Energy Conservation Reconstruction Study of Existing Apartment Buildings in Hot Summer and Warm Winter Area—A Case Study of Apartment Building in Xiamen University

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Abstract. In order to study the energy saving and emission reduction of existing student apartments in hot summer and warm winter area, and based on the dynamic simulation analysis software of building energy consumption and the reconstruction experience of building energy saving at home and abroad, and combined with the characteristics of climate and environment in Xiamen, where is located in hot summer and warm winter area, and through selecting the more energy-saving material and establishing the dynamic simulation model to simulate the apartment internal thermal environment, and then it can be drawed that the comparative analysis of energy conservation before and after the reconstruction. Research shows that improving energy-saving performance of the roof, wall and window glass can better reduce energy consumption and achieve the purpose of energy conservation. At the same time the paper puts forward relevant suggestions for building energy efficiency design and existing building energy saving and provide reference for energy conservation.

Introduction

Xiamen City is located in the hot summer and warm winter area, and the residential energy consumption is mainly consists of thermal insulation in summer and keeping warm in winter. In recent years the country began to pay attention to existing building energy conservation work in the hot summer and warm areas, so it needs theory to guide the experience. There is a certain gap between energy conservation criteria and the thermal performance of outer envelope in Xiamen City[1]. Xiamen traditional student apartments generally use transparent single-layer glass windows, and the thermal insulation performance is poor. And increasing the thickness of external walls with a single material to achieve the practice of insulation has been unable to meet the requirements of energy saving and environmental protection, and lacking of energy-saving roof design leads to a high building energy consumption. Therefore, to promote energy-saving reconstruction of the existing building and the extensive implementation to reduce building energy consumption have become an urgent problem for China's energy-saving work.

Research Status at Home and Abroad

Development of building energy efficiency in foreign countries

In the 1970s, Western scholars began to study the building energy efficiency technology. GA. Florides made a comprehensive simulation analysis on a typical building through the TRNsys software, and found that with the promotion of the building thermal insulation level, the energy efficiency of natural ventilation will be enhanced. In the study of the building orientation, it is pointed out that the long side of the building towards north-south is the most reasonable [2]; NurdilEskin and HamdiTurkmen used the Energy-Plus simulation software to study and analyze the concrete data which affect the energy consumption of the whole year [3]; Mari- Louise Persson used the DEROB-LTH software to make simulation analysis, and found the optimal size of the doors and
windows towards south[4]; Elisabeth Gratia and Andre De Herde made in-depth study and pointed out that the innermost material of the building wall plays a key role on the building interior temperature control[5]; Indian architect Charles Coria proposed the design concept of form follow climate, and advocated to support domestic and use more natural lighting and natural ventilation. Malaysian eco-architect Yang Jingwen advocate the principle of limited bio-climate and low energy consumption.

Development of building energy efficiency in China

In China, building energy efficiency research started late. In 1982, the country issued the first scientific research work of building energy conservation, and began to develop a series of energy-saving building standards. Since 1997, China began to strictly implement the building energy-saving work. In 2005, China remained in the understanding of green energy-saving buildings, and began to have a preliminary definition on the building energy efficiency and build a sustainable development framework of the national construction industry. During 2005 to 2010, the country encouraged and guided the building energy efficiency research work through policies, and the research results of building energy efficiency had become more and more, the research results involved various fields. Xue Zhifeng and other, who come from Tsinghua University, carried out the actual survey on large public buildings in Beijing, analyzed the energy-saving potential of the public building[6]. Li Zhisheng and others used eQUEST simulation software to compare the energy consumption of different enclosing structures, which illustrated the necessary of researching building exterior wall insulation system[7]. Hebei Institute of Architecture Science and Technology, based on Design Builder software, carried out the energy consumption simulation analysis of passive and low energy consumption office building which is building science and technology research center in Hebei province, and analyzed the difference combining with the actual operation data, and provided a reference for the rationality of the simulation application of passive energy consumption of low energy consumption in cold area and the feasibility of operational management and simulation optimization strategy[8]. For the issues of the comprehensive evaluation system is not perfect and evaluation methods are unscientific in the existing building energy saving effect, Inner Mongolia University of Science and Technology constructed the evaluation index system of three levels and established a comprehensive evaluation model of existing building energy saving effect based on AHP and cloud model [9].

However, the energy-saving simulation analysis of the hot summer and warm winter area is not enough, so it is necessary to discuss the simulation analysis of the hot summer and warm winter area. Therefore, the paper considered the actual case, and selected a student apartment in Xiamen University. DesignBuilder, which is widely used among energy consumption analysis softwares, is used to analyze the energy consumption before and after energy saving reconstruction so as to guide the energy saving reconstruction in hot summer and warm winter areas.

Energy-saving Simulation Model of Student Apartment in Xiamen

Climate conditions in Xiamen area

In the normal circumstances, solar radiation is the greatest impact of indoor thermal environment in the building. The sun radiation and sunshine time are closely linked, so the building needs to be designed by different functions of space according to its daily sunshine need. Annual sunshine total hours are about 2000 hours in Xiamen area, and the cumulative annual sunshine hours percentage is 51%, and it is the most in July and least in March. The summer time in Xiamen is longer than other city, and influenced by the coastal Pacific air flow, so it can provide good ventilation for the building conditions.

Overview of student apartment

In order to study the situation of the student apartment before and after energy conservation in the hot summer and warm winter area, the paper takes the building of Lingyun 4 # in Xiamen University as the simulation object. The building has 6 layers, and all are the student dormitory. Except the roof thickness, the remaining layers are all 3000mm height, and the main part is the brick structure. We
will test the thermal environment changes in the wall of apartment building after the change of insulation materials.

The simulated test dates are in July and January. The simulation test items include indoor temperature and regional heat loss.

Method of software analysis

The model was established in the DesignBuilder with the field of building-related energy consumption data. First, set up building materials and HVAC system modules, then simulated a variety of building envelope HVAC type and building lighting one by one, and finally outputted the individual energy consumption load data, which were aimed at studying the impact of variables on energy consumption.

The basic parameter settings of the model

The basic parameters settings of the model include the following parts: the number of indoor activities of the staff is 0.242/m²; heating control temperature is 22°C; cooling control temperature is 28°C, the proportion window in wall is 20%, the density of lighting power is 5W/m².

Table 1 shows the thermal performance of the main simulation components. Table 2 shows the basic performance of the glass before and after reconstruction.

### Table 1. Thermal Performance Table of Main Components.

| Material                     | R_i, m²·K/W | R_e, m²·K/W | R, m²·K/W | K, W/m²·K |
|------------------------------|-------------|-------------|-----------|-----------|
| Roofing(before reconstruction)| 0.100       | 0.040       | 0.882     | 1.133     |
| Roofing(after reconstruction) | 0.100       | 0.040       | 1.19      | 0.84      |
| Wall(before reconstruction)  | 0.130       | 0.040       | 0.362     | 2.765     |
| Wall(after reconstruction)   | 0.130       | 0.040       | 0.752     | 1.336     |
| Partition                    | 0.130       | 0.040       | 0.276     | 3.621     |
| Floor                        | 0.170       | 0.040       | 1.500     | 0.667     |

### Table 2. Table of Glass Performance.

| Material                  | K, W/m²·K | SC  |
|---------------------------|-----------|-----|
| Glass(before reconstruction)| 1.960     | 0.691|
| South glass(after reconstruction) | 2.685   | 0.497|
| The other glass(after reconstruction) | 2.822  | 0.499|

### Simulation Test

Simulation test in summer

The whole building is used as the summer data analysis object, and the simulation period is from July 1 to July 31. Figure 1 shows the relevant indoor thermal data before reconstruction, Figure 2 shows the relevant indoor thermal data after reconstruction. Figure 1 shows that the maximum outdoor temperature in July is 20.4°C, the maximum effective temperature is 27.4°C, the lowest effective temperature is 23.6°C and the maximum solar radiation in the room is 1200kWh, which is the main source of heat in the room. Figure 2 shows that the maximum effective temperature in the room is 26.4°C, the lowest effective temperature of 22.8°C, the temperature in average is about 1°C lower than before. The indoor solar radiation heat, after reconstruction, is only half of the before, and the maximum solar radiation in the room is only 600kWh.
Simulation test in winter

Similarly, the whole building is used as the winter data analysis object, and the simulation period is from January 1 to January 31. Figure 3 shows the relevant indoor thermal data before reconstruction, Figure 4 shows the relevant indoor thermal data after reconstruction. Figure 3 shows that the maximum outdoor temperature in January is 10.4°C, the maximum effective temperature is 19.4°C, the lowest effective temperature is 18.1°C, the maximum solar radiation in the room is 500kWh, which is the main source of heat in the room. Figure 4 shows that the maximum effective temperature of the room is 10.1°C, the lowest effective temperature of 17.0°C and the temperature in average is about 1°C lower than before. The maximum solar radiation in the room is only 600kWh.

Annual total energy consumption in comparison

The simulation test of energy consumption of HVAC system before and after reconstruction, which the temperature is controlled by the indoor air conditioning system. The ratio of air
conditioning heating energy consumption is 83%, and the radio of its cooling energy consumption is 167%. Heating opening temperature is 12℃, and comfortable temperature is 18℃. Cold opening temperature is 28℃, and comfortable temperature is 25℃.

Table 3 shows the average energy consumption before reform and the average energy consumption after renovation. Before reconstruction, the cooling energy consumption of the air conditioning is 33.60kWh, and the heating energy consumption is 196.8kWh. The total energy consumption is 230.42kWh. After reconstruction, the cooling energy consumption of the air conditioning is 16.9kWh, and the heating energy consumption is 198.7kWh. The total energy consumption is 215.55kWh. So the cooling energy consumption decreases by about 16.73kWh, yet the heating energy consumption only increases by 1.86kWh, then it can save 14.90kWh everyday.

Table 3. Indoor thermal data of 3 storey buildings before and after retrofit.

| Index                      | Energy consumption before the day of reform | Energy consumption after the day of reform |
|----------------------------|--------------------------------------------|------------------------------------------|
| Zone Cooling(MWh)          | 33.6                                       | 16.87                                    |
| Zone Heating(MWh)          | 196.82                                     | 198.68                                   |
| Total(MWh)                 | 230.42                                     | 215.55                                   |

**Conclusion**

We can have some conclusions as follow through comparing the data before and after the reconstruction:

1. The use of external polystyrene particle jelly coating greatly improve the insulation properties, and indirectly play the role of energy saving.
2. Improving the thermal insulation properties of the glass, can reduce the heat radiation into the room, and play a significant cooling effect in summer.
3. Comparatively speaking, The role and meaning of adding roof insulation layer is not significant.

Xiamen is located in hot summer and warm winter area, so we can be appropriate to reduce the consideration of winter warmth and focus on solving the summer heating insulation and cooling problems when both can not be met at the same time. It can also be seen in the analytical results that the length of uncomfortable time in winter is much shorter than in summer in Xiamen.

In summary, there is a strong feasibility and practical effect to improve the indoor environment of the apartment building through improving the physical properties of glass and wall. So we suggest, for energy-saving reconstruction of existing residential buildings, the reconstruction parts should focus on the outer window, roofing and external walls, and technically combining with the use of affordable thermal insulation materials and taking the shade, roof greening, vertical greening and ventilation into account. Energy-saving reconstruction of the existing buildings could reduce energy consumption through improving the total thermal resistance of building facades and roofs and improving the basic performance of glass. The external walls can be made of polystyrene paste, and let the glue powder compound the polystyrene particles by adding water and formed slurry, and paint the outer surface of the wall to form the cavity insulation layer. Window frame is made of UPVC plastic profiles, and glass is Low-E6+9A+6 insulating glass. Roof adds 35mm height with extruded polystyrene foam board, and the method of overhead ventilation is used with roof for the effect of heat insulation and cooling. As Xiamen is located in the south part of hot summer and warm area, where sunshine time is longer, it is necessary to consider the full use of natural energy such as solar energy, and it is recommended to implement the integrated application of solar water heater and transform the existing roof solar hot water system. Organizing energy-saving reconstruction can not only beautify the city, but also can save energy and improve the thermal comfort of households, which can achieve the aim of multi-win.
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