to 12.6 from the inside out, and the maximum glare value appears at 165°, which meets the requirements for UGR in educational lighting.
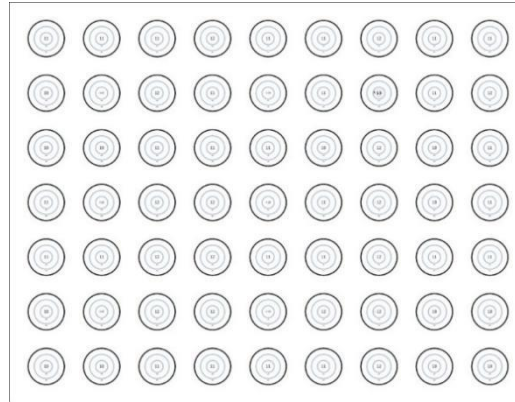

Fig 7.UGR distribution map of unified glare value on the desktop of the course

5 Conclusion and outlook

Analyze and calculate the spatial scale and lighting layout of ordinary primary school classrooms, and use the lighting design software DIALux evo to build a classroom lighting space model. Simulate and render the classroom lighting design plan. Analyze and compare the results of working face illumination and uniform glare values, simulate and verify the lighting environment and lighting effects of primary school classrooms. Develop and apply the concept of health lighting in the field of educational lighting, form educational lighting environmental indicators that contribute to the physical and mental health of primary school students, and expand the application scenarios and light source layout of traditional classroom lighting.

References

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