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Thermal Environment Analysis and Thermal Comfort Evaluation of Huizhou Folk Dwelling Houses Guided by Auxiliary Interior Space Layout

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ABSTRACT

The Huizhou folk dwelling houses are important carriers of the traditional Huizhou cultural and architectural heritage in China. However, such dwelling houses have obvious shortcomings such as damp, dark, insufficient lighting, and inability to cope with cold weather. Existing studies on Huizhou folk dwelling houses haven't considered factors such high humidity or low temperature that can lead to poor indoor thermal environment in winter, and few have concerned about the theoretical analysis on the formation mechanism of the indoor thermal environment. Therefore, to fill in this research blank, this paper aims to give thermal environment analysis and thermal comfort evaluation on the Huizhou folk dwelling houses under the guidance of auxiliary interior space layout. At first, this paper took the first courtyard of the typical "series-courtyard" structure of the Huizhou folk dwelling houses as the subject, and analyzed the thermal environment of the second courtyard, including the outer wall, door, roof, patio, and ground, and the amount of heat transfer, the amount of radiant heat, and the amount of heat exchange of ventilation were tested. Then, based on the location selection, layout, and architectural morphology of the Huizhou folk dwelling houses, this paper studied the relationship between the thermal comfort of Huizhou folk dwelling houses and the wind and heat environment in winter, the specific test items were indoor temperature, comfort degree, wall temperature, and air tightness, and the test results could provide basis and direction for the renovation of indoor thermal environment of Huizhou folk dwelling houses. At last, this paper gave the analysis results of an actual example, and verified the effectiveness of the analysis and evaluation methods in this paper.

1. INTRODUCTION

The ancient town Huizhou is located in the center of Shexian County, a historical and cultural town in China, and it is the seat of the government of ancient Huizhou which has the history of more than a thousand years. Main buildings in Huizhou include the Renhe Mansion, the Deyue Mansion, the Tea House, the Huifeng Stone Archway, the Primary Mansion of Huiyuan Garden, the arcades, and the ancient theater, besides, there're also hundreds of antique-style commodity residential buildings gathered in it, and all of these buildings are important architectures that can reflect and show the culture of Huizhou [1-9].

The Huizhou folk dwelling houses are important carriers of the traditional cultural and architectural heritage of the ancient town Huizhou, they have this special enclosing structure showing the simple ecological design idea and the regional folk culture [10-14]. However, with the continuous improvement of national economy, these dwelling houses that built a long time ago can no longer meet people's requirements for modern living conditions [15-18]. The traditional Huizhou folk dwelling houses have obvious shortcomings such as damp, dark, insufficient lighting, and inability to cope with cold weather [19-20]. Therefore, studying the thermal environment of Huizhou folk dwelling houses located in Huangshan City and Jixi County of Anhui Province and in Wuyuan County of Jiangxi Province is conductive to improving the indoor comfort of Huizhou folk dwelling houses in winter, promoting their sustainable development in the future, and raising the living quality of local residents.

Zhong et al. [21] proposed that the Huizhou-style buildings can provide a comfortable indoor environment in summer, but the same effect couldn't be achieved in winter, so they tested the thermal comfort in Xingfu Hall of Wufu Club, a renovated Huizhou-style building, and found that due to slow wind speed and poor ventilation, the hall is stiflingly hot in summer. Huang and Wu [22] argued that a variety of climatic creating techniques have been accumulated during the long-term adaptation of Huizhou-style traditional dwellings to the local environment, and the natural ventilation creating technique is one of them; the authors combined three methods, theoretical analysis, simulation and actual measurement to study the natural ventilation creating technique of Huizhou-style buildings, and summarized the natural ventilation modes into four types: basic ventilation mode, reinforce of natural ventilation, passive cooling, and control strategies. On-site measurement of the natural ventilation performance showed that both the hall and the bedroom could meet the minimum number of air changes per hour. Huang et al. [23] believe that creating comfortable indoor environment is the main development direction of the current architecture based on energy conservation, which has triggered people's interest in the passive design strategies of traditional vernacular dwellings, so the authors conducted field measurement on a typical traditional vernacular dwelling in Huizhou to investigate the performance of the building, then they gave a one-year assessment on the building from four aspects of thermal environment, visual environment, acoustic environment, and thermal comfort, and the results suggest that the dwelling has a good indoor environment and thermal comfort in spring and autumn. Asadi et al. [24] studied the summer sections of Yazd traditional homes and their thermal behavior. Yazd is located in hot and arid regions of Iran, the researchers used the software EnergyPlus to investigate the thermal behavior of the target house. Then, to validate the developed model, they also carried out a field study with the help of a lascar electronics data logger, and the results reveal that the internal temperature of summer sections in all seasons has less fluctuation than the outdoor temperature.

After reviewing relevant literatures on the Huizhou folk dwelling houses, it's found that existing studies mostly focus on the parameter estimation of the wind and heat environment, few have considered the factors such high humidity or low temperature that can lead to poor indoor thermal environment in winter, and few of them have concerned about the theoretical analysis on the formation mechanism of the indoor thermal environment. Therefore, to fill in this research blank, this paper aims to give thermal environment analysis and thermal comfort evaluation on the Huizhou folk dwelling houses under the guidance of auxiliary interior space layout. In the second chapter, this paper took the first courtyard of the typical "series-courtyard" structure of the Huizhou folk dwelling houses as the subject, and analyzed the thermal environment of the second courtyard, including the outer wall, door, roof, patio, and ground; then, the amount of heat transfer, the amount of radiant heat, and the amount of heat exchange of ventilation were tested. In the third chapter, based on the location selection, layout, and architectural morphology of the Huizhou folk dwelling houses, this paper studied the relationship between the thermal comfort of Huizhou folk dwelling houses and the wind and heat environment in winter, the specific test items were indoor temperature, comfort degree, wall temperature, and air tightness, and the test results could provide basis and direction for the renovation of indoor thermal environment of Huizhou folk dwelling houses. At last, this paper gave the analysis results of an actual example, and verified the effectiveness of the analysis and evaluation methods in this paper.

2. THE WINTER THERMAL ENVIRONMENT OF HUIZHOU FOLK DWELLING HOUSES

The Huizhou folk dwelling houses (hereinafter referred to as Huizhou-style houses for short) are generally built with a large depth. After entering the front door, there is a front yard, a patio set in the middle, and there's a hall serving as the living room in the back yard. The hall is separated from the back yard by a middle door. In the back yard, there's also a hall and two bed rooms, behind which is a firewall set against the patio, and there're wing-rooms on both sides, and all these buildings are called the first courtyard. The structure of the second courtyard is still divided into two halls with one ridge, there're two patios, one in the front, one in the back, with a partition screen in the middle, and there're four bedrooms and two halls. The structure of the third, the fourth, and many more courtyards is the same, one courtyard is built after another, forming a series-courtyard structure. In this paper, the first courtyard of a typical Huizhou folk dwelling house is taken as the subject, the thermal environment of the second courtyard, including the outer wall, door, roof, patio, and ground, is analyzed, and the specific three test items are the amount of heat transfer, the amount of radiant heat, and the amount of heat exchange of ventilation.

According to the first law of thermodynamics, no matter what type of interior space layout is, the overall heat gain and heat loss of a Huizhou-style house is balanced. Assuming: W_{sun} represents the heat gain of the target house received from solar radiation; W_{in} represents the heat dissipation of internal heat sources; W_{ground} represents the heat transfer of the ground; W_{wind} represents the heat gain of ventilation; W_{ENV} represents the heat gain of heat transfer of the enclosing structure; ΔW_{total} represents the overall heat increment of the target house, then there is:

$$W_{sun}+W_{in}+W_{ground}+W_{wind}+W_{ENC}=\Delta W_{total} \quad (1)$$

For the target house, the W_{sun} (heat gain from solar radiation) is the amount of solar radiation entering the patios. Assuming: ST represents the opening area of the patio; SR_{PE} represents the solar radiation perpendicular to the surface of the transparent enclosing structure, then there is:

$$W_{sun}=ST\cdot SR_{PE} \quad (2)$$

Assuming: RT represents the area of heat transfer of the ground; γ represents the convective heat transfer coefficient; e_h represents the ground temperature; e_{air} represents the air temperature, then the calculation formula of W_{ground} (the overall heat transfer of the ground of the target house) is:

$$W_{ground}=RT\gamma\left(e_h-e_{air}\right) \quad (3)$$

The W_{wind} (overall heat gain of ventilation of the target house) is equivalent to the sum of the amount of heat consumption of cold air infiltrating into the room from the door and window cracks and the amount of heat exchange of the ventilation of patio openings. Assuming: D_t represents the specific heat of air at constant pressure; σ_{qm} represents the outdoor air density; SR represents the volume of infiltrated air; o_{qm} and o_m represent outdoor and indoor temperature; SQ represents the wind volume of the patio; SD represents the specific heat of air, then there is:

$$\begin{aligned}W_{wind}&=0.3D_t\sigma_{qm}SR\left(o_{qm}-o_m\right)\\&+SQ\sigma_{qm}SD\left(o_{qm}-o_m\right)\end{aligned} \quad (4)$$

The W_{ENV} (heat gain of heat transfer of the enclosing structure) is equivalent to the amount of heat transfer from outer wall, roof, and door, which are respectively represented by w_1, w_2, and w_3, then the value of W_{ENV} can be calculated by the following formula:

$$W_{ENV}=\Sigma\left(w_1+w_2+w_3\right) \quad (5)$$

Based on indoor air temperature and wall temperature, w_1 can be calculated by the indirect heat balance method, and w_2

and w_3 can be calculated by the steady state calculation method. Assuming: ϑ_R represents the area of roof or door, η represents the heat transfer coefficient of the roof and door, then there is:

$$w = \vartheta_R \eta (o_o - o_i) \tag{6}$$

To investigate the heat flow law of the heat balance process of the enclosing structure of the target house, the heat loss parameters need to be analyzed to get the optimal "more heat gain than heat loss" indoor thermal environment optimization scheme.

Assuming: $w_{\rho, sun}$ represents the amount of heat absorbed by the outer surface of the enclosing structure of the target house from solar radiation; w_{sl} represents the long-wave radiation heat dissipation of the outer surface; w_d represents the convective heat dissipation of the outer surface; w_l represents the amount of heat transferred into the inner side of the wall/roof, then, the heat balance equation of the outer surface of the enclosing structure of the target house is:

$$w_{\rho,sun} = w_{sk} + w_d + w_l \tag{7}$$

Assuming: ρ represents the absorption rate of the outer surface of the enclosing structure of the target house to the solar radiation; SR_e represents the solar radiation incident perpendicular to the outer surface; ϑ_W represents the outer surface area, then the formula for calculating $w_{\rho, sun}$ is:

$$w_{\rho,sun} = \rho \vartheta_W SR_e \tag{8}$$

To calculate the heat of solar radiation of the target house, this paper measured the intensity of solar radiation in five directions (east, south, west, north and vertical directions) at day and night. Assuming: MO_S represents the normal solar radiation (perpendicular to the house roof); β represents the angle between roof and ground plane, then the calculation formulas of $MO_{e, N}$ (normal solar radiation of the south roof) and $MO_{e, B}$ (normal solar radiation of the north roof) are:

$$MO_{e,N} = MO_S \cdot cos\beta + MO_N \cdot sin\beta \tag{9}$$

$$MO_{e,B} = MO_S \cdot cos\beta + MO_B \cdot sin\beta \tag{10}$$

For the target house, if there is a temperature difference between the ambient environment and the outer surface of its enclosing structure, there will be a radiant heat exchange w_{pk} between the two. Assuming: ϑ_E represents the radiation surface area; φ represents the surface emissivity; ε represents the Boltzmann constant; T_iE_i represents the outer surface temperature; E_{SK} represents the effective sky temperature; E_{GR} represents the ground temperature; A_{ir} and A_{ih} respectively represent the wall-to-sky angle coefficient and the wall-to-ground angle coefficient, then the calculation formula of radiant heat exchange w_{sk} is:

$$w_{sk} = \vartheta_E \cdot \phi \cdot \varepsilon \cdot \begin{bmatrix} A_{ir} \cdot \left(E_i^4 - E_{SK}^4 \right) \\ + A_{ih} \cdot \left(E_i^4 - E_{GR}^4 \right) \end{bmatrix} \tag{11}$$

Assuming: ϕ_{air} represents the emissivity of the air near the ground, then the effective sky temperature can be obtained according to the radiant heat balance relationship of the air near the ground and the atmospheric layer:

$$\begin{aligned} &\varepsilon E_{SK}^4 = W_{SK} = W_{air} = \varphi_{air} E_\beta^4 \\ &\Rightarrow E_{SK} = \sqrt[4]{\beta_{air}} E_\beta \end{aligned} \tag{12}$$

Assuming: w_d represents the amount of convective heat transfer of the outer wall; f represents the convective heat transfer coefficient; ϑ_{HR} represents the heat exchange area; e_w and e_{air} respectively represent the wall temperature and the air temperature near the wall, then, based on the Newton's cooling law, the calculation formula of w_d is:

$$w_d = f \vartheta_{HR} (t_w - t_{sk}) \tag{13}$$

Based on above analysis, the calculation formula of the amount of heat transferred into the inner side of the enclosing structure of the target house is:

$$w_l = w_{\rho,sun} - w_{sk} - w_d \tag{14}$$

Based on the analysis of heat balance process of the inner surface of the enclosing structure, the amount of heat gain transferred into the house from the wall could be attained; then, according to the heat balance process of the outer surface of the enclosing structure, the heat storage and release laws of the wall could be further studied. Assuming: q_{oi} represents the amount of heat transferred from the outer wall to the inner wall, which includes the convective heat transfer w_{cov} and the radiant heat exchange w_{rad}, then the heat balance equation is:

$$w_{oi} = w_{\text{cov}} + w_{rad} \tag{15}$$

Assuming: f represents the convective heat transfer coefficient of the inner surface of the enclosing structure of the target house; e_i represents the inner surface temperature; $e_{i\text{-}air}$ represents indoor air temperature, then w_{cov} is:

$$w_{\text{cov}} = f \vartheta_{HR} (e_i - e_{i-air}) \tag{16}$$

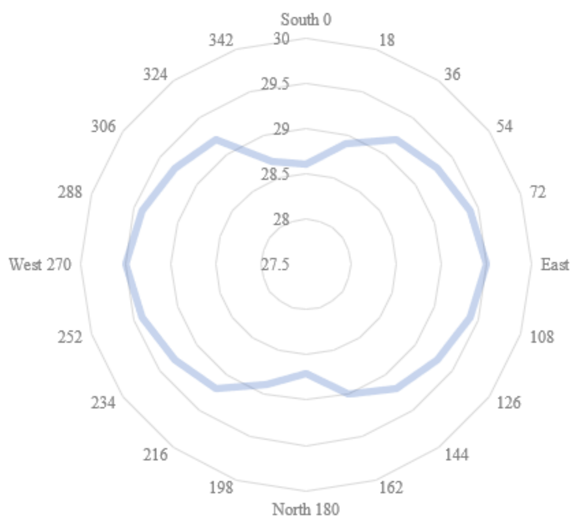

Figure 1. Simulation results of indoor air temperature of the north-facing Huizhou-style house

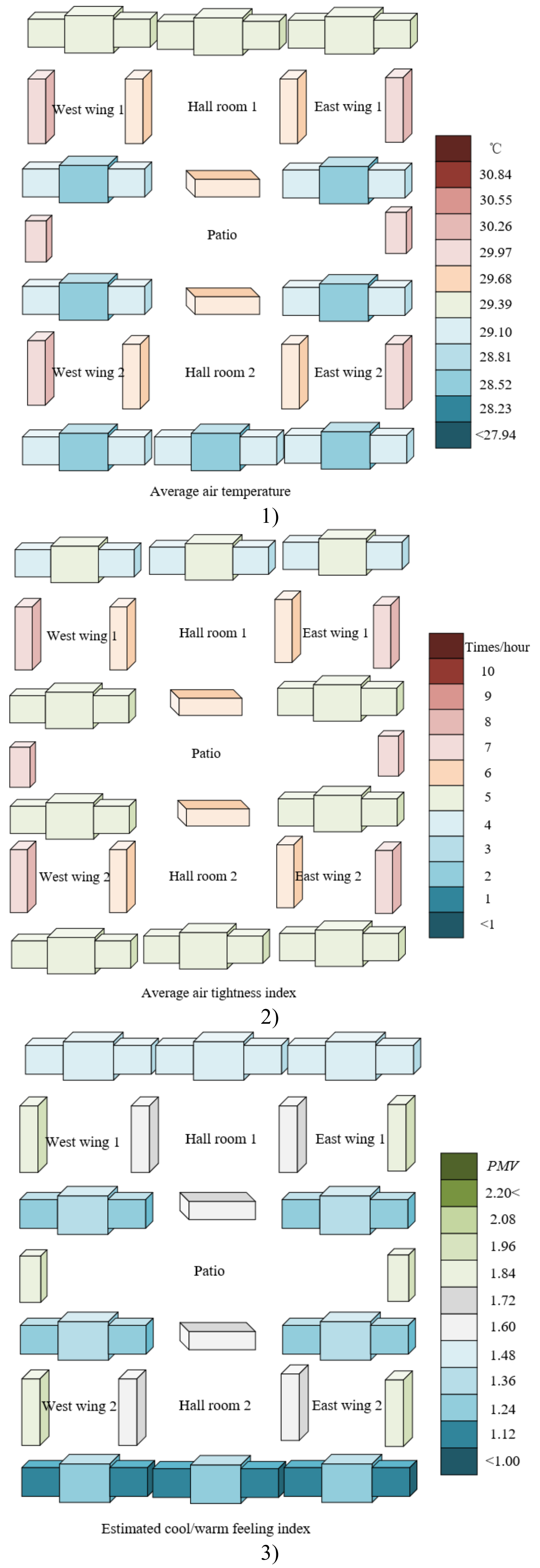

Figure 2. Spatial distribution of thermal comfort simulation data of Huizhou-style house

To this day, tens of thousands of ancient north-facing Huizhou-style dwelling houses have been retained, and this is the living habit of the ancient residents of Huizhou. Figure 1 shows the simulation results of indoor air temperature of north-facing Huizhou-style dwelling houses in summer. According to the figure, overall speaking, the indoor air temperature of a north-facing house is obviously lower and the fluctuation amplitude is smaller, so the indoor thermal environment is more comfortable.

However, for houses with different interior space layout patterns, there're certain differences in the radiant heat exchange of the inner surface of the enclosing structure. Assuming: A_{1i} represents the angular coefficient of the radiant surface to the i-th inner surface; E_1 represents the temperature of the inner wall of the enclosing structure; E_i represents the temperature of the i-th inner surface; for the target house, the radiant heat exchange between the indoor environment and the inner surface of its enclosing structure is equivalent to the radiant heat exchange between the inner surface of the enclosing structure and other walls in the interior space, then there is:

$$w_{rad} = \vartheta_{HR} \rho \varepsilon \sum_{i=1}^{m} \left[A_i \left(E_w^4 - E_i^4 \right) \right]$$
$$\sum_{i=1}^{m} A_i = 1 \tag{17}$$

This paper summarized the influencing factors of the indoor thermal environment of the target house into five items: W_{sun}, W_{in}, W_{ground}, W_{wind}, and W_{ENV}; wherein W_{sun}, W_{in}, W_{ground} are heat gain items of the interior space; W_{wind} and W_{ENV} are heat loss items of the interior space. Assuming: M_i represents the heat transfer contribution rate of each balancing item; W_i represents the heat transfer item affecting the indoor thermal environment; $\sum|W_j|$ represents the sum of the size of each heat transfer item, then the calculation formula of the heat transfer contribution rate of each item is:

$$M_i = \frac{W_i}{\sum\left|W_j\right|} \times 100\% \tag{18}$$

3. MEASUREMENT AND ANALYSIS OF INDOOR THERMAL ENVIRONMENT

Based on the location selection, layout, and architectural morphology of the Huizhou-style house, this paper studied the relationship between the thermal comfort of Huizhou-style house and the wind and heat environment in winter, the specific test items were indoor temperature, comfort degree, wall temperature, and air tightness, and the test results could provide basis and direction for the renovation of indoor thermal environment of Huizhou-style houses.

This paper constructed a thermal comfort evaluation model for the interior space of the first and second courtyards of a typical Huizhou-style house. Figure 2 shows the distribution of the average air temperature, average ventilation times, and estimated cool/warm feeling index in the interior space of the target house. The specific calculation methods are given below. Assuming: ξ_m represents the most comfortable neutral temperature at which the cool/warm feeling of human body is the best; ξ_n represents the average outdoor temperature, then there is:

$$\xi_m = 10.092 + 0.607\xi_n \tag{19}$$

Assuming: χ represents the self-adaptive coefficient; SI represents the average cool/warm feeling index; since the target house in this paper has a natural ventilation environment, then the expression of the average cool/warm feeling index TSI that measures the comfort degree of human body is:

$$TSI = \frac{SI}{1 + \chi \cdot SI} \tag{20}$$

In the rooms of a Huizhou-style house, the radiant heat dissipation intensity of human body is greatly affected by the indoor wall temperature, defining the radiant heat exchange between indoor wall temperature and human body is the average radiant temperature κ_s^*, assuming $\kappa_{pr}(A, B, C, D, E, F)$ represents the wall temperature in different directions, and A, B, C, D, E, F respectively represent the six directions of up, down, left, right, front, and back, then κ_s^* can be calculated by the following formula:

$$\kappa_s^* = \begin{cases} 0.18\left[\kappa_{pr}(A) + \kappa_{pr}(B)\right] \\ +0.22\left[\kappa_{pr}(C) + \kappa_{pr}(D)\right] \end{cases} \\ +0.30\left[\kappa_{pr}(E) + \kappa_{pr}(F)\right]\Big\} \\ \div\left[2\left(0.18 + 0.22 + 0.30\right)\right] \tag{21}$$

The thermal comfort degree of human body is greatly affected by the radiation and convection modes between the human body and the environment. Defining: the weighted sum of ambient air temperature and average radiation temperature is the operating temperature κ_p, assuming f_s represents the radiant heat exchange coefficient; f_d represents the convective heat exchange coefficient; κ_x represents the air temperature, then κ_p can be calculated by the following formula:

$$\kappa_p = \frac{f_s \kappa_s^* + f_d \kappa_x}{f_s + f_d} \tag{22}$$

To quantify the air tightness of the target house, this paper calculated the indoor ventilation times of the targe house, assuming N represents the indoor air volume; N_S represents the indoor volume; N_i represents the total volume of indoor objects, then the indoor air volume is:

$$N = N_t - N_i \tag{23}$$

Assuming: D_0 represents the carbon dioxide concentration at the initial moment; D_1 represents the carbon dioxide concentration after t hours; D_x represents the carbon dioxide concentration in the air; then N_x the air volume naturally infiltrated into the room within e hours can be calculated by the following formula:

$$N_x = \frac{1}{e} N \times ln \frac{D_0 - D_x}{D_1 - D_x} \tag{24}$$

Then, for the target house under natural conditions, the number of indoor ventilation times RV can be calculated by the following formula:

$$RV = \frac{N_x}{N} \tag{25}$$

4. EXPERIMENTAL RESULTS AND ANALYSIS

By sorting out the parameters of the spatial layout factors of Huizhou-type house, this paper built a corresponding Multi-Linear Regression (MLR) model in SPSS to compare the different effects of each factor on the thermal environment and thermal comfort of Huizhou-type house. Table 1 gives the parameters of each spatial layout factor.

The results of MLR analysis revealed that, the relationships between four spatial layout factors (height ratio, orientation, material of the enclosing structure, and patio space ratio) and the thermal environment and thermal comfort degree of the target house were more significant. Therefore, by optimizing the height ratio, orientation, material of the enclosing structure, and patio space ratio of the Huizhou-style house, we could achieve the purpose of improving the thermal environment and comfort of the house.

Table 2 summarizes the thermal environment conditions of measurement points in each space. There're certain differences in the activity density of different spaces in the target house, the setting of patios enables more sunlight to come inside the house so that the rooms would be warmer; besides, the air flow and visual viewability of the hall rooms and wing rooms would be better. In terms of the microclimate environment of the target house, during transition seasons, the average radiant temperature of different spaces was between 23.5°C and 29.5°C, the average temperature was about 23°C, the average cool/warm feeling index was within 1.15-1.95, and the number of ventilation times was more than 5 times per hour.

Table 1. Parameter values of each spatial layout factor

	Unstandardized coefficient		Standardized coefficient		Collinearity statistics		
	B	**Standard error**	***Beta***	***t***	**Significance**	**Tolerance**	***VIF***
Constant	1.625*E*-15	0.126	/	0.024	1.269	/	/
Height ratio	0	0.348	0.859	2.306	0.036	0.057	13.629
Shape coefficient of the enclosing structure	0.847	0.426	-0.647	-1.928	0.169	0.092	18.327
Patio space ratio	0.284	0.284	0.692	2.847	0.058	0.128	5.374
Geographical location	0.617	0.291	0.348	1.362	0.096	0.294	3.528
Orientation	0.025	0.237	0.769	4.154	0.029	0.429	2.518
Material of the enclosing structure	0.793	0.184	-0.237	-0.526	0.685	0.017	16.325
Type of the courtyard	-0.259	0.116	-0.169	-0.896	0.437	0.325	2.174
Number of doors and windows	-0.162	0.295	-0.157	-0.637	0.518	0.296	3.928
Vegetation coverage	0.158	0.237	0.192	0.589	0.596	0.142	5.176

Table 2. Thermal environment conditions of measurement points in each space

Measurement point	Space type		Average radiant temperature	Average air Temperature	Average cool/warm feeling index	Number of ventilation times
1	Hall room 1	Mean	28.6	22.9	1.71	5
		Maximum	39.2	23.4	1.23	7
		Minimum	15.7	11.7	1.48	7
2	Hall room 2	Mean	31.2	22.6	1.95	8
		Maximum	45.9	28.5	1.17	8
		Minimum	22.6	12.4	1.71	6
3	East wing room 1	Mean	26.9	21.9	1.16	6
		Maximum	37.4	28.5	1.84	7
		Minimum	16.8	14.7	1.62	5
4	East wing room 2	Mean	29.4	26.3	1.19	6
		Maximum	44.5	28.9	1.52	7
		Minimum	19.7	15.2	1.37	5
5	West wing room 1	Mean	23.9	22.7	1.21	7
		Maximum	38.5	28.9	1.56	5
		Minimum	15.2	16.1	1.81	6
6	West wing room 2	Mean	27.4	25.7	1.59	6
		Maximum	35.8	28.1	1.53	7
		Minimum	17.2	16.9	1.67	8

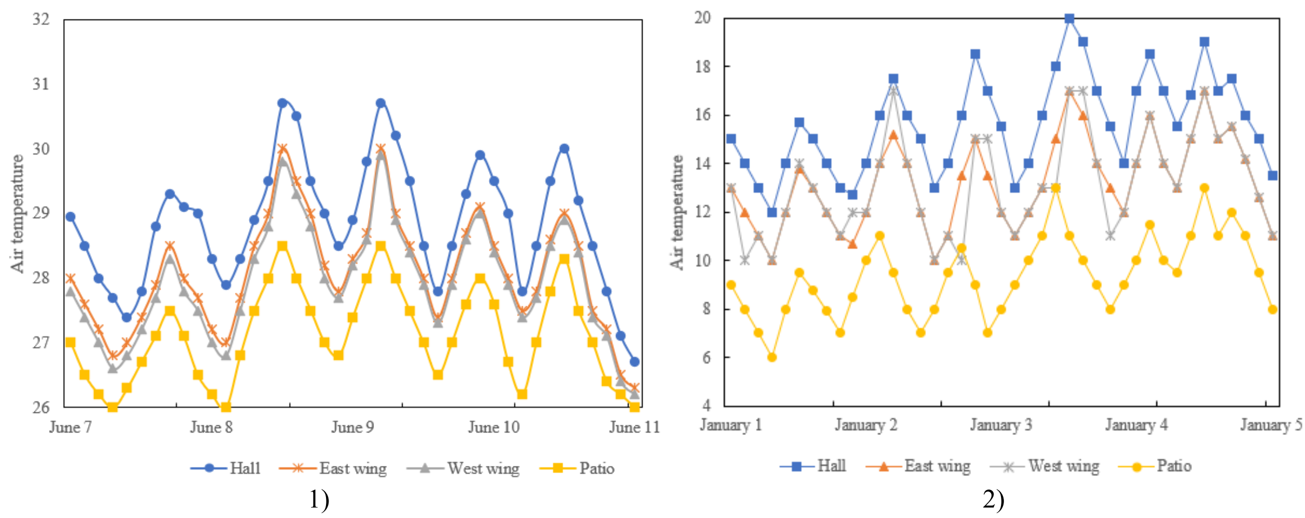

Figure 3. Simulation results of air temperature in different spaces of Huizhou-style house during different seasons

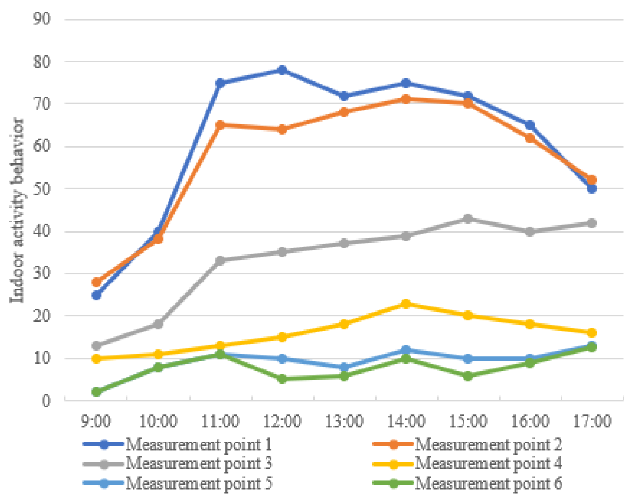

Figure 4. Distribution of the total amount and time of activity behaviors in different spaces of the target house

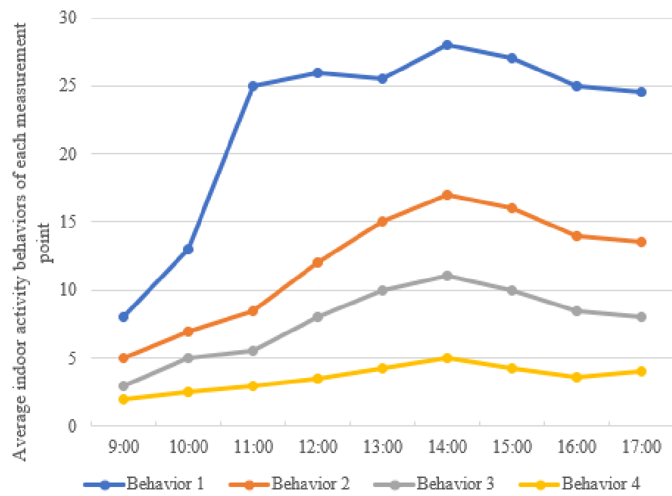

Figure 5. Distribution features of the total amount and time of different indoor activity behaviors

Figure 3 shows the simulation results of air temperature in different spaces of a Huizhou-style house during different seasons. According to the figure, there're certain differences in the air temperature in the different spaces of the target house during different seasons, but for the four measurement points set in the hall, east wing, west wing, and patio, the fluctuation of temperature was relatively small. The average air temperature of the patio was the lowest; due to less doors and windows, the average air temperature of the hall was the highest.

Figure 4 shows the distribution of the total amount and time of activity behaviors in different spaces of the Huizhou-style house, and Figure 5 shows the distribution of the total amount and time of different indoor activity behaviors. As can be known from the figures, with the passing of time, the total amount of activity behaviors in the target house showed a trend of increasing first and decreasing later, and there wasn't much difference for different spaces. Measurement points 1 and 2 were set in the space of hall rooms, so the amount of various work and leisure activities was the highest, so a higher thermal comfort degree during day time is required; measurement points 3, 4,5 and 6 were set in the space of wing rooms, so the amount of indoor activities during day time was lower, and a higher thermal comfort degree during night time is required.

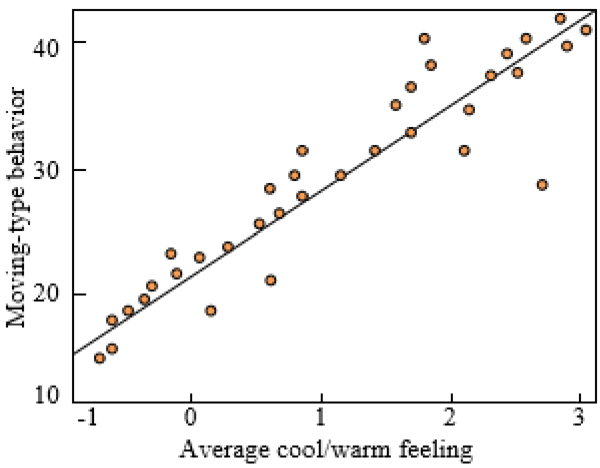

Figure 6. Regression of moving-type behavior and average cool/warm feeling index

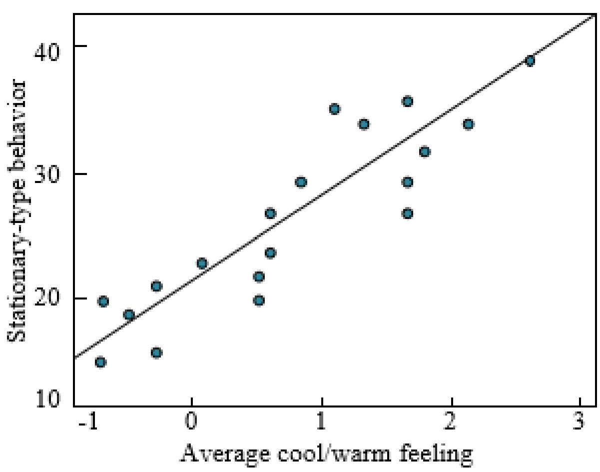

Figure 7. Regression of stationary-type behavior and average cool/warm feeling index

Referring to the existing research results, for the positions where the thermal comfort degree was not that satisfactory, at first, regression was performed on the indoor activity behaviors of different types and the average cool/warm index; then, the average cool/warm index was divided into 10 grades, and the assumed values of indexes with unsatisfactory thermal comfort degree were selected and substituted into the regression formulas of different-type indoor activity behaviors, in this way, the corresponding thermal stress range of the different-type indoor activity behaviors in the Huizhou-style house could be attained. As seen from the figure, in terms of the ability to accept strong hot stress, there're large differences between different-type indoor activity behaviors. Compared with stationary-type behaviors, the ability of moving-type behaviors to accept strong hot stress is weaker, while their ability to accept strong cold stress is better (See Figures 6 and 7).

5. CONCLUSION

This paper studied the thermal environment analysis and thermal comfort evaluation of Huizhou folk dwelling houses based on auxiliary interior space layout. It took the first courtyard of the target house as the subject and analyzed the thermal environment of the second courtyard including the outer wall, door, roof, and patio, and the specific test items included the amount of heat transfer, the amount of radiant heat, and the amount of heat exchange of ventilation. Then, based on the location selection, layout, and architectural morphology of the target house, this paper studied the relationship between the thermal comfort of the target house and the wind and heat environment in winter, the specific test items were indoor temperature, comfort degree, wall temperature, and air tightness, and the test results provided a basis and direction for the renovation of indoor thermal environment of the target house. After that, the results of MLR analysis revealed that the relationships between four spatial layout factors (height ratio, orientation, material of the enclosing structure, and patio space ratio) and the thermal environment and thermal comfort of the target house were more significant. In the experimental part, this also summarized the thermal environment conditions of measurement points in each space of the target house, gave the simulation results of air temperature in different spaces of the target house during different seasons, and showed the distribution of the total amount and time of activity behaviors in different spaces of the target house and the distribution of the total amount and time of different indoor activity behaviors. At last, for the positions where the thermal comfort degree was not that satisfactory, regression was performed on the indoor activity behaviors of different types and the average cool/warm index, and the corresponding analysis conclusions were attained.

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