Study on Indoor Natural Light Environment Optimization of Traditional Residential Buildings in South Sichuan

Jing Li, Ye Yang, Jian Zhong and Yu Liu

Abstract With the progress of economy, technology, natural conditions and lifestyle, the protection and update of traditional residential buildings should adapt to the requirements of the new era and the changes of residents' needs. However, the indoor natural lighting of most traditional residential buildings cannot meet the design standard of architectural lighting 300 lx. Building windowing is an important way to get indoor natural lighting, but improper windowing location, windowing area and window form may cause the room to lack privacy, cold air penetration, indoor thermal comfort decline and other problems, thus leading to the decline of indoor environment comfort. Aiming at comfort and energy saving, this paper puts forward the idea and method of optimizing the design of buildings. Taking the Minzhu community of Hengjiang town, a representative national traditional village in the south of Sichuan province as an example, this paper analyzes and studies the building window form with excellent comprehensive performance based on the local climate characteristics. The simulation software Ecotect was used to simulate the light environment of the optimized building and compare it with the pre-optimized architectural light environment. The results show that the optimized window opening form can not only make the indoor natural illumination reach the design standard of architectural lighting, but also make the indoor thermal environment, wind environment and visual field comfortable and have the effect of energy saving.

Keywords Natural illumination optimization · Multi-objective · Windowing · Software simulation

1 Introduction

On October 18, 2017, President Xi proposed the strategy of rural revitalization in his report to the 19th national congress of the communist party of China (CPC). Since

J. Li (✉) · Y. Yang · J. Zhong · Y. Liu
School of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu, China
e-mail: 493624055@qq.com

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then, the issue of agriculture and rural farmers has become a top priority in the work of the whole party [1]. There are a large number of traditional residential buildings in most rural areas. With social progress and economic development, users' demand for better living conditions is increasing, and the protective development of traditional residential buildings is extremely urgent.

The concept of "traditional residence" is not a static inherent object, but a dynamic architectural category. With the change in time and the change in external conditions, as well as the increase in living space use requirements and facilities, residential buildings are also constantly being transformed, expanded and rebuilt [2]. This paper investigated the natural light environment of traditional residential buildings in southern Sichuan, analyzed the current situation of the light environment, proposed the protective transformation strategy and explored the development path of residential buildings.

2 On-Site Research and Analysis

2.1 Questionnaire Analysis

This paper selected a typical courtyard residence in Hengjiang town Minzhu community, a national traditional village in southern Sichuan, for analysis. The building was built in the middle of the Qing dynasty, which has a very high reference value for the study of the architecture of the Qing dynasty in southern Sichuan. Selected courtyard is located in Yibin county, Sichuan province; its sit toward the northwest, building orientation is good. It covers an area of about 801.7 m^2, with a floor area of about 447.73 m^2. There are 14 families living in it. The interior space includes bedrooms, kitchen, parlor/dining room, lavatory and utility room. The plan is shown in Fig. 1.

Through questionnaire survey, the users of quadrangle courtyard make post-use evaluation on the natural lighting of rooms with different orientations. The questionnaire mainly asks residents to evaluate the lighting effect of rooms with different orientations and select the rooms with the worst and best subjective lighting perception, and the surveyors make judgments based on the evaluation. The room number and room orientation are shown in Fig. 2.

A total of 45 questionnaires were distributed, and 40 were recovered, with a recovery rate of 88.9%. In addition to the blank questionnaires because of some users could not be contacted or could not be communicated due to age, a total of 36 valid questionnaires were obtained. Among the valid questionnaires, 27 were filled out face-to-face inquiry by the surveyors and nine by telephone communication. Among all users who filled out valid questionnaires, 30 are original residents, accounting for 83.3% of the total sample size. The remaining residents are tenants and married people, and the ratio of male to female is 20:16. The surveyors believe that the users generally have good qualities and have accumulated certain experience and

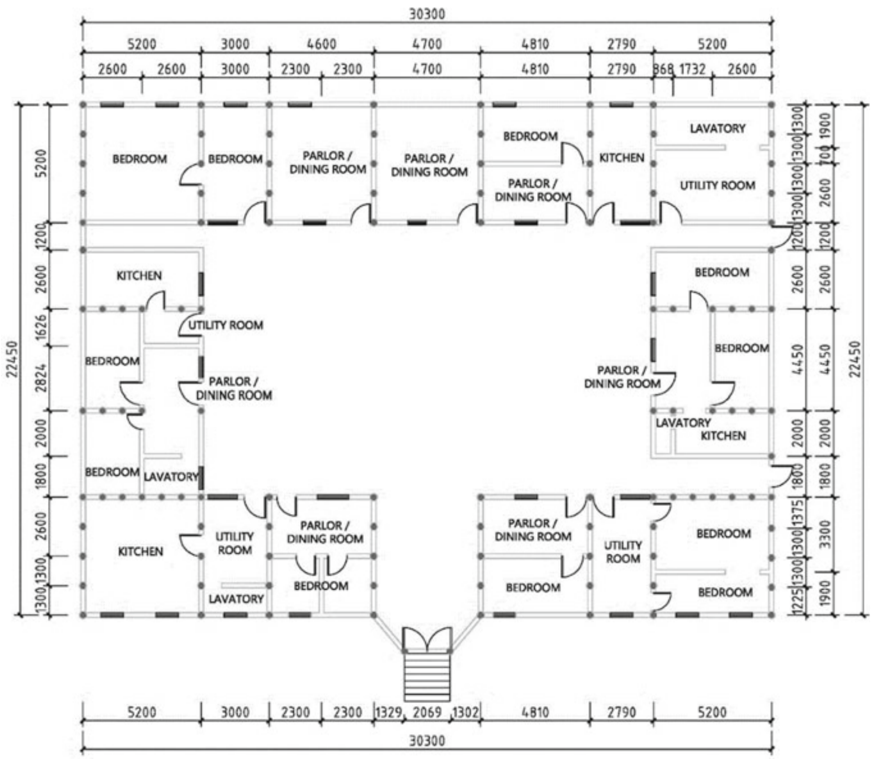


Fig. 1 Floor plan

subjective feelings in the use of various spaces of quadrangle courtyards. Therefore, the evaluation results can reflect the current situation of natural lighting in quadrangle courtyards better. The statistical results of the questionnaire are shown in Table 1.

It can be concluded from the statistical results that:

Depending on the function and lighting conditions, users have different evaluations of natural lighting in different orientations. Among them, to the west, room 3 has the best natural lighting, and room 8 has the worst natural lighting; to the east, room 5 has the best natural lighting, and room 1 has the worst natural lighting; to the south, room 3 has the best natural lighting, and room 4 has the worst natural lighting; to the north, room 3 has the best natural lighting, and room 2 has the worst natural lighting.

According to the result, investigator chooses rooms with the best or the worst natural lighting from different orientations to measure the illumination.

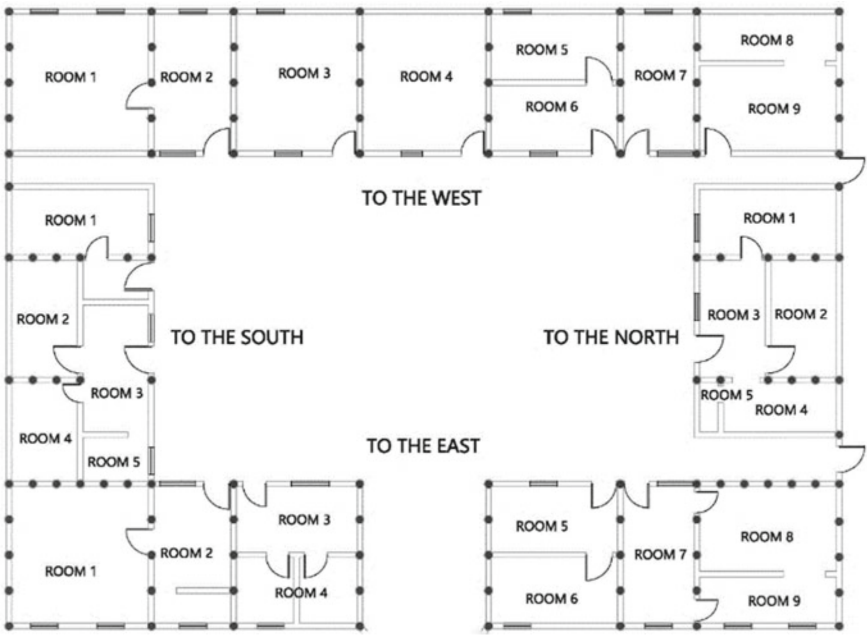


Fig. 2 Rooms with different orientation

Table 1 Questionnaire survey results

Heading level	To the east	To the west	To the south	To the north
Best natural lighting	ROOM 5	ROOM 3	ROOM 3	ROOM 3
Worst natural lighting	ROOM 1	ROOM 8	ROOM 4	ROOM 2

2.2 *Illumination Measurement*

According to "The Lighting Measurement Method" GB/T 5699-2017, the measurement was taken under overcast weather in winter. In the eight rooms, measuring points were evenly arranged at an interval of 1 m and measured outdoors at the same time (Fig. 3). Data were collected every half an hour from 10:00, and the last data were collected at 14:00. A total of nine groups of time points were obtained.

The measurement data of each time point in each room were simplified to an average, and nine average data were obtained in each room. Plus nine data of outdoor measuring points, a total of 80 measurement data were obtained. It can be shown from Figs. 4 and 5 the change trend of illuminance in different rooms.

We can conclude from the data collected: First, the data are in accordance with the law of illumination and are of reference value. Second, even the best-lit rooms cannot meet the required standards, substandard light environment will affect the health and comfort of users. Third, uniformity of daylighting is not good. Last, there

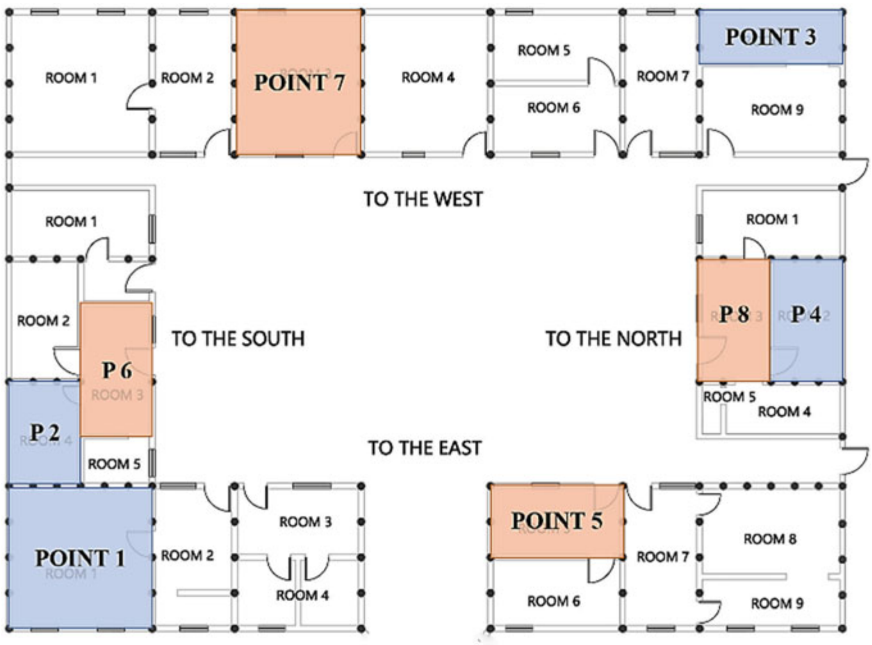
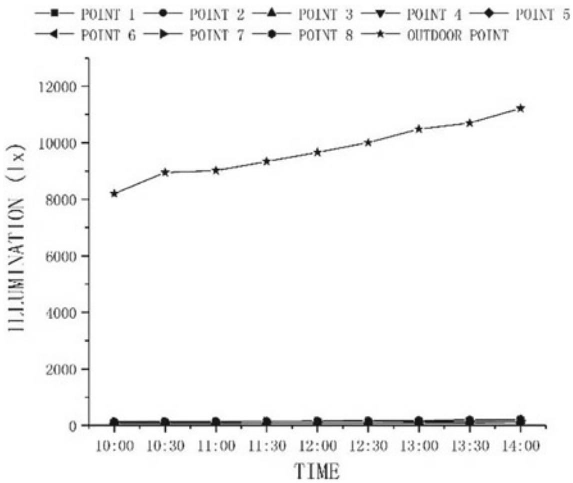


Fig. 3 Arrangement of measuring points

Fig. 4 Indoor and outdoor measurement data



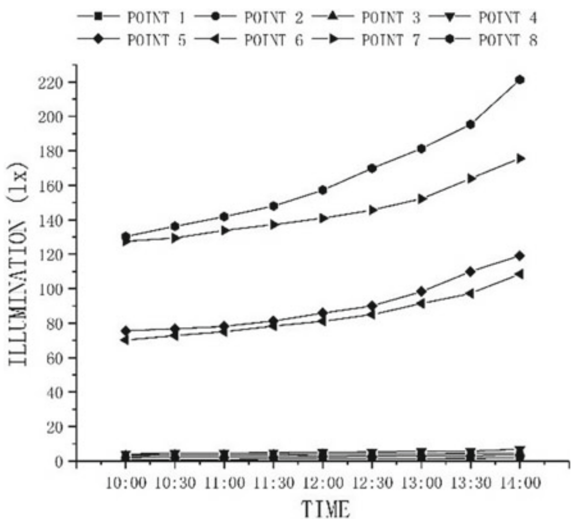


Fig. 5 Indoor measurement data

is a big difference in illumination between different rooms. It is worth noting that in normal use, the building is often closed doors and windows. This survey was carried out under the condition of building opening, so the real natural light environment of the building was darker than this survey [3].

3 The Optimization Design

As the witness and representative of local life and culture, residential houses in traditional villages cannot be duplicated. Its transformation should be more protective use than drastic reconstruction. As an important part of enclosure structure, windows can not only use natural light to satisfy people's visual comfort, but also have an important impact on building energy consumption. Introducing natural lighting through windows can effectively improve the indoor lighting environment and reduce the lighting load. Therefore, the optimization design mainly focuses on the change of windows.

3.1 Resize Windows

In the past, due to economic difficulties, doors and windows were not only used for lighting and ventilation, but also for safety and warmth. Therefore, the doors and windows of traditional houses were small in size. Below the premise with harmonious proportion, enlarged dimensions of door and windows can increase indoor natural daylighting, meanwhile, enter and exit a room more comfortable and convenient.

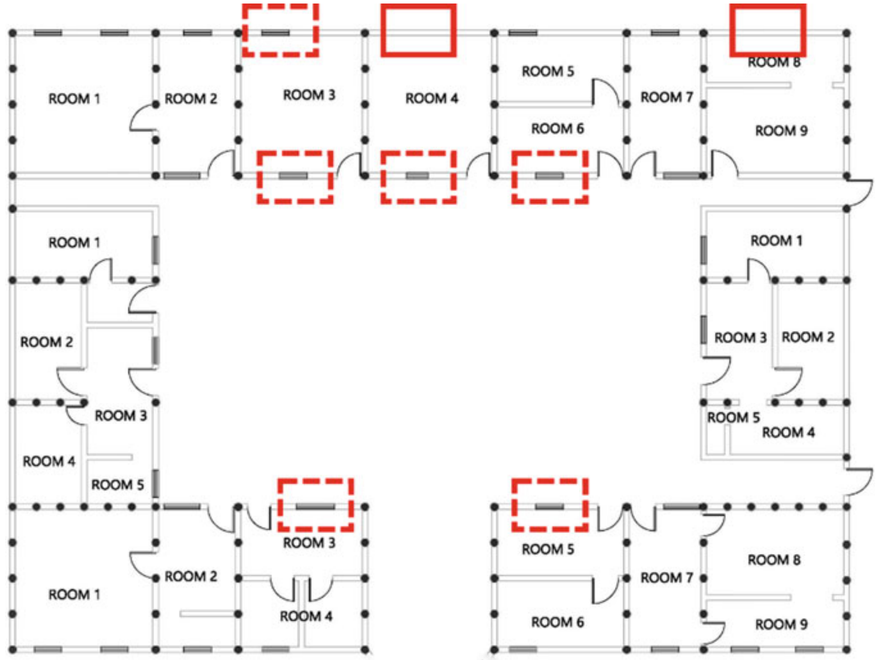


Fig. 6 Changed window position indication

According to "Code for Thermal Design of Civil Buildings" GB 50176-93: In residential buildings, the area ratio of window to wall of rooms toward the north is not more than 0.25, the area ratio of window to wall of rooms toward the east and west is not more than 0.30, and the area ratio of window to wall of rooms toward the south is not more than 0.35. Therefore, increase the height of the windows to get more natural light while meeting the requirements.

As shown in Fig. 6, the original dimension of the window marked with dotted lines is 1000 × 1000 mm and 1200 mm off the ground. Now, its height has been increased and its size has been adapted to 1200 × 1000. Its area has been increased from 1 to 1.44 m^2. Where the solid line was marked, there were no windows. Now, open a 1000 × 1000 mm window to increase the light.

3.2 Change the Material of Windows

Nowadays, more and more studies have been done on window materials, and many materials have been verified by experiments, which are green and energy saving. The combination of wood panes and new materials can not only improve lighting efficiency, but also ensure the unity of traditional style and features.

This article recommends the use of thermotropic double-glazed windows. Results show that thermotropic double-glazed windows can reduce 70 and 53% of highly uncomfortable indoor thermal environmental conditions in west-facing room, respectively, compared with double-glazed windows and tinted double-glazed windows. Moreover, they can reduce 19% of cooling electricity requirements in west-facing rooms compared with double-glazed windows and provide an appropriate indoor illumination condition [4].

4 Simulation Verification

The simulation of Ecotect combines edition and modeling tools, besides luminous evaluation and thermal consequences of daylight use. It also considers the architectural project as a combination of various factors, giving the architect the chance to integrate knowledge by using accessible digital processes [5]. Before the simulation calculation, the building parameters before optimization are used to model and simulate illumination, which is consistent with the measured data in the error range.

The simulation results are shown in Fig. 7. The average illumination of the rooms in the east–west direction is better than that in the north–south direction. Because of

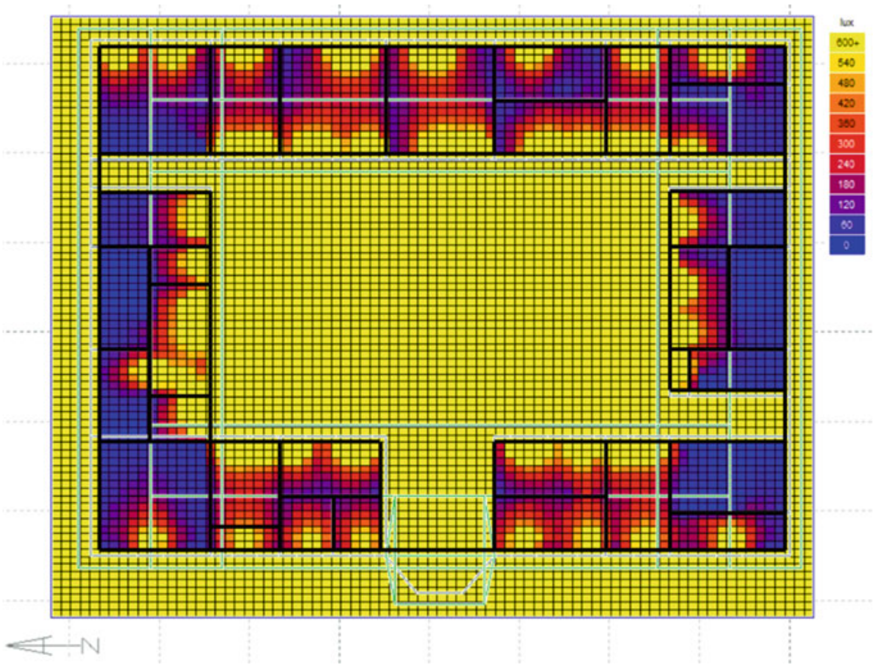


Fig. 7 Ecotect simulation results

the restriction of the architectural layout, the buildings in the north–south direction cannot open windows on the back wall, so the lighting of north–south direction is poor. After optimization, all rooms have met the requirements of lighting standards according to their different functions.

5 Conclusion

In this paper, the illumination intensity of the data obtained from the field survey is analyzed, and the results of the questionnaire survey are synthetically analyzed. According to the analysis results and social requirements, the design strategy of optimizing indoor natural light environment is put forward from the aspect of window modification. Natural lighting is the main lighting system of the building after renovation, which provides sufficient illumination for the whole building, and no artificial auxiliary lighting is needed during the day [6].

In this paper, the subjective wishes of users are obtained by questionnaire survey. On the basis of respecting their wishes and combining with the results of measured data, the optimal design strategy of light environment is put forward. While inheriting the local traditional residential culture, it can also help to improve the indoor natural light environment of traditional residential buildings and improve the quality of life of residents. It provides some references and suggestions for the optimum design of natural light environment of rural residential buildings in the future.

Permissions Appropriate permissions from house owners were obtained for studying in house and investigating of traditional dwelling light environment.

Ethical Standards The authors declare that the questionnaire analysis complies with the current laws of the country in which they were performed.

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