Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 00 (2017) 000–000

Procedia Engineering

www.elsevier.com/locate/procedia

International High- Performance Built Environment Conference – A Sustainable Built Environment Conference 2016 Series (SBE16), iHBE 2016

Energy-saving Renovation of Bayu Traditional Residence ——Taking Anju Town of Chongqing as the Example

Ke Xiong[a,b],Zhenjing Yang[a,b] *

[a]Faculty of Architecture and Urban Planning, Chongqing University, Chongqing 400045, China
[b]Key Laboratory of New Technology for Construction of Cities in Mountain Area, Ministry of Education,Chongqing University,Chongqing 400045,China

Abstract

Traditional residence is an important part of our culture and heritage of ancient architecture, which contains rich experience in the construction of ecological. But limited at the construction technology and economic level, traditional residence also has shortcomings. Therefore, in addition to heritage of its ecological wisdom, syndrome differentiation treatment should be used. In this paper, on the basis of the energy-saving reconstruction project located in Anju town of Chongqing, its energy-saving advantages and disadvantages were analyzed. Then methods of traditional residence in energy-saving were proposed, which not only met the energy requirements and economics, but also improved the thermal comfort significantly. Analyzing the annual energy consumption of its before-after renovation by Design Builder. The building energy saving rate was 54.36% after renovation.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: Traditional residence；Renovation；Energy saving；Simulation

1. Introduction

With the rapid development of the national economy, people's demand for living standard is higher and higher [1, 2], and the quality of human settlements environment and building energy consumption have attracted attention

Ke Xiong. Tel.: +86-136-5243-5540;
E-mail address: 457425819@qq.com
*Corresponding author: young30331@163.com

1877-7058
Peer-review under responsibility of the organizing committee iHBE 2016.

widely [3]. “13th Five Years Plan ”clearly pointed out that to speed up the construction of the beautiful livable countryside, comprehensively improve production and living conditions in rural areas, carry out ecological civilization demonstration action of villages and towns and the rural living environment comprehensive rectification action, increase the traditional villages and residents and the national characteristic town’s protection, heritage of rural civilization, construction idyllic and beautiful country scene, harmony and happiness of the beautiful livable countryside[4]. Chinese traditional dwelling is an important part of the rural construction in China, which it can best embody the local culture and carry nostalgia plot, how to protect the traditional dwelling and develop it is facing the grim task of current building in the livable villages and small towns’ construction period. But traditional dwellings are unable to meet the requirements of modern living from the space form, health conditions, lighting and indoor thermal comfort environment. The residents have the desire to improve the indoor environment strongly which lead to the heating and air conditioning energy consumption grow very prominent [5]. At the same time, with the blind pursuit of bright and spacious to pull down the old houses, the construction of a large numbers of low qualities and high energy consumption of simple brick houses has caused the loss of regional culture and will eventually lead to serious damage to the environment. Therefore, it is of great significance to seek suitable traditional dwellings update mode, to realize the sustainable development of traditional dwellings, and to protect the local culture and environment.

This paper takes one of the traditional residences which located in Anju Town of Chongqing as the research object. Combining with characteristics of local climate to analysis the climate adaptation passive energy saving strategy. Changed the typical functional layout of the traditional residences, and indoor physical environment of comprehensive transformation of the integration, and through energy simulation and actual measurement to evaluate the effects of the reconstruction.

2. Climate analysis and passive energy saving strategies analysis in Chongqing area

The building's passive adjustment to achieve low energy consumption and high comfort is advocated by the means of ecological [6], so it needs to take full account of the impacts of climate and take appropriate measures.

2.1. Analysis of the climate in Chongqing

Chongqing is located in the southwest of China, which is a typical hot-summer and cold-winter area. As can be seen from the Fig.1, the highest monthly average temperature of Chongqing in summer is 28.3 degrees Celsius, and the lowest monthly average temperature is 10 degrees Celsius. While Chongqing belongs to high humidity area in China, the average annual rainfall is abundant, and the annual average relative humidity is 70%~80%. In addition, as one of the least annual sunshine area in China, the annual sunshine time is 1000~1400 hours, and the percentage of sunshine is only 25%~35% [7].

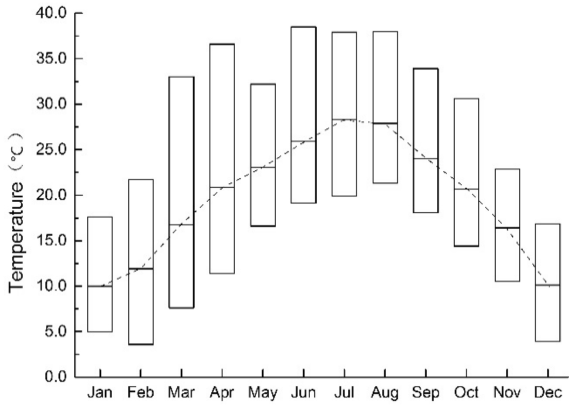

Fig.1 the monthly temperature in Chongqing.

2.2 Analysis of passive energy saving strategies

The weather tool with the same parameter setting is used to analyze the percentage of time periods accounted for comfort after the six passive strategies, such as passive solar heating, thermal mass effect, mass and night ventilation, natural ventilation, direct evaporative cooling and indirect evaporative cooling, which were used in Chongqing. The results are shown in Fig.2.

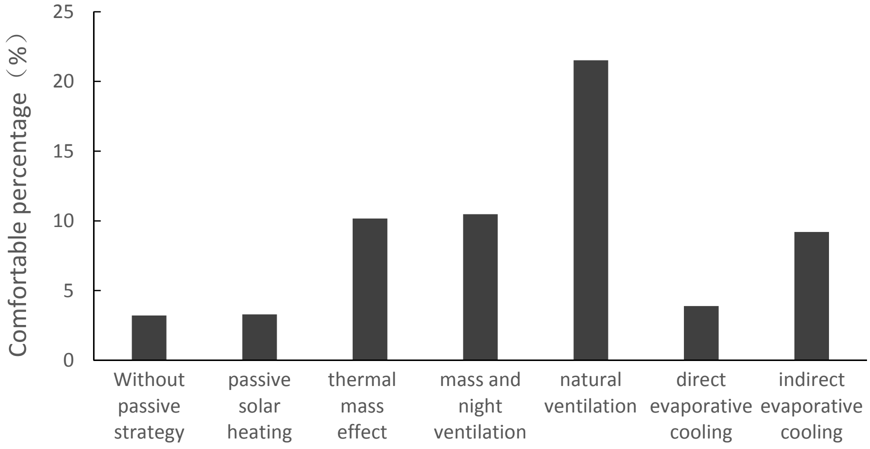

Fig.2 use of passive energy saving strategies and not by the comfortable percentage in Chongqing.

It can be seen that the use of natural ventilation in Chongqing to improve the comfort is the best method, which can be about 7 times of without the natural ventilation, and 2 times of using mass and night ventilation. Consequently, the preferred order of the technology that low energy consumption and high comfort is natural ventilation, mass and night ventilation, thermal mass effect.

3. The typical residential renovation

3.1 The typical residential introduction

The renovating typical residence is located in Anju town of Chongqing (Fig.3). Based on the field measurement of the typical residential layout before renovation is shown in figure 4. We can see from the figures that the residence is a typical architectural pattern which is “small broad and great depth”. The building function along the depth direction spread out. It is situated at the west of mountain, due east of Vulcan Temple Street, and the north and south side are closed to neighbours (Fig.4). It is two-story high, the first layer is 3.00m, while the second layer is 2.65m. The main material of wall is bamboo with mud, while sloped roofs of the residence are made of timber and covered with clay tiles. Due to the construction materials were made for so many years, part of the walls were used brick to reinforce it. The material of the first floor is simple cement, and the second floor is wood. All the doors and windows were made of wooden, the window of the bedroom by street-side was single glass, worst of all, some windows glass were missed.

Fig.3 landscape of Anju Town.

Fig.4 facade style of the residence.

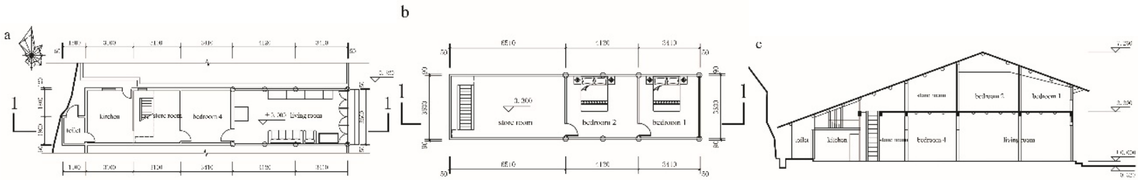

Fig.5 (a) ground floor plan; (b) second floor plan; (c) 1-1sections.

3.2Existing problems of the typical residence

The residential form is single, which led to the poor privacy. At the same time, the stair was located at the end of the building, so that the other side of the rooms were intermeshed. The architectural pattern is special, and the west side is closed to the mountain, which led to the light can only pass through the short sides of the building and the roof (Fig.5). All of these factors caused a serious poor lighting. Besides due to the large depth of it, the indoor room unable to have a good ventilation, in addition, the rain is to the drain of the west wall all the years, caused the indoor humidity increases, resulting in serious ground dew, especially in the washroom and kitchen at the first floor. The thermal environment in the residence was measured on the summer of 2014, while chose one day which the temperature was high and steady as a typical day for analyzing the indoor and outdoor temperature (Tab.1). From the table, it can be found that the indoor thermal environment of the first floor is well, while the second floor is very bad, the highest temperature and the average temperature were higher than outdoor. It didn’t meet building thermal protection requirements apparently.

Tab.1 the measurement results of the indoor thermal environment (in summer）

	Outdoor	Living Room	Bedroom 1
Avg. temperature/（℃）	31.5	29.2	32.5
Max. temperature/（℃）	39.7	32.2	39.8
Min. temperature/（℃）	24.0	28.2	27.3

3.3 The typical residential renovation measures

According to the climate characteristics of Chongqing, the plane function, indoor thermal environment, lighting and ventilation of the typical residential building are inadequate. Following the principle of maintaining the traditional style of the building, comprehensive renovation measures were used.

3.3.1 Improving the function and the indoor environment

To adapt to the living needs of modern people, reasonable zoning of the residential building space is adopted (Fig.6). The flow line of building is divided into two, the inner and the outer. The first layer is for the external, while the second layer is for the inside. The second layer was designed with three bedrooms side by side, and through the design gallery to improve the privacy of them. Meanwhile, according to the needs of resident, the slope roofs closed to the mountain were turned into flat roofs, which can bring outdoor space of the viewing and leisure.

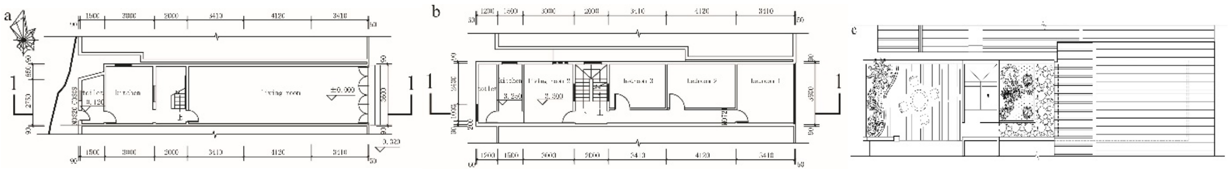

Fig.6 (a) ground floor plan after renovation; (b) second floor plan after renovation; (c) roof plan after renovation.

The staircase to the roof with windows will lead the light into the room at least. The rooms on both sides of the stairs are open to the window, and the illumination is improved by indirect lighting, while the bedroom 2 is by raising the original slope of the west side of the roof to achieve the purpose of direct lighting (Fig.7). From the analysis of the climate in Chongqing, it can be founded that natural ventilation is the most effective passive measure to improve the thermal comfort in summer. Therefore, in order to strengthen the indoor ventilation effect, the methods of the thermal pressure ventilation and fan are used (Fig.7).

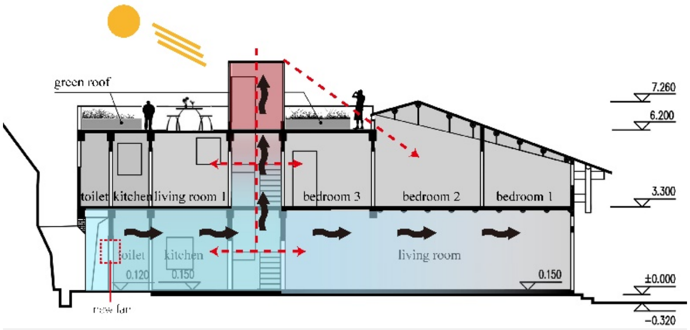

Fig.7 Schematic diagram of ventilation and lighting after renovation.

3.3.2 Improving thermal performance of building envelope

The main material of wall is bamboo with mud, while sloped roofs are made up of timber and covered with clay tiles. The windows are with a single layer of glass or no glass. The heat transfer coefficient of building envelope is relatively large, leading to the poor indoor thermal environment. Therefore, the building envelope are renovated reasonably. The renovation approach and performance parameters are shown in Tab.2, and the final renovation effect is shown in Fig.8.

Tab.2 Performance of building envelope after renovation

Position	Main construction methods	Heat transfer coefficient W/(m2.K)
Flat roof	Cultivation layer + Mortar（20mm）+XPS（20mm）+ Waterproof layer + Sloping layer（50mm）+ Concrete（120mm）	0.93
Slope roof	Clay（15mm）+ Pine（100mm）+ Air gap of the celling（600mm）+ Heat-proof compound plate（20mm）	0.67
Part of the new wall	Fired shale hollow block（200mm）+ Heat-proof compound plate（20mm）	0.77
Bamboo with mud	Bamboo + Grass with clay + Lime mortar	2.21
Raised floor	Mortar（20mm）+ Fiber Reinforced Cement Mortar Board（60mm）	0.69
Window	Aluminum Alloy profile, Transparent thermal reflection 6+9A+6	3.30

Fig.8 rendering after renovation.

4. The effect of renovation

The residence was renovated in March 2015. Then the indoor thermal environment and energy consumption before and after renovation were compared by measurement and simulation.

4.1 The indoor thermal environment

The temperature measurement of the residence was conducted during the summer of 2015. Then, select one day which is the closest to the outdoor temperature before renovation for analyzing. Compared of the bedroom 1 which the indoor thermal environment is worst before and after renovation (Fig.9), it can be found that the indoor temperature is more stable and the reduction of peak is more obvious all day long after renovation. The maximum temperature is reduced by 2 degrees, and the average temperature is reduced by 0.4 degrees. However, its indoor thermal environment improved significantly.

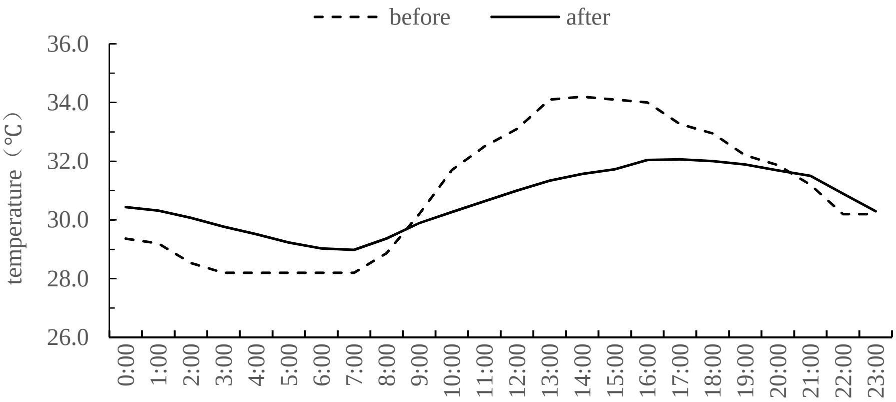

Fig.9 the comparison of temperature before and after renovation of bedroom 1.

4.2 The simulation results of energy consumption

DesignBuilder was used to build the model before and after renovation with typical meteorological year data of Chongqing. The parameters were based on the actual situation of building, and the simulation results is shown in Fig.10. Seen from the figure, the annual energy consumption decreased significantly after the renovation, especially the building envelope, which makes the building thermal insulation performance enhanced greatly and heating energy consumption decreased significantly. Actually, the building annual energy consumption per unit area decreased from 152.25kwh/㎡ to 69.46 kwh/㎡, and the energy saving rate is 54.35%.

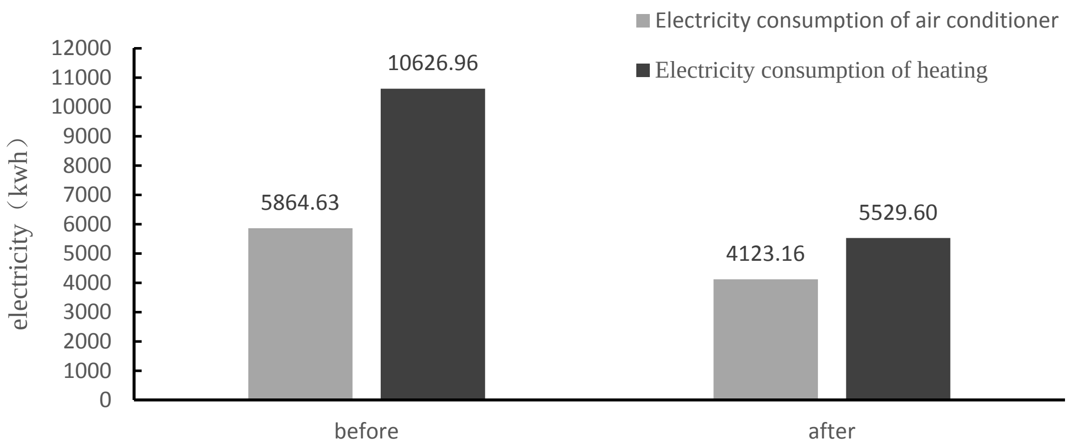

Fig.10 comparison of energy consumption before and after renovation.

The heat loss of building envelope is disadvantage in winter, but it is favorable in summer. It is found that per unit area of building is less loss of heat by analysis of the building envelope in the summer and winter (Fig.11). The heat of the main room decreased more significantly in the winter. It can be seen from the table 3, the heat loss is only about 50% before renovation, and the thermal insulation performance has been improved in the winter. The first floor in living room is raised, so the heat is greater than before in the summer, which can avoid the ground condensation. In addition, the heat of bedrooms on the second floor are far less than before the renovation, which indicates that the renovation of the heat insulation effect of the building envelope is better (Tab.3).

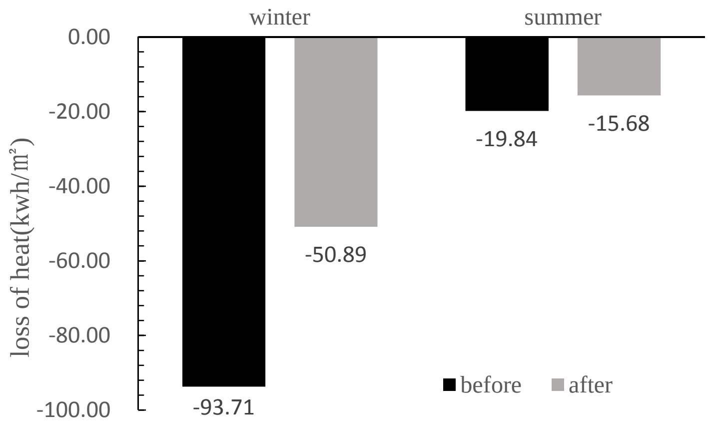

Fig.11 comparison of envelope heat loss of building unit area.

Tab.3 the main rooms of the building envelope unit area gain and loss heat in summer and winter

	winter			**summer**		
	living room	bedroom 1	bedroom 2	living room	bedroom 1	bedroom 2
Before(kwh/㎡)	-60.06	-81.81	-79.43	6.17	48.45	50.12
After(kwh/㎡)	-32.98	-35.84	-35.45	12.58	11.71	16.21

The heat loss of the roof is the most significant in the whole year through the simulation analysis of the whole year's gain and loss heat in all parts of the building envelope. It shows that the renovation of the roof is great in the thermal environment of traditional residential renovation, which is urgent and the most effective renovation part (Fig.12).

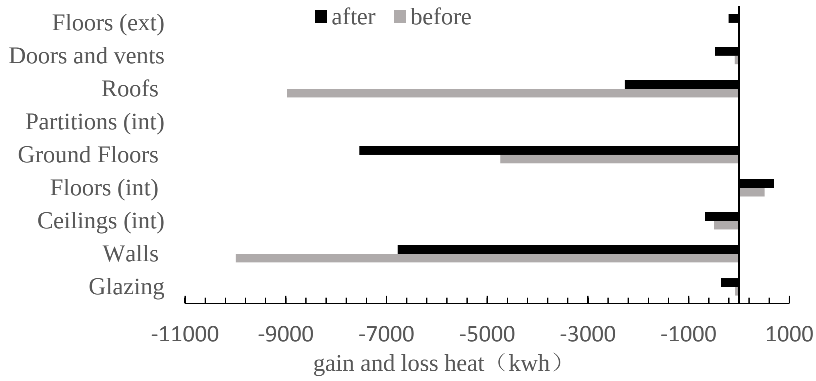

Fig.12 gain and loss heat contrast of each building envelope.

From Fig.12 can be obtained that energy-saving effect of the bedrooms on the second floor is obvious after the renovation of the building envelope. Therefore, the monthly gain and loss heat in bedroom 1 of each building envelope is analyzed (Fig.13-16). It can be seen that the renovation of the building envelope has been improved after the renovation, which the heat is less in summer, and heat loss is also reduced in winter. The construction of the thermal insulation effect is very obvious, especially walls and roofs which increased the insulation.

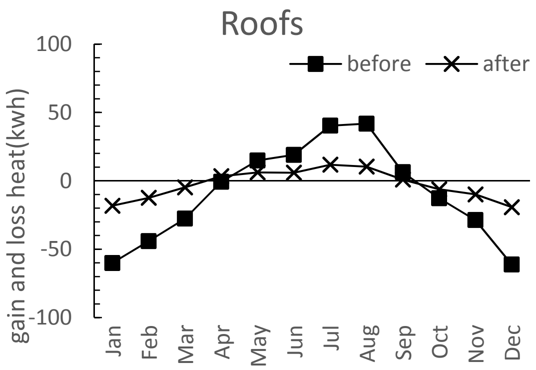

Fig.13 the gain and loss of the roofs of every month.

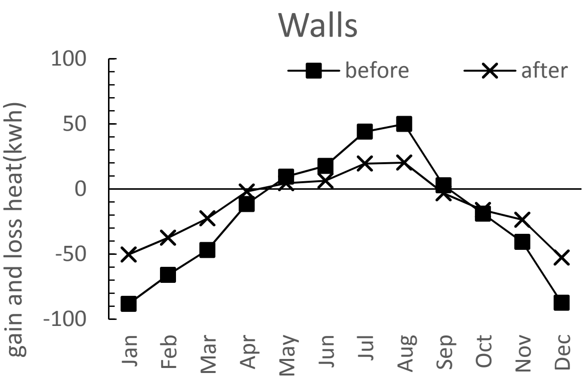

Fig.14 the gain and loss of the walls of every month.

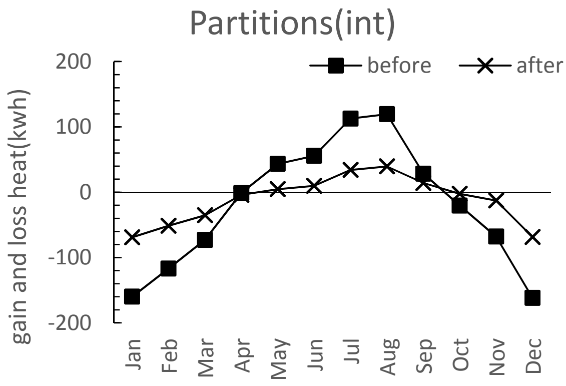

Fig.15 the gain and loss of the partitions (int) of every month.

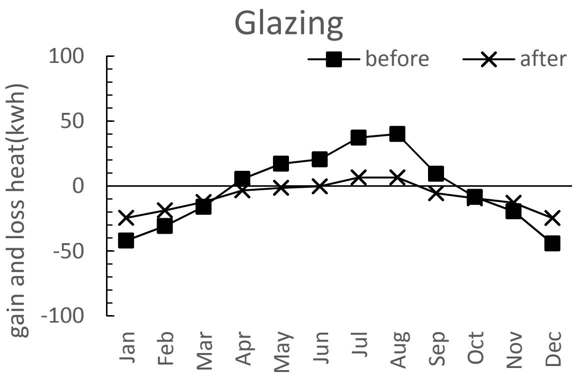

Fig.16 the gain and loss of the glazing of every month.

5. Conclusion

Traditional residence is not only a primary part of Chinese traditional culture, but also a place for people to live. The renovation of traditional residential buildings should be based on protection. However, it also needs to reduce building energy consumption and improve human comfort. Designing with the methods of the green houses, the traditional residence can call forth the new vitality. The renovate project of the typical residence in Anju Town which combined with the protection of the traditional culture and the improvement of the indoor physical environment reduced the building energy consumption, and the building energy efficiency rate was 54.35%. The renovation of walls and roofs are great in the view of the traditional residential building envelope renovation. This project will provide a feasible method for the renewal design of Bayu traditional residence, and provide practical reference for the retrofit of existing traditional architecture.

Acknowledgements：

This work was supported by the National Key Technology Research and Development Program of the Ministry of Science and Technology of China during the “12th Five Years Plan” （2013BAJ11B04）, and the Fundamental Research Funds for the Central Universities (106112014CDJZR190008).

References

[1] D. Zheng, Designing the New Rural Residence: An Ecological Approach, Journal of Zhejiang Normal University (Social Sciences), 2014(04) 85-91.
[2] Y. Wu, X. Liu, Q. Li, Study on Status, Trends and Development of Building Energy Efficiency in Rural Areas in Northern China, Building Science, 2010(12) 7-14.
[3] Y. Wang, The Research on Climatic Adaptation of Traditional Houses of Architectural Forms in North-central Region of Human Province, Hunan University, 2012.
[4] Editor of association, Guidance of the Ministry of housing and urban construction on the creation of Green villages, 2016, http://www.chinaasc.org/news/zonghexiaoxi/20160325/112788.html.
[5].Yilmaz, Z, Evaluation of energy efficient design strategies for different climatic zones: Comparison of thermal performance of buildings in temperate-humid and hot-dry climate, Energy and Buildings, 2007, 39(3) 306-316.
[6] L. Yang, Bioclimatic Architecture, first ed., China Building Industry Press, Beijing, 2010.
[7] Encyclopedia of Geography Group, Chongqing, 2016, http://baike.baidu.com/subview/2833/6922767.html.
[8] Q. Bao, M. Wang, Analysis and Improvement on Thermal Performance of Rural Common Wall in Zhejiang Region, Journal of Anhui Agricultural Science, 2009, 37(5) 2329- 2331
[9] T. Zhang, Study on Climate Adaptability of Typical Traditional Dwellings Envelope, Xi`an University of Architecture and Technology, 2013.