OPTIMISATION DESIGN STRATEGY OF RURAL BUILDING FORMS FOR A HEALTHY MICROCLIMATE ENVIRONMENT

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Abstract. The paper based on microclimate environment of the site takes the optimized design of rural building form to help the rural revitalization and sustainable development. The reconstructed house project in Baihua Village of Tangchi Town in Anhui Province is taken as the research case to discuss the form optimization strategies. Based on the principle of passive priority and active optimization, the building in Baihua Village is analyzed by field investigation and numerical simulation. First, the outdoor environment is interpreted by using Weather Tool software to offer a building form proposal. Then, with the drawing software CAD, ecological building simulation software Ecotect, and green building analysis software PKPM, the optimization strategy analysis of healthy building form was carried out to verify the optimal solution of building form based on China's national standards. Finally, this paper summarized and improved the rural building optimization design system for a healthy microclimate environment. The results of this paper are hoped to use for the contemporary rural architectural form design.

Keywords. Building form; Healthy environment; Design optimization; Software analysis.

1. Introduction

In 2017, "Healthy China" became China's national strategy. However, the majority of the rural population in China has been attracted by the rapid and efficient development of cities in recent decades. From the countryside to the city, the urban architectural form, function, and cultural characteristics have been brought back to the countryside and grafted into the development and reform of the countryside. Rural renewal and construction not only improve the living quality of rural residents but also directly or indirectly affect the traditional building microclimate environment that has been formed in rural areas for a long time. It is one of the strategies to solve the contradiction between rural tradition and modern development to explore the form of rural architecture that is conducive to the creation of a healthy microclimate environment.

The primary significance of the architectural form is to improve the natural climate and create a comfortable indoor environment, and the diversity of the microclimate creates the diversity of the architecture. Natural ventilation can

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enhance human comfort (Li, B., et al., 2020). New houses can be simulated and analyzed with the help of local wisdom (Li, B., et al., 2020). Scholars have determined that appropriate building forms provide better passive results for shading and natural ventilation (Olgyay, A., et al., 2015). The reflectivity and emissivity of the surface of the corridor on the influence of solar radiation will have different rules (Maragno, G.V. and Roura, H.C., 2010). Solar energy and wind energy can be used to realize the effective operation and increase energy saving of buildings with variable forms (Schumacher, M., Schaeffer, O., and Vogt, M., 2010). In addition to the discussion of technical analysis means, the focus on regionalism and practicality is also an important factor to realize the optimization of architectural form. Therefore, under the background of fully analyzing the traditional microclimate environment and combined with the modern lifestyle, this paper discusses the optimization design strategy of the rural architectural form.

2. Object and methods

2.1. OBJECT

Baihua village is located in Tangchi town, the westernmost part of Lujiang County, Hefei City, Anhui Province, in central China. It covers an area of 9 square kilometers. Baihua village is a mountainous village with undulating terrain and mountainous mountains from east to west, which also has a fundamental influence on the layout and form of buildings in the village.

The architectural form of Baihua Village is dominated by strip buildings. The single building with grey tiles, rammed earth walls, and stone foundations as the main structural materials (Figure 1). Among them, rammed earth wall architecture, an important architectural form of Baihua Village, is based on the raw earth that can be recycled and used locally as the main raw material. Rammed earth wall houses have good thermal performance and high indexes of thermal resistance and thermal inertia, so rammed earth buildings have an excellent thermal insulation effect, which will make the indoor warm in winter and cool in summer. The porous nature of rammed earth walls has a particular regulating effect on indoor humidity. Based on the original building materials and forms of Baihua Village, it is crucial to find the appropriate analysis means and realize the optimization of the new building form.

Figure 1. Status Quo of Grey Tile, Pitched Roof and Rammed Earth Wall.

2.2. METHODS

Weather Tool is a sub-software in Autodesk Analysis Ecotect software. It is widely used in the field of building ecological environment simulation and analysis, which can effectively improve energy efficiency and assist sustainable design. The Weather Tool reads and transforms a range of commonly used Weather data formats, including TMY (Typical Weather Year), TMY2, and DAT (Data), in a graphical visual representation. It contains hourly meteorological parameters commonly used in most performance-based building simulations.

In the early stage, meteorological data were analyzed through the Weather Tool to offer the design proposal. After that, the drawings made by software CAD based on field study. Then ecological building simulation did by software Ecotect to analyze the indoor natural lighting performance. And the software PKPM analyzed the indoor wind environment and air quality to verify whether the building form is healthy enough or not based on the relevant standards.

3. Results

3.1. CLIMATE ANALYSIS

3.1.1. Orientation and Solar Radiation analysis

The best orientation is calculated based on the amount of local solar radiation during the overheating and supercooling periods throughout the year. The optimal orientation of buildings in Hefei is due south, while the appropriate orientation is due south by west 5° and due south by east 15°, so the orientation should not be due west. It can be seen that the annual average solar radiation amount in the Hefei area is most in the direction of 25° South by east, 7.5° South by east in the period of subcooling, and 10° East by 10° South in the period of overheating.

Solar Radiation refers to the analysis and comparison of annual Solar Radiation on the facade facing all directions. From the figure, it shows the overheating period in the red zone is from late May to early September in Hefei. The supercooling period in the blue area is from late November to early March. The thick yellow line represents the annual average solar heat gain due south (Figure 2).

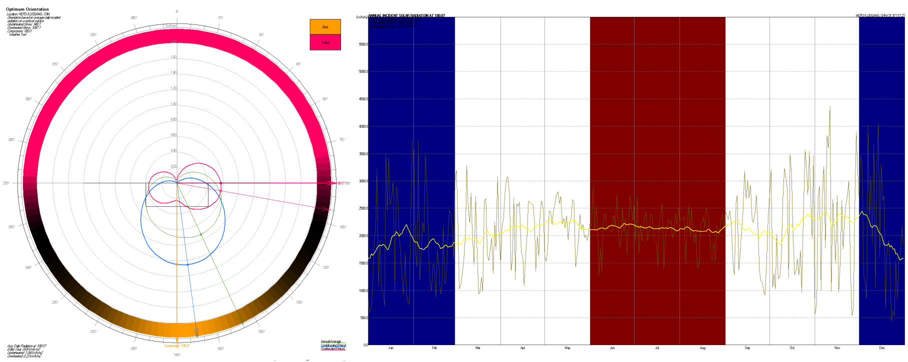


Figure 2. Solar Radiation and it’s Optimal Orientation.

Through comparative analysis, the solar radiation heat of each facade is obtained during the overheated period and the under cold period in a year, and the relative optimal architectural orientation for the design of the building plane and facade is summarized, to meet the optimal effect of building lighting and sunshine.

3.1.2. Enthalpy analysis

Enthalpy is a quantity of energy in a matter, a parameter representing the state of the matter in units of K.J. or K.J.kgˆ-1. Enthalpy and Humidity figures are used in ventilation and air conditioning engineering to determine the state of air, including temperature, moisture content, atmospheric pressure, and the relationship between water vapour pressure and thermal environment. Generally, Enthalpy and Humidity diagrams are used in the process of climate design to intuitively analyze and determine the cold, hot, dry, and wet conditions of the indoor and outdoor climate of the building, as well as the deviation degree from the comfort zone. The horizontal coordinate of the Psychrometric Figure is the dry bulb temperature (unit: Degrees Celsius); The ordinate is absolute humidity (unit: g.kgˆ-1); The oblique line with different slope indicates wet bulb temperature (unit: Degrees Celsius); The parallel slash represents Enthalpy in K.J.kgˆ-1. The comfort zone in the Enthalpy Figure is determined by air temperature, relative humidity, airflow velocity, and ambient radiation temperature.

The annual time range of Hefei is selected for analysis (Table 1) - using software prediction, simulation, and quantitative expression functions. Six passive technologies were selected: passive solar heating, high heat capacity material applications, night ventilation, natural ventilation, direct evaporation cooling, and indirect evaporation cooling. It can be seen from Table 2 (a-f) that the measures suitable for improving the thermal comfort of the local climate in Baihua Village are as follows: adopting high-heat melt enveloping material to increase heat storage capacity, strengthening nighttime and natural ventilation, and indirect evaporation cooling. Compared with other measures, passive solar energy and direct evaporation cooling methods are slightly less effective. The main reason for this phenomenon is that Baihua Village is in the subtropical monsoon climate zone, and the solar radiation intensity is not high.

Table 1. Total Annual Solar Radiation (MJ/mˆ2) in Major Cities of China in 2001.

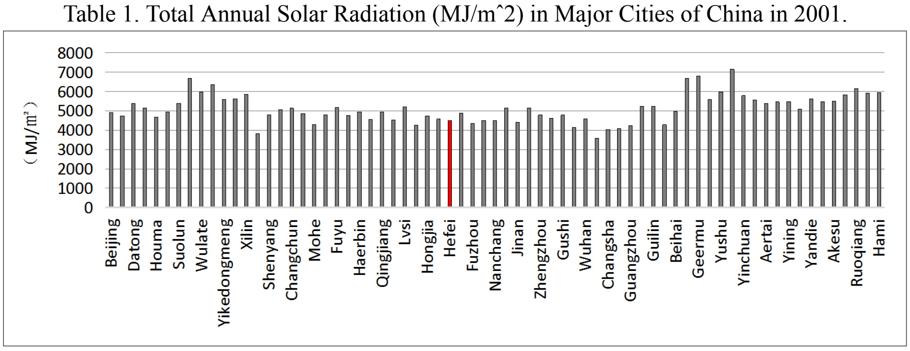
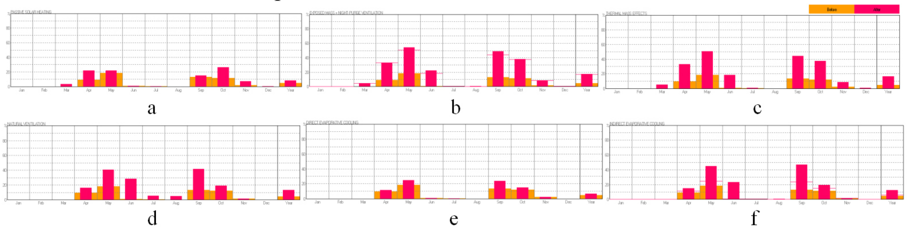


Table 2. Comparison of Passive Measures Before and After Use.



3.1.3. Wind analysis

The Wind Analysis figure includes Wind frequency (colour depth), Wind direction (circular coordinate), and Wind speed (vertical coordinate) (Figure 3). The figure shows the Wind environment of Hefei in 12 months, and the comprehensive Wind environment of the whole year. It can be judged from the figure that the perennial wind direction of Hefei is the southeast wind in summer, south wind and east wind in a transitional season, and northwest wind prevails in winter with obvious seasonality. The architectural design can guide the use of the dominant wind in summer and transitional season to prevent and weaken the prevailing wind in winter, to achieve natural ventilation, dehumidification, and cooling.

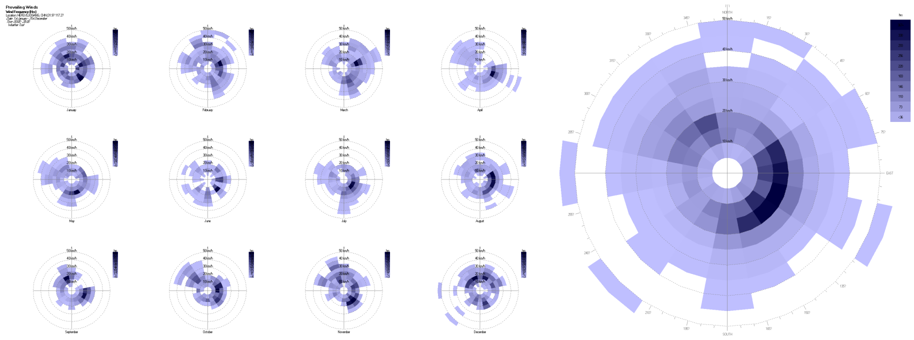


Figure 3. Wind Environment in 12 Months and the Whole Year of Hefei.

3.2. FORM OPTIMIZATION

3.2.1. Shape

The sloping roofs, courtyards, and single shapes of the original village buildings have become the key reference objects for the new buildings in Baihua Village. The architectural shape elaboration is shown in Figure 4: According to the status quo of the base boundary, conduct site slope finding treatment (a); Limit the scope of new buildings and level off the site (b); Determine the body block area and limit the height (c); Divide the block according to the optimal orientation and site form (d); Set the location of the air shaft and the height of the wind guide wall to create ventilation conditions (e); Set the way to enter the building, use the space in the west direction and the space in the north direction, and minimize the occupancy of the lighting resources in the south direction (f); The bottom is raised on stilts to form a ventilation corridor (g); Build a semi-climatic landscape platform between the blocks (h); Rammed earth envelope, independent block (i); External balcony, separated from the main load bearing system (j); Select sloped roof elements and place solar water heaters (k); Assist the roof of the north-facing slope to avoid direct sunlight and build a roof rest platform with full climate (l).

3.2.2. Function

The best orientation of Baihua Village is due south, and the accommodation and other main functions are set in this area according to the topographic characteristics of the base. The meeting room and reception room are designed to face the southeast. Combined with the traditional architectural features of Baihua Village, courtyard space and landscape platform are added to assist the main building in ventilation and lighting. The surrounding scenery of the project is pleasant. The interactive experience between humans and nature is fully considered in the design, and the visual effect is also considered (Figure 5).

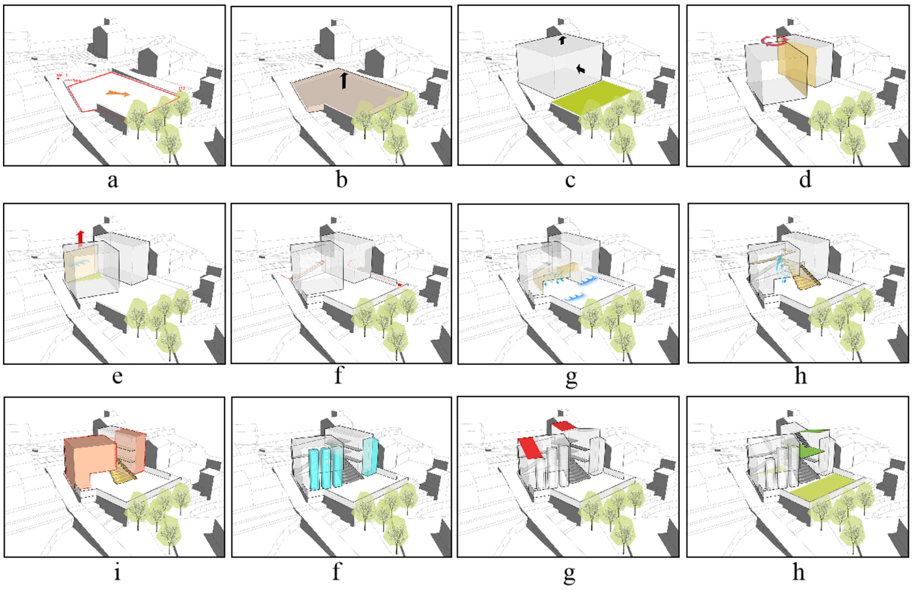


Figure 4. Healthy Building Technology Deduces Building Form.

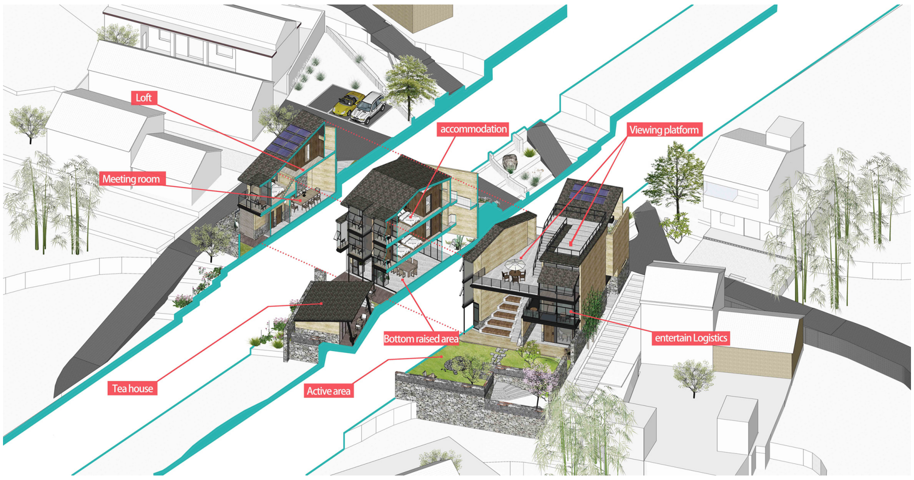


Figure 5. Planar Function Configuration.

3.2.3. Facades

This building facade selects the contemporary curing agent rammed earth enveloping material. This material overcomes the defects of the traditional rammed earth wall, effectively increases the load-bearing capacity of the wall, and is convenient for construction with low cost. Besides, the annual solar radiation of the base is sufficient, the summer rainy season rainfall is large, and the natural water resources outside the base are abundant. So, auxiliary facilities such as wind guide patio, solar thermal equipment, balcony without heat bridge, and rainwater collector are set to realize the optimization of the building form (Figure 6).

Figure 6. Configuration Optimization Technique Tests the Integration.

3.3. OUTDOOR SHADOW RANGE

Hefei city is located in north latitude N31°49' 21.30". Under sunny conditions, the intensity of solar radiation energy and ultraviolet radiation received on the surface of the earth is directly proportional to the sine of the solar altitude angle. The lower the latitude, the higher the altitude Angle of the sun, the more solar radiation energy the earth receives, and the higher the relative temperature. It can be seen from the shadow range that the sun's altitude Angle is the largest in a day at noon, is larger in summer than in winter, the maximum at the summer solstice and the minimum at the winter solstice. According to the outdoor shadow range of different period to set the Angle of solar photovoltaic system equipment and its distribution form, to get the best slope and orientation of slope roof (Figure 7).

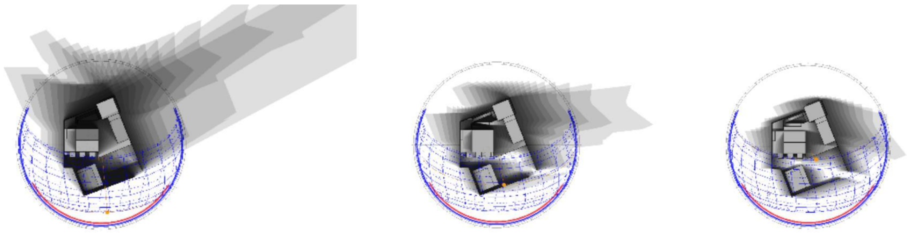


Figure 7. Shadow Range in Winter, Transition Season, and Summer.

3.4. INDOOR MICROCLIMATE

3.4.1. Natural lighting

Existing national norms, for different attributes of the building to the use of an indoor natural light area, lighting coefficient, and other aspects to make detailed provisions. Ecotect V5 software was used to simulate the daylight lighting situation of the design building, and daylight elements were divided into 11 visual levels from 0 to 5.5%. We can see from the graph, the main bedroom room is north-south facing, have a better daylighting condition. The partial function uses a room, like toilet, because to daylighting requirement is not high, did not design the daylighting effect of the large area. If there is a need for functional replacement in the later stage, the optimization design can be carried out by partially adjusting the size of the window (Figure 8).

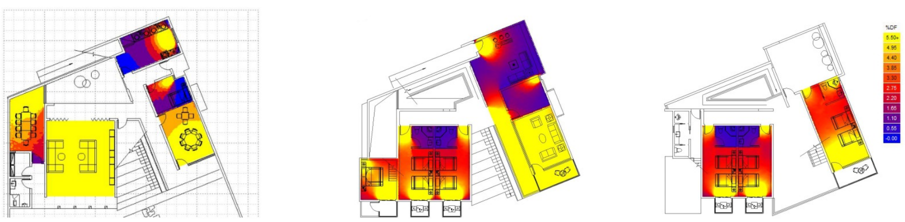


Figure 8. Daylighting Simulation Results on the First, Second and Third Floors.

3.4.2. Natural ventilation

The indoor ventilation effect of the building is a direct reflection of the optimization quality of the architectural form. The building wind environment is simulated with the help of PKPM-CFD green building software. It can be seen from Figure 9 that the building space on the first floor has a better ventilation environment due to the overhead ground floor and the installation of air Wells. The second-floor space is set south, north to the door, and the window only opens 1/3, the visible ventilated effect is not very good. As a contrast, the North-South Windows of the three floors with similar layout were all opened, and the bathroom was opened, and the ventilation effect was significantly improved. It can be seen that a good indoor wind environment can be controlled only with the help of opening Windows to guide natural ventilation (Figure 9).

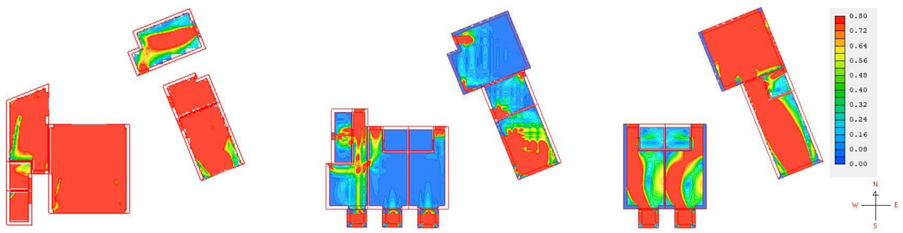


Figure 9. Plane Wind Speed Simulation Results on the First, Second and Third Floors.

3.4.3. The air age

The air age can reflect the time of air particles from entering the room to arriving at a certain point in the room, and it can also reflect the freshness of indoor air. Generally, it is used to measure the ventilation effect of the room, which is an important index for the evaluation of indoor air quality. Green building software PKPM was used to simulate the indoor environment of the building. It can be seen from Figure 10 that the blue area occupies 98% of the indoor space. Blue represents the state of zero air age. The younger the air age is, the fresher the air at this point is, the better the air quality is.

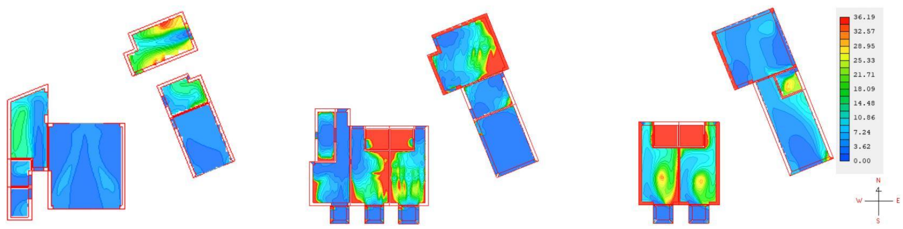


Figure 10. Plane Air Age Simulation Results of the First, Second, and Third Floors are Shown.

4. Discussions and conclusions

First of all, the paper extracts the architectural form characteristics of Baihua Village and finds the relevant elements of the microclimate environment. It is concluded that the most exposed to radiation is the winter-summer 172.5 ° east by south and east by south 100 ° according to Weather Tool software on a comprehensive interpretation of Baihua village building external environment. The simulation also revealed by enhancing dominant wind in summer and transition seasons, cut off winter prevailing winds to optimize construction form, and selects high melt palisade structure and building additional components to improve ventilation at night. Second, better solutions of different architectural forms are obtained by interpreting the results. With the help of software, the optimization strategy analysis of healthy building form in the early stage was carried out to obtain the optimal solution of building form. Third, according to the latest published healthy building standards, the simulation analysis and verification were carried out on the indoor microclimate environment such as wind, light, and heat after the optimization of the building form, to ensure the rationality of the optimized design of the building form. This paper presents the feasibility of comprehensive analysis methods and design strategies and illustrates the role of normative standards in analysis and verification. The research method of this paper has reference value in other rural areas of China and can be used to explore the combination of rural building form optimization and simulation software. In the following research, genetic algorithm (GA) and finite element analysis (FEA) methods will be considered to make the research methods and tools more scientific and reasonable, and provide a reference for other similar research.

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