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Climate Adaptability Analysis of Rural Housing in Guanzhong Region based on Climate Consultant

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Abstract

Energy conservation has been a hot issue contemporarily. Green building design needs to use computer technology to realize modeling and numerical simulation, which is an important method of building sustainable design. China has a vast territory, and the climate difference between different regions is significant, which also leads to the difference of building forms, structure and materials. This research analyzed the climate characteristics of Baoji through Climate consultant 6.0 software, and pointed out that Baoji is cold in winter and hot in summer, and its natural comfort time is short. Thus, it needs to be optimized through passive architectural design. At the same time, this research puts forward solutions to the climate adaptability of buildings, including expanding the southward window opening, introducing natural ventilation, improving the thermal insulation performance of the enclosure structure, and providing technical support for rural building energy conservation and rural revitalization in Guanzhong area.

Keywords

Climate Adaptability; Guanzhong Region; Building Energy Conservation.

1. Introduction

Energy reform is one of the most important factors restricting global economic development, which is the fundamental guarantee for national economic development and the circular development of various industrial links. In November 2020, the Proposal of the CPC Central Committee on Formulating the Fourteenth Five Year Plan for National Economic and Social Development and the Vision for the Year 2035 clearly stated that green production and lifestyle should be widely formed, and carbon emissions should be stable after reaching the peak. At the same time, the development of green buildings and the promotion of efficient use of energy have been explicitly incorporated into the national strategic plan. Building energy conservation is the key to achieve energy conservation and emission reduction. At present, among the existing buildings in China, high energy consumption buildings account for 99%. The building area of new buildings in the country every year reaches 1.6-2 billion cubic meters, and the high energy consumption buildings are about 95% [1]. According to the Research Report on Building Energy Consumption in China (2020) issued by China Building Energy Conservation

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Association, in 2018, the total energy consumption in the whole process of building in China was 2.147 billion TCE (Ton of Standard Coal Equivalent, per ton of standard coal equivalent), accounting for 46.5% of the total energy consumption in China; The total carbon emission of the whole process of construction in China is 4.93 billion t CO2, accounting for 51.3% of the national carbon emission. Among them, the carbon emissions during the production and operation of building materials accounted for 28.3% and 21.9% respectively [2]. China is a large agricultural country with a large rural population. As of 2019, the country's rural population is 552 million, accounting for 39.40% of the total population [3]. As one of the main buildings in China, the total amount of rural housing is huge. In 2017, China's total building area was about 59.1 billion m2, of which the rural residential building area was about 23.1 billion m2 [4]. Therefore, China's rural residential energy conservation and emission reduction is an important part of the implementation of China's carbon neutral and carbon peak action plan.

Climate is a key factor to be considered in rural planning and residential design. The regional characteristics of architecture are mainly reflected in the response of architecture itself to climate and environment. The climate adaptability of buildings refers to the adaptation of buildings to the local climate, including special building materials and structures, which can adapt to local conditions and provide a more comfortable living environment. In recent years, with the rapid development of computer technology, architectural design and related efficiency evaluation methods have been continuously optimized. Computer software simulation can greatly reduce the time and labor cost in the architectural design process, and improve the design efficiency [5]. At the same time, for existing buildings, computer simulation can timely find problems in building operation, realize quantitative analysis of problems, and propose solutions.

2. Research Area

Guanzhong region is located in the middle of Shaanxi Province, including Xi'an, Baoji, Xianyang, Weinan, Tongchuan and Yangling. With a total area of 55623 km2, it is a representative region in northwest China. Guanzhong area belongs to the second building climate zone of China's building climate division, the warm temperate semi humid continental monsoon climate, and the cold climate zone of building thermal climate division. This research takes Baoji as the research object, and analyzes the climate adaptability of representative rural housing. Baoji is located in the west of Guanzhong Plain, with a total area of 18117 km2. Statistics in 2021 show that the permanent population of Baoji city is 3.282 million, and the proportion of urban population is 58.74% [6].

3. Method and Data

This research adopted Climate Consultant 6.0 to analyze the climate adaptability of rural residential buildings at Baoji. This software is developed by UCLA Energy Design Tools Group. It can read hourly climate date for a whole year, and form visual analysis chart. In this research, the residential mode of building type and ASHRAE Standard 55 model was selected. The data is from the World Meteorological Organization(WMO)570160 Station, which is located at 34.35°N, 107.13°E. Besides, the elevation is 610 meters. It was downloaded from EnergyPlus, funded by U.S. Department of Energy's (DOE) Building Technologies Office (BTO), and managed by the National Renewable Energy Laboratory (NREL).

4. Results and Discussion

According to Figure 1, the annual temperature in Baoji city varies greatly. The monthly temperature curve is a typical inverted U shape, cold in winter and hot in summer. The coldest

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temperature in winter occurs in January, reaching minus 10 ℃, and the hottest temperature in summer occurs in July, reaching 37 ℃, with a temperature difference of 47 ℃. The annual average temperature is 14 ℃, and only 1/3 of the time is in a natural and comfortable state. Therefore, the control of temperature should be considered in architectural design.

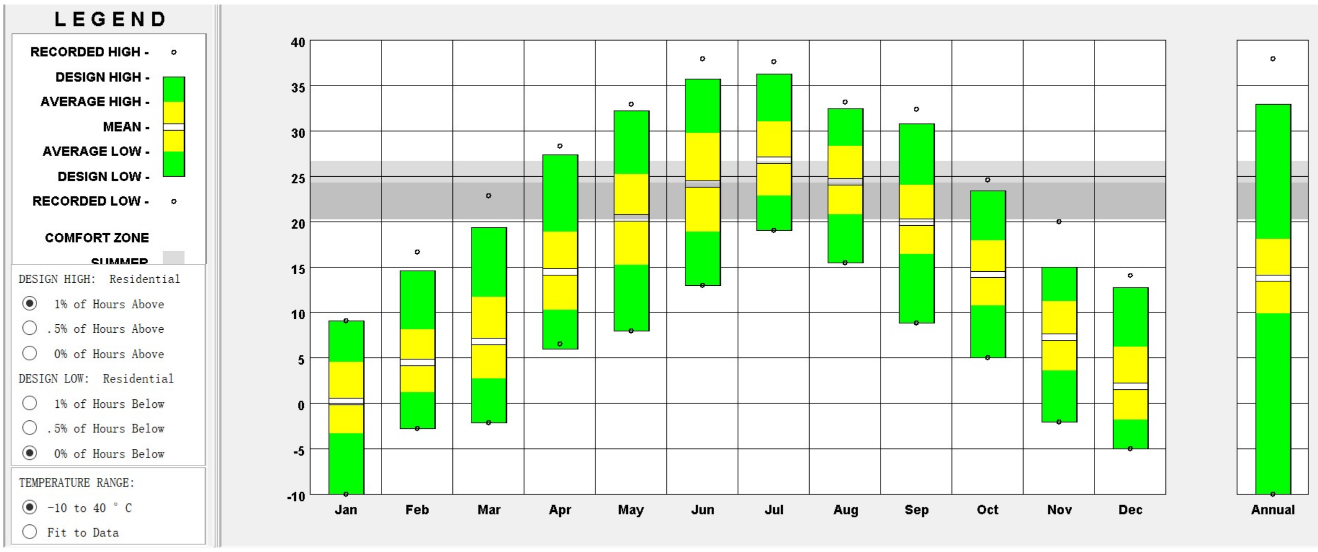

Figure 1. monthly and annual temperature range of Baoji

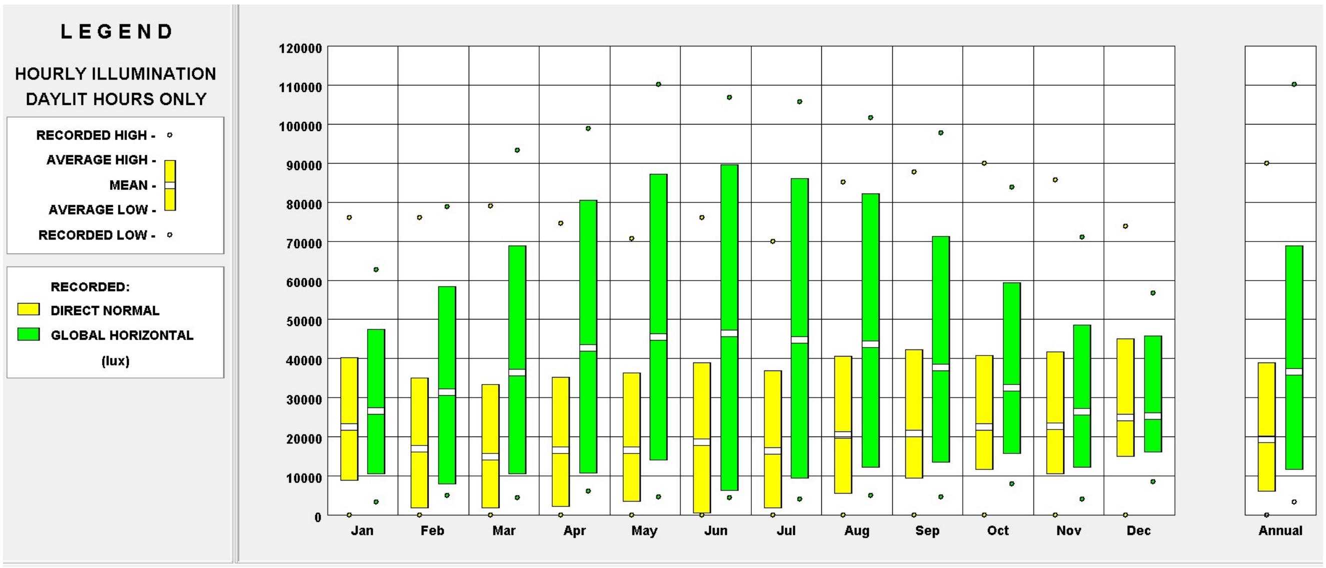

Figure 2. monthly and annual illumination range of Baoji

According to Figure 2, the monthly global horizontal irradiance (GHI) obviously changes while the direct normal irradiance (DNI) slightly changes. The annual average DNI is lower than 20000 lux. The GHI is close to 40000 lux, which is twice as much as DNI. The max value of GHI existed in June, in which the max mean is approximately 47000 lux and the max mean is about 90000 lux. Similarly, the change trend of GHI is inverted U-shaped. Generally, the illumination resource of Baoji is abundant.

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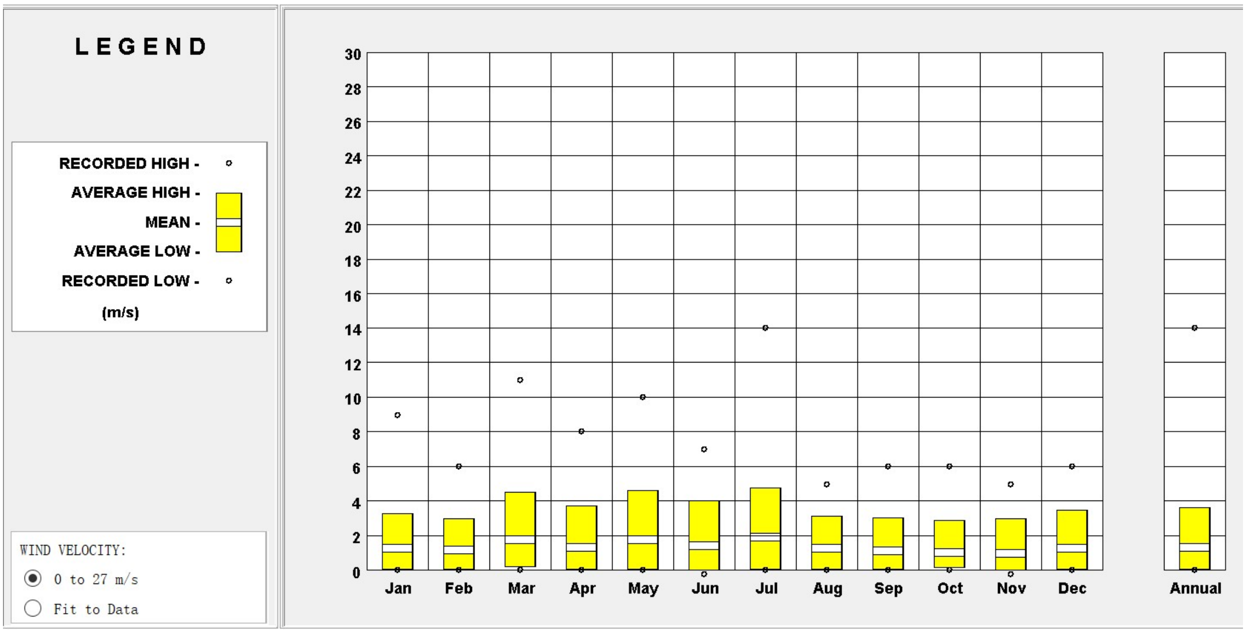

Figure 3. wind velocity range of Baoji

As shown in Figure 3, the monthly wind velocity averages are all lower than 2 m/s. Monthly changes rule is not obvious, indicating a random way. The wind velocity in March, May and July is relatively high, with its average high value larger than 4 m/s. The recorded high value happened in July, which is over 14 m/s.

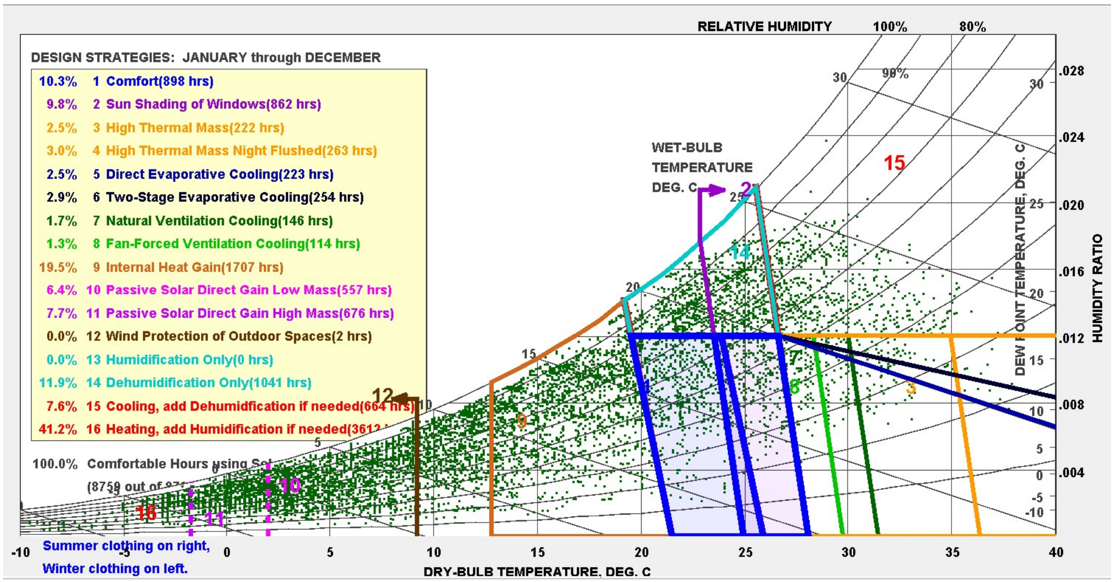

Figure 4. psychrometric chart of Baoji based on ASHRAE Standard 55

Eventually, the software formed a psychrometric chart base on climate statistics analysis of Baoji. It can be found that only 10.3% is regarded as comfort without any manual adjustments. The adjustment of indoor temperature and humidity is the key to improving human comfort. The comfort zone will increase 41.2% by heating and adding humidification if needed. Additionally, improving the capability of internal heat gain can increase comfort zone by 19.5%. Dehumidification in rainy period and usage of sun shading of windows should not be ignored.

Based on above analysis, Climate Consultant offers design strategies for the full year. First, for passive solar heating face most of the glass area south to maximize winter sun exposure, but

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design overhangs to fully shade in summer. This will maximize the use of natural light and solar radiation, which is prominent in the present residential buildings of Baoji (Figure 5). At the same time, providing double pane high performance glazing (Low-E) will increase passive solar gain. In fact, glazing with good light transmission and thermal insulation performance not only improve living comfort, but also saving energy and the cost. However, many people especially rural residents are not aware of the point. In summer, lower the indoor comfort temperature at night can reduce heating energy consumption. This strategy is important while easily be neglected. In recent years, the government has regulated the indoor air conditioning temperature of public buildings should higher than 26℃. A research indicates that 6% power consumption can be saved when the temperature is raised by 1 ℃ . Additionally, the introduction of natural ventilation can decrease indoor temperature and bring fresh air. It is a useful measure to improve human living environment.

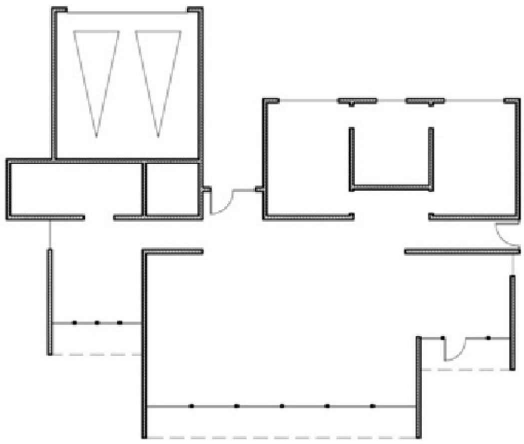

Figure 5. large area glazing at south to increase passive solar gain

5. Conclusion

At present, the rural areas of China stay at a rapid transformation period. The village in Guanzhong region is the representative of northwest rural areas. Passive architectural design method can make better use of natural resources and is an important method to save energy and improve the quality of human settlements in the green development stage. This study analyzed the climate characteristics of Baoji, proposed solutions to the climate adaptability of rural housing, and interpreted from the policy level. Rural buildings should pay more attention to the harmonious coexistence of human and nature, adhere to the sustainable development strategy, and make contributions to energy conservation and emission reduction.

Acknowledgments

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