Applying Ecotect Software to Analyze Natural Lighting of Traditional Dwelling Architecture—Experiences from the Huwan Village, Fuzhou City, Jiangxi Province, China

Qiquan Chen, Ji Weng*

College of Architecture and Urban Planning
Chongqing University
Chongqing City 400045, China

Abstract **— The performance of the window of a traditional dwelling architecture significantly influences the natural lighting level of such a building. This study aims to determine the best strategy for the natural lighting of traditional dwelling architecture by examining No.37 residence in Huwan village. Window-floor ratio, window position, and window lattice were studied through Ecotect software involving lighting simulations. Results show that the optimum window-floor ratio is 1/7. The combination of high windows and ordinary windows is the ideal option to improve the natural lighting. The window lattice exerts a minimal effect on natural lighting increase. Adopting the best natural lighting strategy combination can further improve indoor natural lighting. This strategy is also applicable to the middle and lower reaches of Yangtze River in China, which flow through Fuzhou and have a climate similar to that of the said area. Future research should be directed toward applying Ecotect software to quantitatively evaluate the lighting effects of other components of traditional dwelling architecture and produce the best natural lighting strategy combination.**

Keywords - Ecotect; Traditional dwelling architecture; Natural lighting; Simulation; Verification

I. INTRODUCTION

In order to create a comfortable indoor living environment,suitable lighting, ventilation and excellent thermodynamic conditions will be crucial elements[1]. However, due to material and technical constraints and other drawbacks, the exterior wall of courtyard dwellings has few direct windows to the external. Therefore, many rooms generally have got poor indoor lighting.

Detailed measurements of No. 37, Zhan Jia Xiang in Hu Wan village as shown in Figure 1. The residents in Hu Wan village suit one's measures to local conditions and obtain raw materials locally, mainly including stones, wood and bricks. Besides structural function, external wall is also responsible for security requirements. Thus, most parts of exterior wall use stone, and the external wall has few windows opened unless high windows which their openings are small[2]. The inner wall consists of timbers , boards, doors and screens which is more decorative than the external wall, especially in the windows and doors where there are too many carved grille, which results in the lack of lighting from the courtyard which is blocked from the outside by it.

II. SIMULATION AND ANALYSIS

Simulation object: Simulation and selection of No. 17 Zhan Jia Xiang ,in Hu Wan village as the research object, there are high windows inside and outside.

The basic condition: Beijing time is 18th August, at 116.6 of east longitude,27.9 of north latitude , light climate zone belongs to third area, light climate factor is K=1.

Sky illuminance setting: in calculation of ecotect lighting, weather status is set to GIE ,the cloudy weather and the sky illuminance 5000lx. Take the coefficient of lighting and indoor illumination as the reference object[3]. When simulating caculation in Ecotect, setting parameters enables outdoor natural light to be only diffuse light which will not form shadow[4]. Therefore, the direction of windows does not affect the simulation of lighting condition.

Three rooms in the first layer in No.37, Zhan Jiagang are simplified as a regional model in order to carry out simulation (Figure 2). Window/ground ratio and windows' position of the three rooms are different, but the common situation is they are high windows and have grids on them. The basic situation of three areas refers to table Ⅰ.

Take the window/ground ratio, the windows' position and whether there is a grid or not as variables, use control variable method and Ecotect to calculate the lighting conditions of the three regions[5]. Mainly test the lighting situations under the following circumstances:

(1) Analyse the lighting situations of room a, b,and c;

(2) Analyse the impact of window/ground ratio on indoor natural lighting condition;

(3) Analyse the influence of different opening positions on indoor natural lighting condition.

TABLE I PREDICTION RESULTS OF DIFFERENT ANN MODELS

District	Room size（㎡）	Depth（mm）	window to ground ratio
District a	8.5	2500	0
District b	5.95	1700	0.42
District c	14.34	2500	0.04

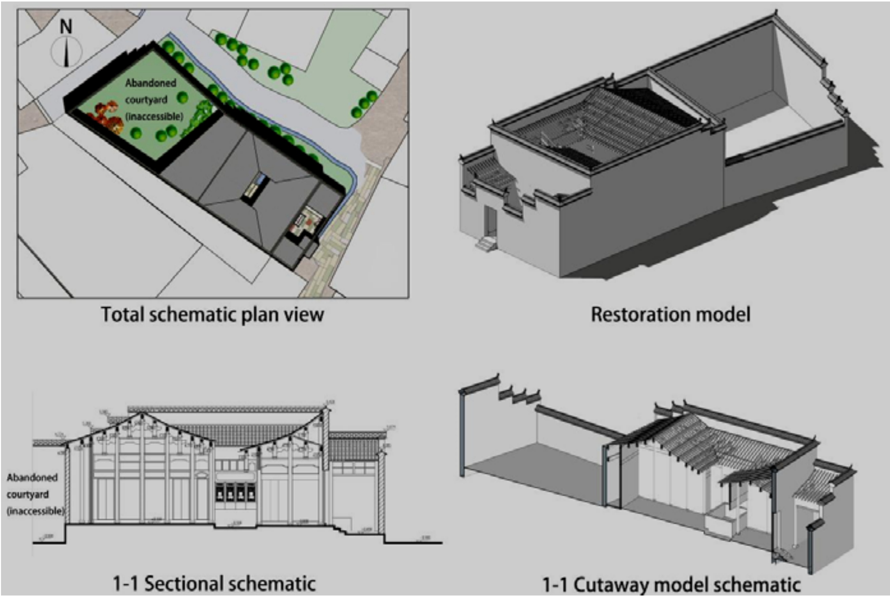

Figure 1. Detailed measurements and modeling results

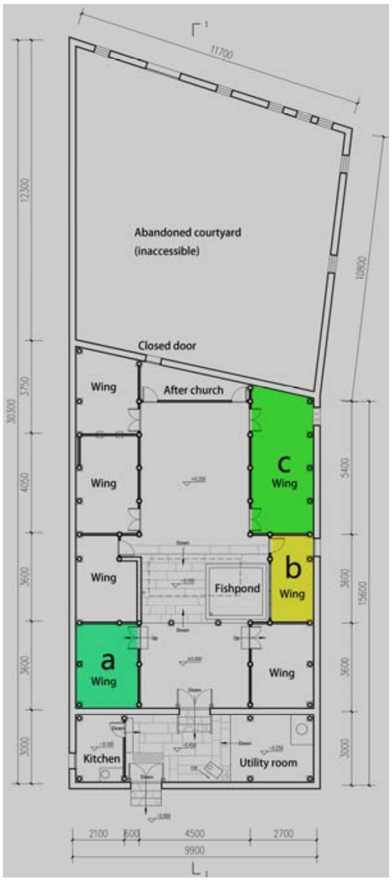

Figure 2. Schematic of first floor plan

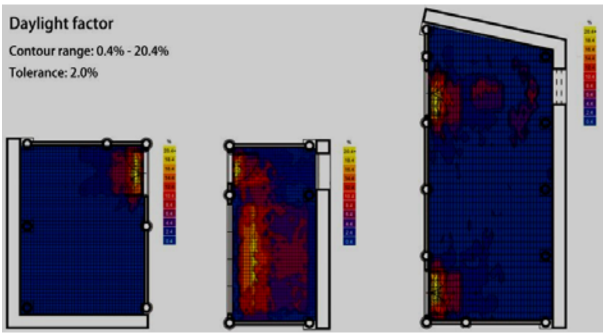

Figure 3. Natural lighting analysis.

III. TEST RESULTS

Test results reflect the natural lighting conditions of these three regions, as is shown below (Figure 3):

As shown in Figure 3, the variation range of lighting coefficient is 0.4%~20.4%, from blue to yellow there are 11 levels, the tolerance is 2%, the coefficient of blue area lighting is lowest. In contrast, the coefficient of yellow area lighting is highest .According to analysis from the chart ,although the area is relatively small, indoor illuminance is inequality, lighting conditions where far from daylight opening are poor. And the minimum value of lighting coefficient is 0.4%, which does not meet the minimum lighting grade design standard of V regulated by building design standard GB/T50033-2001[6](minimum lighting coefficient >0.5%, as is shown in Table Ⅱ).

TABLE Ⅱ STANDARD VALUE OF DAYLIGHT FACTOR OF RESIDENTIAL BUILDING

Lighting level	Room name	Side lighting	
		minimum value of daylight factor Cmin（%）	critical illuminance of interior daylight（lx）
Ⅳ	living room、bedroom、study、kitchen	1	50
Ⅴ	living room、bedroom、study、kitchen	0.5	25

Ⅳ. EFFECTS OF VARIABLES ON NATURAL LIGHTING

Window to ground ratios of room A, room B, and room C have been measured with respectively 0, 0.42, 0.04 by surveying and mapping .According to the regulations by building design standard of daylighting GB/T50033-2001, when civil building grade is in the IV level, the window/ground ratio of side lighting should not less than 1/7 (Table Ⅲ). According to this regulation, only room B can meet the requirements of the window/wall ratio, while A and C rooms are far from meeting the demands of it, when that of room C is 0. Tests of lighting coefficient in two room A and C illustrate that the place where the lighting coefficient is higher is near the door, so people must rely on door's long-term openning to ensure indoor natural lighting[7].

TABLE Ⅲ GLAZING FLOOR AREA RATIO AC/AD

Lighting level	Sidelighting	
	Side window	
	Civil building	industrial building
Ⅰ	1/2.5	1/2.5
Ⅱ	1/3.5	1/3.0
Ⅲ	1/5.0	1/4.0
Ⅳ	1/7.0	1/6.0
Ⅴ	1/12.0	1/10.0

Room A, however, without windows can not directly obtain the natural lighting from outdoor, that makes lighting coefficients of most part of the room are around 0.4%. On the external wall of room C there is a high window matches 600mm*800mm which can obtain lighting directly from the outside. However, only the place where near the window can reach 6.4% in lighting coefficient, whereas in other regions of the room lighting coefficient is 0.4%. Therefore, the high window does not enable lighting coefficient of indoor work surface increase greatly and the impact on regions far from high window is also small.

Room B, which is close to the courtyard, have got a large number of windows on the interior wall, with grids on the sash, and some of them also decorated with ornamental of fish and grass, greatly reduce the amount of incident light. But the application of Ecotect for lighting analysis indicates that regional lighting coefficient near the window can reach 20.4% while that of far from the window can still reach 6.4%. I lighting level regulated by the daylighting design standard of building GB/T50033-2001 sets a minimum lighting coefficient of 5%. Therefore, even with some grids in room B, it can still satisfy the indoor natural lighting.

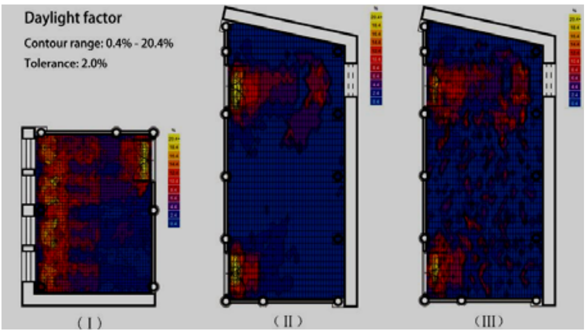

Figure 4. Natural lighting analysis after improvement.

V. THE IMPROVEMENT MEASURES AND VERIFY

The quantitative analysis by Ecotect have shown that: improving the window/ground ratio can effectively increase the indoor natural lighting. In view of the importance and cultural value of Hu Wan village, in the premise of not destroying the original structure, we put forward a series of improvement measures, and use Ecotect to model and simulate[8].

At the same time, avoid opening the high windows while try to open the side windows in the proper position in order to improve lighting coefficient of indoor working surface. In order to verify effectiveness of the method, we choose room A(no humanly scaled) for virtual reconstruction in the Ecotect model: dig some humanly scaled on the exterior wall to make the window to ground ratie higher than1/7, at the same time the windows are set above from the floor of 900mm in order to avoid the high window. Then use Ecotect to simulate and calculate daylighting condition of room A. The results are shown in Figure 4(Ⅰ). It can be seen from the figure that the regional lighting coefficient near the external windows is up to 20.4%, while that in most part of the room is above 6.4%. Therefore, given that other factors remain unchanged, improving the window to ground ratio to more than 1/7 only can greatly improve the indoor lighting conditions.

The sash near the patio can be appropriately decorated with flowers and insects and other grids. However, the grid in the sash of the room which far from the courtyard had better to be reduced as much as possible or even no grid so as to maximize the natural light of the dark room. In order to verify the effectiveness, we choose room C (too much raster outside the window of it)to make virtual reconstruction in the Ecotect model: remove the grid on the window openings and change little on the facade, which increases the luminous flux effectively. And then use Ecotect to simulate and calculate daylighting condition of room C , the results as is shown in Figure 4(Ⅱ). It can be seen that the lighting coefficient near the exterior window is up to 8.4%. Compared with the original, lighting coefficients of the same area increases only by 2%. Although regional lighting coefficient close to the outer window slightly increased, other regional coefficient of lighting remain unchanged. Therefore, the removal of the grid to improve indoor natural condition has little effects.

In the selection of indoor decorative layer material ,we should pay more attention to the use of materials with bright colors and smooth surface, and avoid using materials with dim colors and rough surface as indoor decorative layer. This can enhance twice and multiple reflections of light in the room, improve indoor lighting coefficients, and at the same time improve the degree of unequaty of the indoor natural lighting. In order to verify the effectiveness of these measures, we choose room C (indoor decorative layer of room C is basically made of rough dark wood) to make virtual reconstruction in the Ecotect model: paint white latex paint in the inner wall and then use Ecotect to simulate and calculate daylighting condition of room C.The results are shown in Figure 4(Ⅲ). It can be seen from the figure: lighting coefficients around the room increase slightly by 4.4% to 6.4%, and are distributed equally.

Ⅵ. CNCLUSION

This essay applies Ecotect software to quantitative analysis of courtyard dwellings in Hu Wan village, simulate different natural lighting conditions in different rooms, and summarize existing problems: natural lighting coefficients inside the room are low, window/wall ratios in some rooms do not accord with the standard, indoor illumination equity is poor. Then, take window to ground ratio, window position and whether there is a grid or not as variables to study and draw the conclusion: the window to ground ratio and window position are the main factors which influence indoor natural lighting, grid is a secondary factor on indoor natural lighting. Then, in the premise of not destroying the original structure of traditional dwellings in Hu Wan village, some improvement measures were put forward: increase window to ground ratio, dig windows near the working face, and set grids and choose materials with bright colors and smooth surface as interior decorative layer. Finally, using Ecotect to simulate and caculate the improved indoor model in order to prove that the improved method is effective. This not only help protects the courtyard dwellings in PanXi village, but even has a certain reference value for sustainable development of courtyard dwellings in other ancient villages in Jiangxi Province, China.

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