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ANALYSIS OF RESIDENTIAL ENVIRONMENT AND ENERGY USE IN RURAL AREAS IN HOT SUMMER AND COLD WINTER REGION OF CHINA-A CASE STUDY OF HANGZHOU

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ABSTRACT: With the gradual development of the new rural construction, and the continuous improvement of the rural per capita living space, sustainable development of the rural living environment is becoming an increasingly urgent task. This paper selected three different terrain villages in the rural area of Hangzhou as a study object, which located in the Middle and lower reaches of Yangtze River. Firstly, the investigation, collection and analysis on the building status, energy data and residents' subjective feeling of the three villages had been done through basic research and sampling questionnaire. Secondly, it selected two typical housing in each village, separately carried on the measurement of the building physical environment and computer quantitative simulation of the ventilation, lighting, and energy consumption, along with the comprehensive evaluation with the simulation results. Finally, the major existing problems of the living environment in the rural areas have been found, according to which some operable implementation strategy and policy Suggestions have been put forward.

Keywords: Rural residential environment, subjective evaluation, energy use simulation

BACKGROUND

Rural reform and construction is not only a historical stage of the transformation process from a traditional society to a modern one which many countries or regions of the world must be experienced, but also an important strategic stage that need to be implemented. Rural living environment as an important carrier of rural production and living activities, plays an important role in supporting the construction of new rural.

Currently, there are 166,700 km^2 non-agricultural lands for construction, and more than 3.6 million villages in China. Up to 2011, the rural per capita living area is 34.1 m^2, and the rural residential gross floor area is 230 million m^2, accounting for more than 53% of the total national residential gross floor area (China Statistical Yearbook 2011). However, majority of rural housing has no professional design. The quality of living environment such as thermal environment, light environment and sound environment is still very low, and the vast majority of them are high-energy consumers (Yao et al. 2012). Therefore, improving the quality of living environment, promoting resource-saving and environment-friendly planning mode, using energy conservation technologies, and keeping sustainable development are becoming much more urgent in the rural area than in the cities.

Study of rural living environment abroad began in the late 19^{th} century to the early 20^{th} century. The urbanization leading to the deterioration of the relationship of man and nature, along with the severely affected urban living environment and social development, gave rise to the concern with rural living environment. In 1930, Mumford, an American scholar pointed out that "the urban and rural areas is the same thing; cities, villages and their dependent areas are inseparable parts in urban and rural planning", leading people's vision from city to rural (Lewis 1989). In the 1950s, Sadie Elias founded the science of human settlements, whose "research object including all human settlements, villages, towns, and cities". According to the different nature, the Dow divided human settlements into two patterns-rural and city, and pointed out the basic features of the rural one (Doxiadis 1975). From the late 1950s, Britain, Germany and other countries carried out a large-scale of rural planning, and enhanced the function of the center village. Since the 1970s, Germany did long-term and fruitful exploration in the construction of the eco-village, Bram Sandwich village in the city of Hamburg as a typical one (Yuan 2002). Japan, South Korea in the 1960s and 1970s, carried out "rural Readiness career" and "New Village Movement", which took the rural living environment governance as core content. And through the implementation of village infrastructure and environmental

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governance, they had greatly improved the production and the living condition of farmers and promoted agriculture and rural development (Fang and Liu 2008). In recent years, some Western countries are committed to the research and development of new rural housing. In order to adapt to the restrictions of the new residential land and speed up the progress of the residential construction, the construction companies in Austria , Germany , Switzerland and other countries, specially manufactured sets precast for the construction of the rural standard house, which can complete a rural house in a very short time. Germany has dozens of construction companies engaged in the production of complete sets precast units of rural house and did the installation and construction in various regions of the country (Lu 2004).

In China, Liangyong Wu and other scholars have put forward their own theories and ideas on the residential environment (Wu 1996, 1997 and 2001). Nevertheless the research of living environment and building energy use in rural areas is much weaker, and the only study overwhelmingly concentrated on the western and northern parts of China. Researches related with rural living environment are as follows: the rural living environment sustainable development countermeasures for the waste of land, serious pollution and other problem in rural areas is explored from the urban-rural relations, population and consumption, ecological environment, energy use, community building and use cycle (Zhao 2001). By analyzing the connotation and characteristics, a small town living environment evaluation system has been built, taking three small towns in the suburbs of Shanghai as a case study (Ning et al. 2002). For our new rural construction status and problems, Hu et al. (2006) put forward a set of rural people living environment optimization system. Tang and Guo (2009) studied the residential environment and the sustainable development strategy in western region of China. Improvement and innovation of rural living environment of the central region lies in tradition and reality docking (Huang 2011). Researches related with rural housing energy consumption are as follows: Simulation and analysis on building energy consumption of 12 rural energy-efficient houses in the cold area in China reveal the status of the rural building energy consumption in existing houses in the north part of China (Li et al. 2011) Envelope thermal performance test data detected before and after reconstruction of rural residential energy saving building in Beijing has been studied in order to compare energy saving effect of different reconstruction programs (Xu et al. 2011). Analysis of rural residential CO_2 emissions in China has been provided based on diverse accounting methods, by employing the geographic information system (GIS) to map emissions of each province (Liu et al. 2012). With the development of China's rural construction, certain practice has been done in many rural villages. Like Ganzhou in Jiangxi province, various units of residential for farmers have been designed for free, according to high, medium and low three gears. New residential complement each other, side by side with the natural landscape. And in Yuliang Village, the original appearance of the natural scenery has been retained in rural construction, building an ecological new village with harmonious coexistence of man and nature (Huang 2007).

Earlier research related mainly has the following problems. Firstly, the natural and geographical conditions in rural area in different regions of China are quite different, as well as the socio-economic development level, village construction level and urbanization level. Nevertheless, existing rural environment research mainly focuses on the western and northern parts of China, with the main energy use characteristics of heating, while the research related to the hot summer and cold winter region, as one of the most important section of China, rarely appears. While this region involved 14 provinces and cities, and climatic characteristics of the hot summer and cold winter made the energy use and thermal comfort condition more complex. Therefore the study of this region is very necessary. Secondly, in the same district, residential environment has some differences with different geographic characteristics and landform, which the earlier studies have not concerned. Thirdly, existing rural living environment research primarily studies based on subjective evaluation analysis (Ning et al. 2002; Hu et al. 2006) or objective computer simulation results (Li et al. 2011; Xu et al. 2011), few researches can combine both subjective and objective methods yet.

METHODOLOGY

Introduction

Middle and lower reaches of Yangtze River is located in east China, belonging to subtropical monsoon climate, with a hot summer and cold winter. The development level of economy and rural village construction there is at the leading position in the country. Thus with middle and lower reaches of Yangtze River rural living environment as the

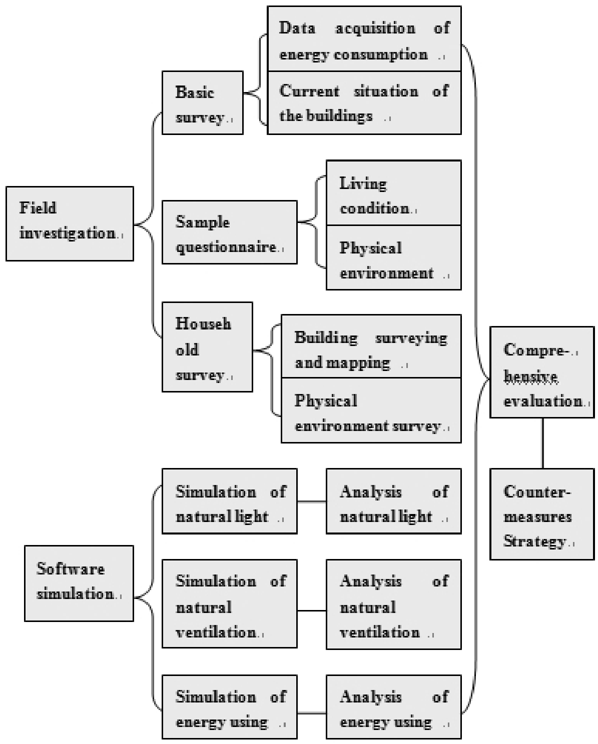

Fig. 1 Methodology diagram

research object, has an important guiding meaning and reference on rural village construction of eastern China and even the whole country. In this paper, we selected the typical city Hangzhou, which is one of the capital cities in the middle and lower Yangtze River region, as the research object. And through site survey and computer simulation of three different topography of typical village around Hangzhou, the rural residential environment and the real situation of building energy use there have been studied.

As shown in Fig.1, survey divided into three parts, basic investigation, sampling questionnaire and typical household measurement. First, we selected three representative villages around Hangzhou, classified and carried out the building energy consumption research and data acquisition; second, in each village 50 doors sampling survey has been done, which related to the rural living conditions and building physical environment; then we chose two typical houses, did the building measurement and the physical environment test. In the computer simulation step, using computer software we simulate the indoor natural lighting, natural ventilation and energy using of typical units in rural areas. Finally, through the comprehensive comparative analysis of the survey data and simulation results, we got the evaluation results of the rural living environment in Hangzhou. This study provides references for Hangzhou new rural living environment planning, as well as the design methods for rural buildings and the first hand information for future research on the province level and even the country level.

Table 1 Village classification

Village	Pu Er Village	Bao An Village	Long Quan Village
Terrain	Plain	Hills	Waterside
Popolation	1555	1956	1923
Number of households	441	650	533
Area(km^2)	1.5	3	6

Current Survey

Basic facts

Depending on different terrain, a plain village, a hilly village and a waterside village are selected as the study object for comparison and analysis of living environment and energy use as shown in Table 1. Three research sites are in the same climate which is cold and wet in winter, hot and humid in rainy summer, and both affected by the monsoon. The average highest temperature in summer is 32.9º C, and the average lowest temperature in winter is 1.4º C.

Questionnaire survey

In July 2008, 450 households had been investigated in three villages, Pu Er, Bao An and Long Quan. We distributed 450 questionnaires (150 questionnaires each) by random with the sample rate of 34% in Pu Er Village, 23% in Bao An Village and 28% in Long Quan Village, and withdrew 412 valid ones with a efficient rate of 91.7%.

The construction of rural building, the surrounding environment, and the terrain had been taken into account in the questionnaires which mostly focused on rural energy use. The contents of the questionnaire related to the rural house status, energy use, indoor comfort and farmers' awareness of energy conservation. Through interview with rural residents, which included the survey questionnaires, the rural residents' rough thoughts and feelings were abstracted efficiently. The results of the survey are shown as follows:

(a) Age structure

Table 2 shows the survey results of the age structure which indicates that in three research villages at least nearly half of the households have elderly people , with a highest proportion of 88% in Bao An village, and 48% in the other two village. In addition, there is a high percentage of households with underage in Pu Er Village and Bao An Village, which has a proportion of more than 60%. And Bao An Village has a maximum of households which has three generations living together, accounting for half.

In summary, when designing and renovating the rural residence, we should choose different units, layers and residential area based on different age structures of village

Table 2 Age structure statistic

Age Structure of the Households			
Pu Er	10%	36%	38%
Bao An	38%	12%	50%
Long Quan	28%	16%	20%

Table 3 Educational level

Educational level	primary	Junior middle school	Senior middle school	College and above
Pu Er	10%	26%	54%	10%
Bao An	2%	48%	28%	22%
Long Quan	6%	28%	36%	32%

residents. Most of the families have to consider rooms of children and the elderly with enough sunshine.

(b) Educational level

It is indicated in Table 3 that, Long Quan Village has a highest educational level with 32% people got college and above education; however the main force of the residents' educational level is the middle school, accounting for 64% to 80%. So when doing the public participation in the planning and design as well as the energy-saving awareness education, the residents understanding ability should be considered seriously.

Table 4 Annual household incomes

Annual household income	<18 (1000 CNY)	18-24 (1000 CNY)	24-30 (1000 CNY)	30-36 (1000 CNY)	>36 (1000CNY)
Pu Er Village	10%	12%	16%	12%	50%
Bao An Village	42%	14%	10%	12%	22%
Long Quan Village	36%	12%	12%	6%	34%

(c) Annual average income

Table 4 displays the annual household income in three villages. If we divided the income into three levels, high, middle and low, by 18,000 CNY and 36,000 CNY, Bao An Village and Long Quan Village have a similar income situation which don't have a greatly different in the proportion of high-income, middle-income, low-income. Pu Er Village is more affluent than the other two villages, with more than 50% of household having an annual income above 36,000. Therefore, when doing the rural housing energy saving design the economic conditions should be considered, we'd better select the energy-saving technologies appropriate to the local rural building characteristics, mainly the passive technologies to reduce the cost.

(d) Energy structure

The survey results (Tables 5 and 6) show that the main fuel of the farmers in Pu Er villages and Long Quan Village is gas, while in the BaoAn village is wood, which is related to its hilly environment surrounded by forest. Owned ratio of air-conditioning in three villages is related to the affluent

Table 5 Energy structure

Energy structure		Pu Er Village	Bao An Village	Long Quan Village
Fuel		100% gas	100% wood	92% gas
Use of air conditioning	Owned ratio	90%	40%	38%
	Set temperature in summer (°C)	25.43	28	23.25
	Use of time (h/day)	3.58	At night	4.94
	Winter	No air conditioning	No air conditioning	No air conditioning
Owned ratio of energy saving lamps		74%	74%	80%
Annual power consumption (kWh/ household)		1523	933	944
Annual water consumption (Tons/ household)		209	164	224
Annual fuel consumption		39.2m^3(liquefied gas) / household	2583kg(Wood) / household	36m^3 (liquefied gas)/ household
Total energy consumption (CNY/ household)		2072	961	1441

Table 6 The form of hot water energy

Energy form	Solar	Gas	Electricity	Firewood
Pu Er	54%	28%	15%	3%
Bao An	58%	0%	10%	32%
Long Quan	62%	36%	0%	2%

level. The Pu Er village which has a highest average annual income has a highest owned ratio of 90%, while the other two villages have a much lower one. However, the use of air-conditioning in three villages is very little even in the Pu Er village. Especially in winter, no one use the air-conditioning according to the survey data. People just put on more clothes to against the cold. In addition, energy-saving lamps and solar water has been quite popular in the local rural areas. The penetration rate of former is 74% and the penetration rate of latter is 54%. However, the use of other new energy is almost no.

(e) Residential form

The survey results (Table 7) show that most of houses in the Pu Er and Bao An Village are Three-storey buildings with an average building area of 230m^2 to 250m^2, while most of the ones in Long Quan Village's are One-storey buildings with an average building area of 150m^2. About the construction year, 32% of the houses in Pu Er Village were built in the 1990s, other decades are slightly less; 56%of the houses in Bao An Village were built after 2000; And most of the houses in Long Quan Village were built in the 1980s and 1990s, 48% and 38% respectively. And the envelope structure of the buildings in three villages is basically similar, which is mainly 240 solid brick wall with no insulation measures of the walls, as well as single glass and wooden or aluminum alloy frame with no insulation measures of the windows. In addition external shading is relatively few, only 18% of households in Pu Er village have shade measures, and the other two villages did not have such measures.

(f) Thermal comfort survey

According to the PMV-PPD evaluation method, we did the subjective questionnaire survey on the indoor thermal comfort in summer and winter. The results are shown in Table 8.

The results shows that both in summer and winter, less than a half of the residents think the indoor thermal environment is comfortable. In winter this rate is higher than in summer, which is above 35%; half people or slightly less than a half thinks that the indoor environment is slightly cold, and very few people believed that it is cold or very cold, with the rate of three villages all below 12%. In summer, 18% to 26% people think the indoor environment is hot or very hot, others think it is slightly hot or comfortable. Pu Er Village has a lowest comfortable rate of 20%, while Bao An Village and Long Quan Village have a higher rate of 36% and 38%.

This may be related to their different geography and climate. Bao An Village is located in the mountains which has the valley wind making the village relatively cool. And Long Quan village surrounded by water areas, water evaporating takes away the heat, which make the summer temperature lower in this village.

(g) Waste disposal

The three villages are set garbage to collect trash, and cleaning staffs are employed to focus on it.

Table 7 Residential form

Residential form			Pu Er Village	Bao An Village	Long Quan Village
Average building area (m^2)			244.57	232.9	150.8
Residential Floor	One-storey		4%	20%	58%
	Two-storey		40%	31%	30%
	Three-storey		56%	49%	12%
Construction Year	Before 1980		22%	8%	6%
	1980-1990		23%	23%	48%
	1990-2000		32%	13%	38%
	After 2000		23%	56%	8%
Walls			Mainly 240 solid brick wall, no insulation measures	Mainly 240 solid brick wall, no insulation measures	Mainly 240 solid brick wall, no insulation measures
Windows	Glass		Single glass	Single glass	Single glass
	Window frame	Wooden	18%	50%	52%
		Aluminum alloy	82%	50%	48%
Shade			18%	No shade	No shade

Table 8 Thermal comfort in summer and winter

Indoor thermal comfort	Summer				Winter			
	Very hot	Hot	Slightly hot	Comfortable	Very cold	Cold	Slightly cold	Comfortable
Pu Er	6%	20%	54%	20%	0	12%	53%	35%
Bao An	8%	10%	45%	36%	2%	10%	44%	44%
Long Quan	6%	20%	36%	38%	0	10%	48%	42%

(h) Energy-saving investment

Most villagers of the three villages understand the rural energy-saving, and are willing to invest energy-saving funds. The amount of village residents' funds is shown in Table 9.

It indicates that funds village residents are willing to invest in Bao An Village are the least, 54% of the people only want to invest not more than ￥500. While people in Long Quan Village has a highest investment willing with 56% of the people want to pay more than ￥1000. The differences between the three villages may be related to its level of economic development. Overall, the majority of rural households can receive the investment of less than ￥1,000.

(i) Physical environment survey

In each village we selected two typical residential, measurements of the indoor temperature and humidity, wind speed and other physical parameter are shown as Table 10.

Table 9 The amount of village residents' funds

The amount of funds (1000CNY)	<0.5	<1	<2	<3	<5
Pu Er	39%	7%	14%	14%	26%
Bao An	54%	19%	19%	5%	3%
Long Quan	33%	11%	8%	32%	16%

Because of the hot weather in the measuring date, the outdoor temperature in three villages is quite high, above 36 degrees Celsius. While the humidity is moderate, maintaining at 45%-60%, within the range of human comfort. The measured data shows that on three villages'

Little difference between 1-3°C. Because of the big windows, the ventilation of the houses there in summer is quite good, which leads to the obvious difference between the indoor and outdoor temperature in six households surveyed. Depending on the different window area, four of these houses is greater than 5°C, especially households B in Long Quan Village, the difference has reached 7.5°C. While due to the high outdoor temperature and the noinsulation walls of the houses, all the indoor temperature surveyed is higher than 30°C, beyond the range of human comfort

Comprehensive Analysis

Table 10 Measurement data of the building physical environment

Houses	Outdoor				
	Measuring time	Temperature (°C)	Humidity (%)	Wind speed (m/s)	Air volume (m^3/s)
A in Bao An	10:03	37.8	57.2		
B in Bao An	11:25	38.7	61.5		
A in Pu Er	10:15	36.4	51		
B in Pu Er	14:05	38.5	46		
A in Long Quan	9:02	36.5	54.1	2.84	408.9
B in Long Quan	10:15	39.3	47.6	2.91	418.7
	Indoor test point a (Lobby)				
A in Bao An	10:45	33.2	66.1		
B in Bao An	11:04	31.9	67.5		
A in Pu Er	10:25	33.8	65.2		
B in Pu Er	14:02	32.1	67		
A in Long Quan	9:03	31	68.2	1.64	236.2
B in Long Quan	10:25	32.3	67.2	2.43	350.3
	Indoor test point b (Master bedroom)				
A in Bao An	10:55	32.6	49.8		
B in Bao An	11:55	33	35.5		
A in Pu Er	10:40	33.3	55		
B in Pu Er	14:35	33.2	60.5		
A in Long Quan	9:40	30.9	67	1.67	241
B in Long Quan	10:40	31.8	39.2	2.07	298.2

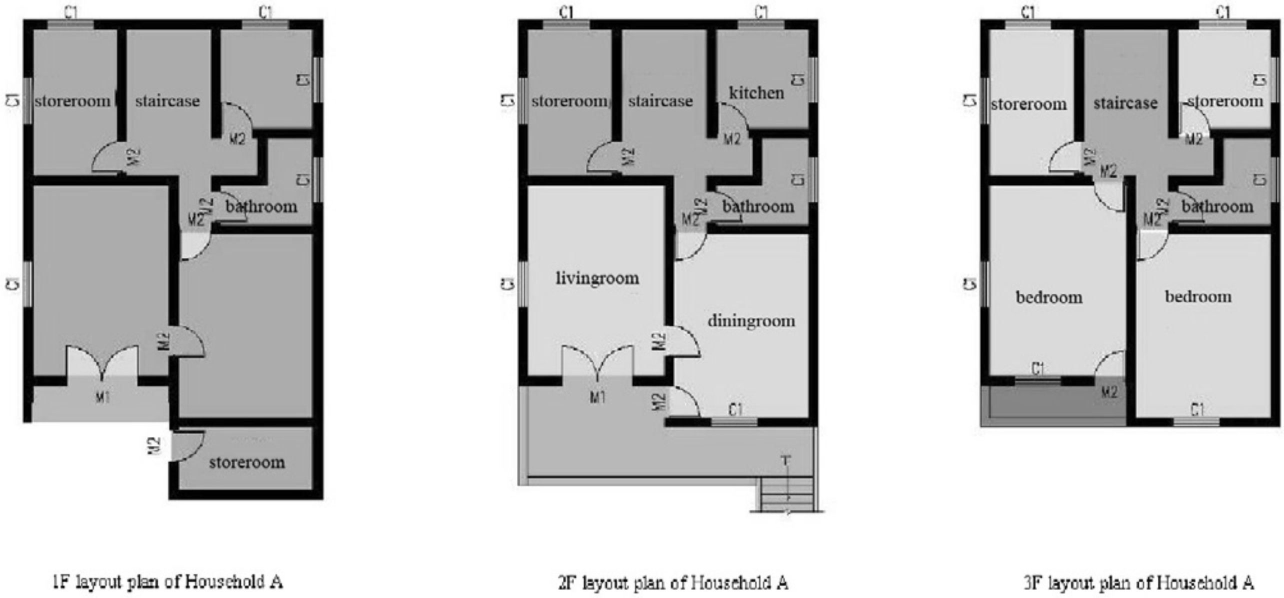

Fig. 2 Households Survey and Mapping plans

According to the field research and the questionnaires survey, as well as the quantitative computer simulation, we analyzed the status of the rural living environment and building energy use, and found that Hangzhou rural living environment had some advantages that can be retained and drawn. Meanwhile, there are also many problems need to improve.

Advantages

a) Good natural lighting

Because the rural residential structure in this area is basically similar, we selected a typical residence in Pu Er Village to do the indoor natural lighting simulation. It is a three-storey building, south-facing, 9.45m high, with the construction area of 233.63 square meters. Households Survey and Mapping plan are shown as Fig.2:

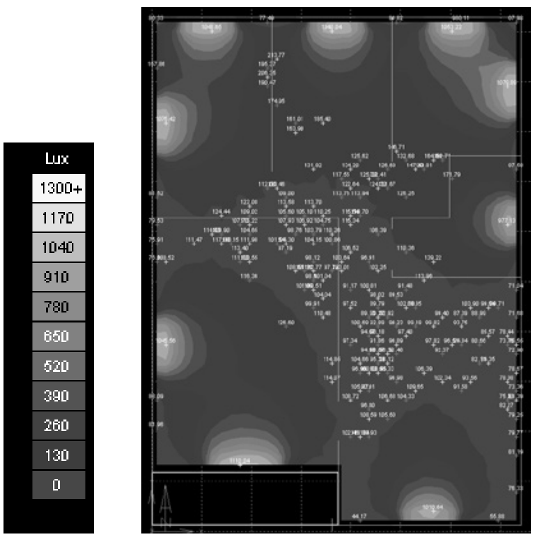

Fig. 3 3 F indoor illumination (lux)

Using the ecological design software Ecotect, the natural lighting of the third floor was simulated. Parameters are set as follows. Weather conditions: full sky, sky design luminance values 9000lux. Time Conditions: all year round from 9:00 am to 5:00 pm. Window design parameters: ordinary clear float glass with the transparency of 88%. Reflection conditions: the reflection of the ceiling, walls and floors are: 0.7, 0.6, and 0.5. The results obtained after the calculation are shown in Fig.3.

Through simulation results, we found this household had a good natural lighting, with the overall average daylight illumination of 242lx, as well as the high ratio of the windows and floors. The illumination in most of the area in the bedroom is above 90lx which can meet the residential requirements; bathroom illumination is also very good which reached 87lx. So, with the open large windows (window and floor area ratio is about 40%) the indoor natural lighting of rural house is quite good, which should be retained and learned in the future rural residential renovation and design.

b) Good natural Ventilation

Using the CFD software PHEONICS, the natural ventilation of the second floor was simulated. Summer dominant wind in Hangzhou is SSW wind with the average speed of 2.3m/s. The results obtained after the calculation are shown in Figs.4 and 5.

The simulation illustrates that the rural units' layout is reasonable with the large window and the good indoor ventilation. Most of the indoor wind speed is lower than 0.8m/s, which meet the requirements of the staff activities. The indoor air age is lower than 200s, and the vast part of the age is below 160s, which shows the air quality is quite good, meeting the staff activities' requirements. Although

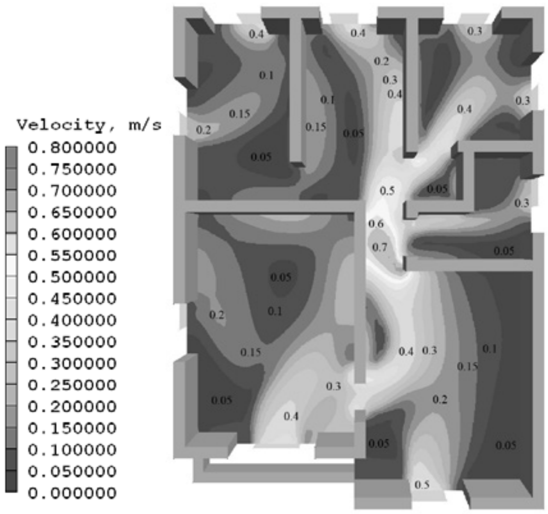

Fig. 4 2 F 1.5m indoor wind speed diagram (m/s)

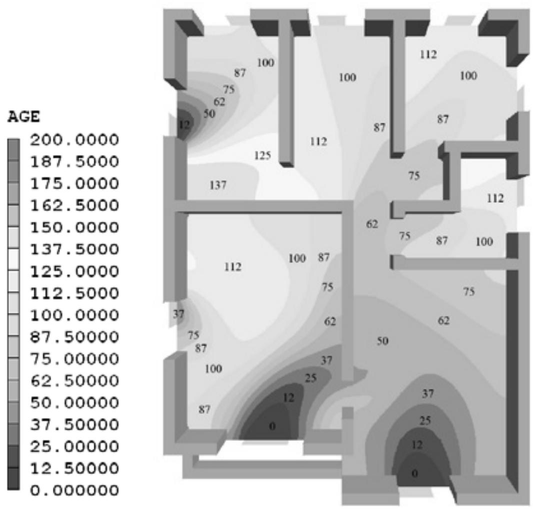

Fig. 5 2 F 1.5m indoor air age diagram (s)

window area is sufficient to meet the ventilation requirements, the improvements are still needed. The eddy phenomenon still can be found in a small partial of the indoor air, so it is recommended to adjust the window position in order to improve the indoor air flow direction.

Problems

a) Inefficient energy use patterns

In this study, more than 92% of the fuel of the farmers in the villages on plains or waterside using is bottled gas, while the farmers in the mountain villages mainly use the firewood. The instruments of heating and cooking in these villages are very simple and crude with the low energy efficiency. And the lack of efficient energy technology and equipment leads to the serious pollution. Although compact fluorescence lamp has a more than 74% penetration rate, there are still one third of the people using incandescent and other ordinary lamps. On the aspect of new energy use, solar water heaters in the local countryside have become more popular, which accounted for 72% of the number of households surveyed. However, other new energy sources such as wind, biomass and so on failed to use .

In addition, with the improvement of living standards of farmers, the majority of the households have air conditioning. While the energy use of air conditioning accounts for about half of the total energy use of the buildings, and the trend upward day after day, which require further improvement of the thermal insulation properties of the building structure.

b) Poor performance of building thermal insulation

b-1 Indoor thermal comfort in summer and winter

In the rural residential indoor thermal comfort survey, people who think the indoor thermal environment is comfortable in winter or summer are less than half, some villages even less than one-third.

In the investigation of the summer thermal comfort, the thermal comfort of the newly built house is relatively good, with the respondents choosing slightly hot mostly, and people living in the old house think the indoor environment is hot. In Bao An village, the number of people who think the indoor environment in summer is comfortable is much higher than other two villages.

In the investigation of winter thermal comfort, the rural residential indoor temperature difference between day and night is quite large. A variety of ways to keep warm will be used, which give priority to air conditioning. In addition, there are still many farmers in winter does not use any heating way, just increase the amount of clothing to against the cold. It displays that nowadays in rural areas, the situation that sacrifice comfort to save energy and money is still widespread.

b-2 Building physical environment measurement

Measured the physical environment of the existing buildings, we found that the performance of the external insulation of the building envelope was poor, and the lack of shade facilities made the indoor average temperature high in summer (above 30°C) and low in winter (below 10°C).

b-3 Building physical environment measurement

In this research, we simulated the surveying and mapping house in Pu Er village by the software PKPM to calculate the energy use. Setting parameters and simulation results are as follows:

<u>Setting parameters:</u>

1) Indoor calculating temperature: 18 °C in winter and 26 °C in summer.

Table 11 Reference and design building thermal parameters

Prescriptive Indicators		Reference building		Design building	
Shape coefficient		0.4		0.593	
Exterior wall	Heat transfer coefficient W (m^2.K)	1.50		1.89	
	Thermal inertia W/(m^2·K)	3.00		3.49	
Roof	Heat transfer coefficient K·W/ (m^2.K)	1.00		2.78	
	Thermal inertia W/(m^2·K)	3.00		2.54	
Floor		2.00		3.04	
Exterior windows (including Transparent curtain wall)	Face	Ratio of Windows to walls	Heat transfer coefficient W (m^2.K)	Windows than walls	Heat transfer coefficient W (m^2.K)）
Single toward	East	≤0.25	4.70	0.05	6.00
	South	≤0.25	4.70	0.23	6.00
	West	≤0.25	4.70	0.13	6.00
	North	≤0.25	4.70	0.22	6.00
Energy use calculation results		Reference building kWh/ m^2		Design building kWh/ m^2	
		38.115		67.608	

2) When heating and air conditioning, the ventilation frequency is 1.0 times / h.
3) Heating and air-conditioning equipment is air source heat pump air conditioner for household, with the air conditioner rated EER taking 2.3 and heating rated EER taking 1.9.
4) The interior lighting heat gain per square meter per day is 0.0141kWh, and the indoor other thermal average intensity is 4.3W/m^2.

Simulation Results:

In the form, reference building shows the index requirements of Zhejiang living building energy-saving design standard in China, design building shows the calculating data for the simulation of the building in Pu Er village. We found that calculation results could not meet the prescribed requirements. The heat transfer coefficient of outer walls, roofs and the Windows is far greater than the standard, especially the window heat transfer coefficient of 6.00 W / (m^2 • k) is 1.28 times the standard data. The calculated energy use of 67.608 kWh/m^2 is also far greater than the reference building the standard specified which 38.115 kWh/m^2 is. So it has great potential of energy saving reconstruction in the rural housing enclosure structure.

c) Economic factors limit

In the survey, we found that most of the three village resident had realized the necessity of energy saving, and were willing to do the energy-saving retrofit program. But due to the economic factors and limitation of the villagers' awareness, the money they willing to spent on energy saving is slightly different. Generally speaking, the amount most of the villagers willing to spent is very low compared to their incomes.

Countermeasures and Suggestions

Promote energy-efficient appliances and the use of new energy

a) Rural house indoor facilities should be energy-saving facilities, such as energy-saving lamps, water-saving sanitary ware, solar water heater, etc.

b) Household air conditioner should choose energy-efficient type, and the air conditioner installation position should not be subject to direct sunlight. Don't set the indoor temperature too low, and often clean the instruments.

c) Make full use of natural light as far as possible, and use the efficient lighting source and lamps.

d) Increase the building energy saving propaganda, improve energy saving consciousness. And as in the home appliance selection, energy use identification should take into consideration.

e) In rural residential design, the use of renewable energy sources should also be pay attention to, such as solar energy, methane, straw energy utilization, etc.

Improve thermal insulating properties of the structure and the living comfort

According to the climate characteristics of Hangzhou area, the living habits characteristics of the rural villagers, and the farmers' economic condition, passive energy saving technology should be preferred in the rural residential building energy-saving design in this region. By improving the thermal insulation performance of the retaining structure, the living comfort can be improved, while the building energy use can be reduced.

According to thermal performance analysis of the present house, we put forward the following several reasonable external enclosure structure energy saving reconstruction scheme.

a) Walls: the construction technology by increasing the thermal insulation layer (such as 30mm powder polystyrene particles insulation mortar) to improve the thermal performance of the outer wall is relatively simple, and the initial economic investment is less, so for the current rural house energy saving reconstruction this way can be chosen. While for the new house it is suggested to use a single energy saving wall instead of traditional 240mm brick wall, such as aerated concrete wall materials, porous brick or hollow block with high rate of hole.

b) Roofs: The roof is the strongest sun radiation position in summer. Considering the farmers requirement to retain the original roof, soilless green roof, no matter from the view of energy saving, environmental protection, economic, or beautyl, is the most effective energy saving reconstruction measures, which also can reduce the solar radiation absorption coefficient.

c) Windows: Outside window is the weakest link in the thermal performance of the whole building peripheral protection structure. Using the model steel hollow glass window to replace the original old window will have a great contribution to the energy saving renovation. But considering the high cost for window change and big influence on household life from the complicated construction, at present, method of sticking glass membrane is proposed to choose in the window energy saving renovation.

d) Shades: Movable external blinds can be used in the outside window, giving attention to the requirements both on summer shading and winter heating

Promote energy saving consciousness education

Due to the cultural and economic condition limit of rural residents, spontaneous retrofit has the certain difficulty. So it is suggested that the local government should first guide household energy saving consciousness education positively, and then give the economic support to reduce the building energy use and pollution emission, to improve the indoor and outdoor living environment.

CONCLUSIONS

China as a nation that the agricultural population accounts for over half, the rural residential environment construction plays a very important role in the development of residential environment of the whole society. The previous studies mostly focused on the heating area, while the research related to the hot summer and cold winter region, as one of the most important section of China, rarely appears. In this research, we selected three different terrain villages in the rural area of Hangzhou as a study object, which located in the hot summer and cold winter region. The investigation, collection and analysis on the building status, energy use data and residents' subjective feeling of the three villages have been done through basic research and sampling questionnaire. And then, we selected two typical houses in each village, separately carried on the measurement of the building physical environment and computer quantitative simulation of the ventilation, lighting, and energy consumption, along with the comprehensive evaluation with the simulation results. By the analysis, it first puts forward the advantages of the rural residential environment which are the good indoor natural lighting and natural ventilation. Then three main problems are found in the rural residential environment, which are inefficient mode of energy use, poor thermal insulating properties of the building exterior enclosing structure, and the economic factors limit. Finally, some operable implementation strategy and policy Suggestions are advocated according to the three main problems.

In addition, because of the time and other various factors, this study also has some shortage, such as tracking evaluation after reconstruction according to the reform strategy has not been conducted. We hope in the future research this kind of work can be continued.

Finally, we hope that this study can provide a reference for Hangzhou rural residential energy-saving renovation and design, a basis for the future Hangzhou rural living environment planning and construction, and the first-hand information for promoting sustainable rural living environment applied research in the province and the whole country. In addition, we hope this study can promote the healthy development of China's rural living environment, and build a harmonious society in urban and rural areas.

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