Research on Building Energy Saving Reconstruction of Industrial Park in Urban Fringe Residential Area in Hot Summer and Cold Winter Area

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Abstract. We find that there are some problems in the process of energy-saving transformation of existing buildings in the urban fringe Industrial Park: according to the current norms, adopting standardized energy-saving transformation scheme, ignoring the actual energy consumption composition of local specific buildings. Based on this, we try to take the government led and household participation as the standard operation procedure to investigate the energy consumption situation, diagnose the weak links, evaluate the transformation results and determine the transformation scheme as the standard operation procedures.

1. Introduction

The implementation of energy-saving reconstruction of existing buildings can not only reduce the outdoor noise interference, but also effectively improve the indoor wet and cold conditions in winter and hot and humid summer in Wuhan area. This can improve the thermal comfort of the building interior. At the same time, it can also reduce the building energy demand and improve the building energy efficiency, which is of great significance to relieve the pressure of building energy consumption growth.

From the perspective of research and practice of energy-saving transformation, the urban fringe area is generally easy to be ignored, especially the industrial park on the edge of the city. However, the number of such residential buildings is large, and the difference is obvious with urban residential areas. They usually have a certain proportion of non-residential components (logistics warehouse, manual manufacturing workshops that mainly rely on Taobao and other online channels to sell goods, small and micro supermarkets, department stores, etc.), and thus affect the residential form (single residential function, mixed function of commercial residence, storage of goods and residential mixed function).

In addition, compared with urban residential areas, residents in urban fringe areas have certain requirements for indoor thermal comfort, but at the same time, due to their relatively low energy consumption capacity, the utilization rate of large and medium-sized air temperature and humidity regulating equipment is relatively low, on the contrary, they have a lot of operation space in passive energy-saving. At present, China has issued design standards for the construction industry (such as Residential Building Energy Efficiency Design in Hot Summer And Cold Winter Area, JGJ 134-2010)
and a series of local regulations are formulated based on the current situation of urban residents and urban housing, which are not fully applicable to residential buildings in urban fringe areas. The economic development of the latter determines that the adoption of such undifferentiated and comprehensive energy-saving measures (passive energy-saving & active energy-saving) in the energy-saving transformation of urban fringe residential areas will make the energy-saving effect and economic evaluation far away from the expected and greatly reduced.

2. Energy saving transformation scheme based on energy saving diagnosis

As mentioned above, based on the national design standard for energy efficiency of residential buildings in hot summer and cold winter zone (JGJ 134-2010), it has become the mainstream practice to carry out corresponding energy-saving transformation of existing residential buildings. However, careful analysis will find that the existing buildings are very different from the proposed buildings. The energy consumption and its influencing factors of existing buildings are relatively specific and fixed. It can be considered to obtain specific values directly or indirectly by comprehensive means such as field measurement and software data processing, which can be used as the basic data of later energy consumption analysis model, which can not be achieved by the proposed building. That is to say, in the case that the existing codes are not targeted, the existing residential buildings in urban fringe residential areas can take targeted transformation measures according to the main factors affecting the energy consumption of buildings by investigating the energy consumption situation, diagnosing the weak links, evaluating the reconstruction results, and determining the standard operation procedures of the transformation scheme to decide. \([1]\)

3. Case study and practice

Husi community neighborhood committee, Husi Town, Jiangxia District, Wuhan City, with a total area of 2.88 square kilometers, was officially established in 1996, with a population of 15050 people, 3428 households and 14 residential communities. The community is composed of four main streets and nine streets, including Fuqiao street, Nandun street, Liliang street and husilao street. The comprehensive renovation and reconstruction project of Industrial Park in Husi community is the construction project of "kouzi town" supported by the municipal government, with a planned investment of 30 million yuan. The design scope includes Nandun Street (the north end starts from the South Gate of town government, the south end starts from the intersection of Fuqiao Street), Fuqiao Street (the east end starts from the intersection of Hushu Road, the west end starts from the gas station), and the old street (the west end starts from Lake) The street is 3055 meters long. 355 buildings are planned to be reconstructed. The facade area is about 79847m². The landscape area is about 9000 m². It is expected to be completed before the end of June 2021.

3.1. Investigation on energy consumption of surrounding enclosure of existing buildings

According to the survey data, 335 buildings along the street are basically 1-4 floors, of which 15 buildings are 5-7 floors. Generally, there is no overhead floor, the building plane is mostly rectangular, and the figure coefficient is basically no more than 0.39. The classification and composition of the surrounding enclosure materials used in the existing buildings are shown in Figure 1, and there are basically no energy-saving structures and measures.

In the process of residential building design in hot summer and cold winter area, passive energy-saving method should be the first choice. Passive energy-saving mainly through optimizing the internal space layout and external shape of the building, in order to reduce the energy consumption of lighting, air conditioning and other systems by fully adopting appropriate technical measures such as natural ventilation, natural lighting, sunshade and thermal insulation of enclosure structure. This idea is equally effective in energy-saving reconstruction of existing residential buildings. Jiangxia District of Wuhan City, where Husi community is located, has been classified into Zone A in the climate zoning of energy-saving design of residential buildings in Hubei Province. There are two mandatory requirements: 1) the shape coefficient of buildings should be \( \leq 0.55 \) (\( \leq 3 \) floors) or \( \leq 0.45 \) (\( \geq 4 \) floors); 2) in rooms with natural
ventilation, the opening area of direct natural ventilation in kitchen should be \( \geq 10\% \) of the floor area of the room and \( \geq 0.60 \text{m}^2 \). The natural ventilation opening area of toilet, bedroom and living room should be no less than \( 8\% \) of the floor area of the room. According to the survey and statistics of the status quo, the two aspects of the prescribed indicators can basically meet.

In the next step, the emphasis should be put on the weight factor analysis of the actual energy consumption composition. After comprehensive consideration, we selected five typical buildings as the detection objects.[2] It includes C25 (1 floor, pure residential), B15 (partial 2 floors, the ground floor is China Post business and warehouse, the top floor is residential), h18 (2 floors, pure residential), A6 (3 floors, bottom floor for shops, upper 2 floors for residential), A18 (4 floors, pure residential), etc. The following is an example of h18.

The building is a masonry structure, the external wall material is white face brick veneer & 240 thick solid clay brick & mixed mortar (from outside to inside); the ground is 80 thick concrete cushion & gray floor tile (from bottom to top); the roof is cast-in-place concrete flat roof. During the detection, wires are used to connect the heat flow sheet installed at the tested parts (ring beam, lintel, partition wall, external wall, ground and roof) with the heat flow detector; the temperature detector is connected with the temperature sensor set around the heat flow meter with the wire. Then input the hourly value automatically recorded by the heat flow temperature detector into the computer, and calculate the data through the software to further verify the heat transfer coefficient.

The test results show that the actual heat transfer coefficient of h18 roof is 1.61 \( \text{w} / (\text{M}^2\cdot\text{K}) \), and the heat transfer coefficient of main part of exterior wall is 2.22 \( \text{w} / (\text{M}^2\cdot\text{K}) \).
3.2. Energy consumption weak link diagnosis of existing buildings

We use the DOE-2 as the core of building energy numerical simulation software t-bec for simulation analysis, and finally establish the model. The enclosure parameters of h18 are selected as follows. According to the design standard of low energy consumption residential buildings in Hubei Province, the solar radiation absorption coefficient ($\rho$) value of the white facing brick of the exterior wall is set as 0.50, the $\rho$ value of the roof (ordinary silica cement) concrete (pressing and plastering natural color) is 0.65; the internal thermal disturbance is set as 4.3w/m$^2$ for indoor personnel and equipment, and 0.59w/m$^2$ for indoor lighting. The calculation index of indoor thermal environment design in winter is that the indoor design temperature of bedroom and living room is 18 °C, and the ventilation rate is 1.0 times / h. In summer, the indoor design temperature of bedroom and living room is 26 °C, and the ventilation rate is 1.0 times / h. The energy efficiency ratio of heating and air conditioning is 3.0 in summer and 2.1 in winter.

The heating degree days (hdd18) and air conditioning degree days (cdd26) were 1657 (°C•d) and 235 (°C•d), respectively. We use t-bec to calculate the total energy consumption of buildings. It is found that the sum of annual power consumption for heating and air conditioning is 58.7 (kW•H / m$^2$). The annual energy consumption of heating and air conditioning is 65.7 (kW•H / m$^2$), which does not meet the requirement of 50% energy saving.

Next, we calculate the energy consumption by item. We first assume that the energy consumption of other sub items remains unchanged, and set this sub component in the system setting to be adiabatic (such as setting the shading coefficient of external window to 0). In this way, we first get the "total energy consumption of other sub items", and then subtract the "total energy consumption of other sub items" from the annual heating and air conditioning energy consumption to obtain the partial sub item energy consumption. If we find that there is an error, we will make the difference in proportion to each other. After revising the calculated energy consumption, we divide it by the whole year's heating and air conditioning energy consumption to obtain the specific energy consumption ratio of envelope. The calculation results of h18 energy consumption ratio are as follows.[3]

We found that the floor and roof accounted for about 10% of the energy consumption of the building envelope; the heat transfer and radiation of the external doors and windows reached 47%; and the energy consumption caused by ventilation and infiltration accounted for about 27%. Therefore, we can draw a conclusion that the key points of energy-saving reconstruction of external enclosure structure are external doors and windows, external walls and roofs.

3.3. Determination of energy saving transformation scheme and measures

About the exterior doors and windows.

It is found that there are two ways to cause the heat loss of the outer door and window: heat conduction, radiation and convection heat dissipation on the surface of the door and window; and the cold air infiltration in the gap between the doors and windows.[4] Therefore, according to the construction conditions and residents' opinions, we adopt the following transformation methods of external doors and windows:

1) Add insulating glass window, and keep the original window: if the net width of the inner window sill is less than 80mm, the insulating glass energy-saving window shall be added inside the original window, and the original window shall be retained.

2) According to the actual situation, the window frame can be replaced by aluminium alloy or steel window frame.

3) Glass replacement: when the external windows of existing buildings are plastic windows with air tightness grade meeting the requirements, the insulating glass shall be directly replaced and the window frame shall be retained.

4) Whole window replacement: when the performance of external window in existing building is poor and the original window frame cannot be used, the whole window shall be removed and replaced. The comprehensive heat transfer coefficient of the replaced external doors and windows should not be greater than $3.2w / (M^2•K)$. Generally, plastic window frame and $5 + 9A + 5$ insulating glass are selected.
About energy saving transformation of sunshade system.

Fixed sunshade and movable sunshade have relatively complex structure and high price. It also has the problem of service life and safety. At the same time, considering the new style of Han style residential buildings that should be reflected after the facade is updated, we generally adopt the method of glass film / coating (that is, the glass of existing external doors and windows is coated or pasted). The thermal insulation film of building glass shall be pasted on the interior surface of glass, and the comprehensive shading coefficient of external window shall not be greater than 0.5, and the visible light transmittance shall not be less than 0.4. This method can effectively improve the thermal comfort, but also has the advantages of simple construction and low cost.\(^5\)

About the roof.

As the roof involves the safety of the main body and load-bearing structure, we confirm whether to carry out structural reinforcement and energy-saving transformation simultaneously according to the site investigation and evaluation. The insulation layer is made of 30 thick polystyrene board. We Two times of polymer coating waterproof is adopted. The wood square of the water bar is directly fixed on the waterproof layer with the spacing of 500-600mm. The hydrophobic expanded perlite plate (thermal conductivity coefficient 0.068, correction coefficient 1.5, thickness generally 70, thermal resistance 0.69) is embedded. 30mm * 30MM wood square is used as the section of the water strip, and 30mm * 20MM tile hanging strip is fixed on the water strip, and then fixed on the tile hanging strip Cylindrical tile or plain tile.

About external walls.

Considering the unique climate characteristics of hot summer and cold winter area, the residents of Husi community generally improve the indoor thermal environment through intermittent air conditioning operation mode (cooling from July to September in summer and heating from December to January in winter). In this case, the principle of laying equal stress on heat preservation and heat insulation should be adopted for local building energy conservation. If we use the external wall internal insulation, although the construction is convenient, there is no hidden danger of the insulation layer and surface falling off, but the thermal bridge insulation at the floor and internal partition wall is difficult, and it will occupy the indoor space. Considering all the factors and combining with the results of computer simulation (the key points of energy-saving reconstruction of external enclosure structure: external doors and windows, external wall, roof), we decided to adopt external thermal insulation system. The thermal insulation material is foam ceramic insulation board (L type), the thermal conductivity is 0.080, the correction coefficient is 1.1, the thickness is generally 30, and the thermal resistance is 0.34.

4. Conclusion

We found that the research and design of the existing building energy-saving transformation of the industrial park in the urban fringe area is not suitable for the research and design, which leads to the failure of the standardized energy-saving transformation scheme to put forward convincing guiding suggestions for the designers and residents in the specific energy-saving practice. In view of this, our research should start from the actual energy consumption composition of specific buildings, we should analyse the optimization possibility of variables from the perspective of changing indoor thermal environment and thermal simulation, and then tap the energy-saving potential, and put forward targeted energy-saving measures, so as to put forward suggestions and ideas with universal guiding significance and strong operability.

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References

[1] Meng, L. (2014), Application of temperature control box heat flow meter method in field detection of heat transfer coefficient of building envelope. Journal of Jilin Jianzhu University, 124: 29-32

[2] Zhishun, Z. (2015), Application of ecological energy saving appropriate technology in existing building renovation design. Building Technology, 152: 110-112

[3] Daoyang, L. (2012), Numerical analysis of building energy consumption based on real-time monitoring by item. Journal of Guangxi University (Natural Science Edition), 231: 965-971

[4] Sheng, C. (2014), Research on energy saving reconstruction of existing residential building envelope in hot summer and cold winter area. New building materials, 251: 11-14

[5] Bailing, Z. (2018), Planning & Design of Industrial Park in the Urban Fringe. In: 2018 5th International Conference on Management Innovation and Business Innovation. St. John's. pp. 461-466