Study on Energy - saving Modification Plan of Mature Residential Area based on AHP

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Abstract

We took the 20th building of mature residential area in X City in China as an example, and analyzed the method and technical measures of energy-saving transformation of mature residential buildings in city. The energy-saving effect of different technical combinations was studied by dynamic energy consumption simulation. The decisions and opinions of residents and communities were studied by AHP method. The final solution is optimized by combining the energy simulation results. The results showed that, through the energy-saving transformation, it can effectively improve the thermal performance of the building, and improve the living comfort. It also has a great contribution to the work of low-carbon emission reduction of the city.

Keywords

AHP; Energy-Saving Transformation; Mature Residential Area.

1. Introduction

The potential of residential energy-saving is huge. The total number of urban housing and energy consumption are very large. The residential construction accounted for 56% of total urban construction area, and the residential energy consumption accounted for 52% of urban non-heating energy. On the one hand, the history shows that per capita building energy consumption and carbon emissions will increase with the increase of income level in the process of urbanization [1]. Various types of statistical data also show that China's residential energy consumption is in the uplink channel. On the other hand, the thermal performance of a large number of existing residential buildings is poor, and the energy losses are serious. For example, up to the end of 2015, 70% residence are non-energy-efficient buildings in X City in China. We can see that the energy-saving potential of mature housing has great significance to the energy-saving emission reduction targets, and the energy-saving transformation is an effective approach [2].

Agis M. Papadopoulos [1] thinks that energy-saving transformation is not only conducive to building energy efficiency, but also more conducive to improving the indoor space thermal comfort degree, and improving the environmental quality of urban space. Germany's experience shows that the air-conditioning energy consumption can be reduced by 63.9% maximum after transformation of residential buildings, and carbon dioxide emissions of per unit area can be reduced by 54.3% maximum. Because the residential comfort was improved after transformation, so the rental rates increased, and the monthly rents increased by 42%. The energy-saving pilot projects cooperated by China and Germany in China's Tangshan, Beijing and Urumqi three residential areas show that the energy consumption of unit area of the building decreased by 38.2% 52.2% and 51.6% respectively after transformation. The energy-saving technology of mature residential building is relatively backward, and in its work, we need to solve more complex problems: First, the regional climate characteristics decided that the transformation should focus on the summer heat insulation, and also should take into account the winter insulation. The effects of the heat flow indoor and outdoor in different seasons on the external building envelop should be considered comprehensively. Second, the status of summer humidity determines that the transformation should not only pay attention to energy-saving issues, but also take into account the moisture dampness problem in daily use [3]. Third, with the rapidly development of the urbanization process, the heat island effect increased year by year. This reality determines that the transformation should focus on improving the thermal performance of external envelop structure, but also take into account the improvement of regional environment and small environment. Fourth, in the absence of the protection of appropriate economic policies and standard system, in order to fully and sustainably promote the housing transformation work, we must balance the investment of local government and the economic burden of the residents, seeking the appropriate transformation methods and technical routes of the input-output ratio [4].

Therefore, we took the 20th building of mature residential area in X City in China as an example, and studied the transformation methods and technical measures that suit the characteristics of hot summer and cold winter areas and have good economic and energy-saving effects.

2. Research methods

The 20th building of mature residential area in X City in China was taken as the pilot project, the status quo of essential information and the thermal performance of the building were researched in field. According to the residential energy-saving design standard, the climatic characteristics of the hot summer and cold winter area and the appropriation budget, the energy-saving transformation content of the building was divided into "key transformation" and "recommended transformation". A variety of more feasible combination of energy-saving transformation programs were put forward. The "key transformation" was mainly for the building walls, roofs, doors and windows and shade. The "recommended transformation" included residential greening, closed staircases and so on. Through the method of reactive coefficient, the energy saving effect of various schemes combination was calculated and the residents' opinion was quantified scientifically by AHP method. Finally, the energy saving scheme was evaluated and screened, and the implementation plan was determined. Finally, the energy saving effects and carbon emissions were analyzed by the analog computation of dynamic energy calculation and actual measurement, and the economic evaluation was given. The specific process is shown in Figure 1.

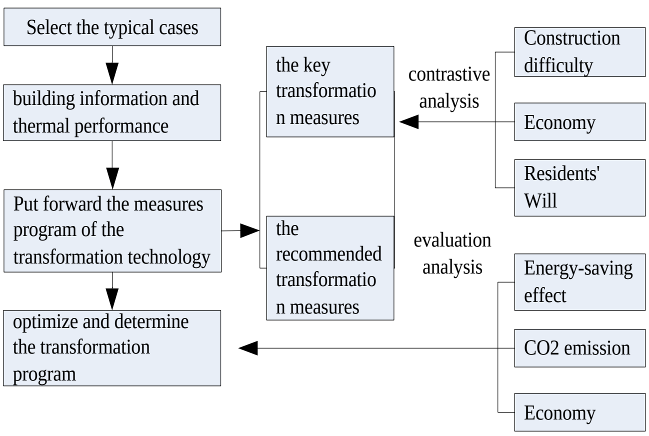

Figure 1. Flow chart of research method

3. Research on transformation scheme

3.1 Preliminary investigation and analysis

According to the detection, the residence has the typical timber and structure of the early 20th century, and the thermal performance is poor. The architectural features, physical properties of structural materials, environmental characteristics and other information were collected and recorded, and the representative test points of the building were selected to detect the indoor environment of the building in the transition season and the summer before transformation to analyze its energy saving status. The living environment of building 20 is quieter, and the PMV values of each test points in the spring were between -0.5 and 0.5. The indoor environment can basically ensure the comfort, but the indoor temperature and humidity change greatly with the outdoor environment in summer and winter. Therefore, the focus of energy-saving transformation is to improve the thermal insulation properties of the external envelop structure, and improve the comfort through measures such as shading. The specific thermal parameters are shown in Table 1.

3.2 Transformation program design

According to the survey results, we can provide a reasonable transformation idea, and calculate the energy consumption of each energy-saving programs through the energy-saving dynamic energy simulation software PKPM.

3.3 AHP method application of public participation in decision-making

Before the technical scheme combination, the researcher communicated with the residents through the communion meeting organized by community, and invited residents to discuss the main aspects of the project (A1 energy saving effect, A2 payment cost, A3 project quality, A4 the effects of construction on normal life, A5 the opportunity of residents participating in the views, A6 duration). There are total six evaluation indexes. The evaluation index of energy efficiency is established by using AHP (Analytic Hierarchy Process). The importance of each parameter is compared with each other by residents. They use "_2_2" five important numbers to represent the five relationships of "very unimportant" to "very important". The evaluation matrix is obtained by analyzing and calculating the residents' questionnaire, and the geometric mean of all the elements in each row of matrix is obtained. C.I. value of this survey is 0. 04528 <0. 1, and the consistency test results are ideal. Finally, the weight is obtained by the calculating and analysis of AHP formula, and it is as shown in Table 2.

3.4 Determine of the maximum comprehensive benefits of the program

From the AHP analysis, we can see that the residents are most concerned about the cost, energy-saving effect and duration. (Table 3 ~ Table 5). The final transformation plan was optimized and determined based on the factors such as the size of energy saving effect, difficulty in construction, economic investment and so on.

Table 1. Information and some thermal performance parameters of building 20 before the transformation

covered area	K value of external window	building superficial area	Height of building	Window-wall ratio	SC value of external window
3054.56m2	4.7W/(m2.K)	3065.80m2	15.3m	0.19	1
Shape factor	Average heat transfer coefficient of exterior wall	Thermal inertia index of external wall	Heat transfer coefficient of roof	Thermal inertia index of roof	building volume
0.35	2.2W/(m2.K)	3.64	2.12	2.37	10024.36m3

Table 2. Weight table of the importance of the evaluation parameters on the residential energy-saving of residents

Number	Indexes	Weight
A1	Energy-saving effect	0.212974
A2	Cost	0.222256

A3	Project quality	0.096471
A4	the effects of construction on the normal life	0.1141428
A5	The opportunities of residents participating the review	0.112817
A6	Duration	0.214054

Table 3. Energy-saving transformation program after optimization

Energy - saving measures	Instructions
Place the solar water heater on the roof and keep the water tank fixed on the solar energy equipment.	It can support residents use renewable energy, reduce the cost of living
The vertical green plant climbing frame is away from the building wall 50cm in the west, the lowest of the steel frame is away from the ground 3.5 m, and the part over the roof bands and extends. The plant is the winter leaves of Parthenocissus.	The setting of air interlayer is for the energy-saving effects and avoiding the disturb of mosquito and fallen leaves. The design of steel frame can prevent theft and is for the total attractive appearance.
Staircase is closed, the security doors are installed, and the balcony is unified outsourcing.	It can reduce the building shape coefficient, and improve safety performance.
Shade: In addition to having the architectural shading on the east side of the window, the removable shade is installed above the windows in north and south and west.	Removable shade is suitable to be used in hot summer and cold winter areas in different seasons, and the indoor comfort of the kitchen in the northwest direction is greatly enhanced
Doors and windows: use Xieda MFT-C6078 thermal insulation film (the visible rate is 65%, integrated thermal insulation rate is 75%, heat transfer coefficient is 1.03, integrated shading coefficient is 0.52, UV blocking rate is 99%).	The replacement of hollow windows and doors will destroy the original decoration of the residents, causing greater impact on the lives of residents. The film construction is simple and convenient, and the cost is lower.
Roof: the flat roof is changed into slope roof. The slope roof is the wind-induced roof.	Due to considering the total environment harmony and the votes of residents, the ventilation roof program is determined, and the flat-to-green program is given up.
Wall: 30mm rubber powder polystyrene particles thermal insulation mortar + coating.	The construction technology is the most simple, the duration is the shortest, the initial investment is small, and the comprehensive cost-effective is high.

Table 4. Some thermal performance of building after optimization

Body coefficient	Average heat transfer coefficient of exterior wall	Thermal inertia index of external wall	Heat transfer coefficient of roof	Thermal inertia index of roof	Solar radiation absorption coefficient of roof and exterior wall surface
0.35	1.24W/(m2.K)	4.12	1.85	2.74	0.5

Table 5. Energy-saving simulation results after optimizing the energy-saving transformation program

Programs	Energy consumption						Contribution rate of energy consumption
	Kmh/year			Kmh/(m2. Year)			
	Summer	Winter	Total	Summer	Winter	Total	
0	104002	171415	275417	35.84	59.08	94.92	
Optimization	85146	118709	203854	29.35	40.91	70.26	26.50

4. Conclusion

For the residential energy-saving programs, we should consider the energy-saving effect and economic differences of passive and active technology, but also evaluate the interest demands and acceptance of the parties on the transformation program, and analyze the effects of various stages of project implementation on the residents' living. We should determine the advantages and disadvantages of technical mean from the perspective of the overall life cycle of the building, and analyze the effects of this technology on the surrounding and urban environment from the perspective of urban ecological environment and urban landscape, a rationally design the programs to balance the interests of the body demands.

Because the different age and living habits of residents, so the residential energy-saving effect evaluation is different from public buildings. In addition to comparing the contribution rate of energy efficiency of the technical measures, we also should pay attention to their contribution rate of comfort improvement indoor environment. Therefore, we can choose a more appropriate technology combination. In the cases, the bathrooms of some buildings are air-conditioned towards stairwells. Therefore, in the transformation of stairwells, it can be hollowed-out structure rather than complete close, which sacrifices some energy-saving properties but ensures the practical functions.

Residential energy-saving transformation needs to rely on community strength to do the publicity and mobilization for residents. The residents' hearing is held through the close coordination of the Community Director and the staff to publicity and explain the transformation program, and to improve the recognition of residents on energy-saving work, which is very beneficial to improve work efficiency and achieve the transformation success.

Acknowledgments

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