Study on fresh air load characteristics and energy saving measures of low energy consumption buildings in severe cold area

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Abstract. In order to study the fresh air load characteristics of low energy consumption buildings with different envelope structure parameters, combined with the law of fresh air load, energy saving measures were studied. Taking the ultra-low energy consumption building of Shenyang Jianzhu University as an example, the DeST simulation software was used to establish five groups of models with different envelope structure parameters for load simulation. The simulation results show that the fresh air heat load in model 1 to model 5 is 29.89%, 34.66%, 38.60%, 44.68% and 53.36% of the building heat load, respectively. The seasonal fresh air cooling load of air conditioning accounted for 13.78%, 13.85%, 13.88%, 13.99% and 14.05% of the building cooling load respectively. The thermal insulation performance of the envelope has great influence on the thermal load of the building, but little influence on the cooling load of the building. The better the insulation performance of building envelope, the greater the energy saving potential of fresh air load. Fresh air heat load is sensible heat load, and fresh air cooling load is mainly latent cooling load. From the theoretical point of view, the building adopts a heat recovery device with a heat recovery efficiency of 0.6, which can save 5989.91kW • h in the heating season and reduce the building heat load by 32.02%. In the air conditioning season sensible heat recovery device can save energy 131.45kW • h, reduce building cooling load by 1.56%; Total heat recovery device can save energy of 708.73kW • h and reduce cooling load of building by 8.43%.With the development of zero-energy building technology, the requirement of fresh air energy consumption is more strict, and the active all-heat fresh air heat recovery device is more suitable for this building. It also has more space for future development. This paper analyzes the change of energy saving potential of fresh air with the development of building envelope. The methods and ideas of reducing energy consumption of fresh air in low energy consumption buildings are discussed.

1 Introduction

In recent years, with the improvement of people's living standards, building energy consumption is huge, consuming 40% of the world's energy [1]. Fresh air volume is an important part of building energy consumption. Due to different standards of fresh air volume in different countries, energy consumption of fresh air system generally accounts for 20%-50% of the total building energy consumption [2]. In the research of low energy consumption and energy saving buildings, fresh air load has become the focus of people's increasing attention. The research results of Peng Yan and Chen Weijiao [3] show that for buildings with near zero energy consumption in cold and cold regions, the influence of fresh air volume on thermal load is much greater than that of cooling load. Lei Xiaohui et al. [4] showed that on the premise of meeting indoor air quality, the energy consumption of using fresh air system with heat recovery, fresh air system without heat recovery and window ventilation increased successively. K T. Papakostas and T. Slini[5] showed that with climate warming, the demand for fresh air load in cooling season increased, while the demand for heating season decreased. Zhongbing Liu et al. [6] summarized and analyzed the advantages, environmental adaptability and economy of different fresh air heat recovery devices in buildings.

At the same time, people reduce building energy consumption by increasing the insulation performance of the envelope. However, with the improvement of thermal insulation performance of buildings, the proportion of fresh air load in buildings is increasingly prominent. In order to better reduce the energy consumption of fresh air in buildings, this paper takes the ultra-low energy consumption building of Shenyang

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Jianzhu University as an example. Designer's Simulation Toolkits(DeST) is used to study the characteristics of fresh air load of residential buildings under different envelope structure parameters. Combined with the case simulation results and the actual situation, energy-saving measures are studied.

2 Model and Validation

2.1 Building introduction

The ultra-low energy consumption demonstration building is located in Shenyang Jianzhu University and belongs to the office building. The building height is 6.9m and the construction area is 334.8m^2. The cooling and heat source room is located on the west side of the building. The air conditioning system is fan coil unit plus fresh air system. The heat transfer coefficients of exterior wall, roof, window and ground of enclosure structure are 0.1W/m^2 • K, 0.12W/m^2 • K, 1.0W/m^2 • K and 0.1W/m^2 • K, respectively. The envelope structure conforms to the technical Standard for Ultra-Low Energy Buildings in Public Institutions (T/CECS713-2020) [7]. The main room functions as office, exhibition room and toilet, etc. The appearance of the ultra-low energy consumption demonstration building is shown in Figure 1.

Fig. 1. Ultra-low energy building

2.2 Simulation Parameter Setting

Taking Shenyang as a representative city in severe cold region, five groups of models (Model 5 as prototype) were established according to building parameters. The modeling steps were building envelope structure establishment, envelope structure parameter setting, outdoor parameter setting and indoor parameter setting. Take the office as an example. The temperature of the air conditioner is set to 24 ° C to 26 ° C in summer and 19 ° C to 21 ° C in winter. The humidity of air conditioner is 50% to 60% in summer and 30% to 40% in winter. Construction personnel density 0.1r/m2, per capita fresh air volume 30m3/hr. The heating season in Shenyang is from November 1st to March 31st, and the air conditioning season is from June 1st to August 31st. Table 1 shows 5 groups of model building envelope parameters. Except for different envelope parameters, other parameters are set in the same way.

Table 1. Five groups of building model parameters

Name	Outer wall (W/m^2·K)	Roof (W/m^2·K)	Window (W/m^2·K)
Model 1	0.50	0.50	2.00
Model 2	0.40	0.40	1.60
Model 3	0.30	0.30	1.40
Model 4	0.20	0.20	1.20
Model 5	0.10	0.10	1.00

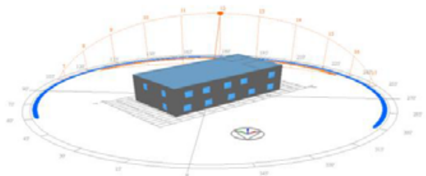

Fig. 2. Software architecture model

2.3 Simulation verification

This paper adopts the method of reference comparison to evaluate the model. Feng Guohui et al. [8] also take this building as an example and use DeST software to establish a building model to study the load characteristics of ultra-low energy consumption buildings. According to the comparison between model 5 in this paper and the quoted paper, the air conditioning running time is set to 9-17 hours in accordance with the comparison paper. The comparison results are shown in Table 2. The annual cumulative thermal load per unit building area is 36.90kW • h /m^2, and the annual cumulative cooling load per unit building area is 40.29kW • h /m^2. Heat load per unit building area is 10.07W /m^2 in heating season, and 12.25W /m^2 in air conditioning season. The maximum error of the four indexes calculated by the two software is 18.59%, and the error of the other three indexes is within 15%.

Table 2. Simulation results of heating and cooling load

Name		This paper	Quotation
Cumulative index	Coll	40.29	44.22
	Heat	36.90	34.89
Average indicatrix	Coll	12.25	10.33
	Heat	10.07	11.66

3 Study on energy saving of fresh air

3.1 Fresh air load analysis

With the increase of thermal insulation performance of the outer envelope of the model, the indoor heat load of the building decreased significantly, and the proportion of fresh air heat load increased significantly. From model 1 to Model 5, the proportion of fresh air heat load to building heat load was 29.89%, 34.66%, 38.60%, 44.68% and 53.36%, respectively. However, the increase of thermal insulation performance of external envelope has little influence on indoor cooling load, and the proportion of fresh air load has little change, which are 13.78%, 13.85%, 13.88%, 13.99% and 14.05%, respectively. With the increase of insulation performance of building envelope in cold region, the proportion of fresh air heat load increased more significantly than that of fresh air cooling load.

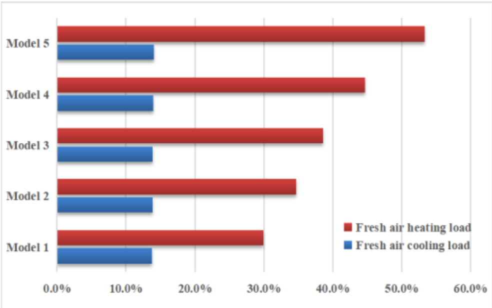

Fig. 3. Ratio of fresh air energy consumption

The energy consumption of the ultra-low energy consumption building is composed of house load and fresh air load. The proportion of building thermal load and cooling load is similar, and the cooling load is mainly room load. Mainly due to the fresh air temperature difference is small, as well as the impact of indoor device heat emission. Fresh air heat load is sensible heat load, and fresh air cooling load is dominated by latent cooling load. In addition, the monthly proportion of fresh air load in heating season and air conditioning season has little change, and the change of fresh air load is consistent with that of house load. The coldest month of heating season in Shenyang is January, and the hottest month of air conditioning season is July. Fresh air load in the coldest and hottest months is shown in Figure 4.

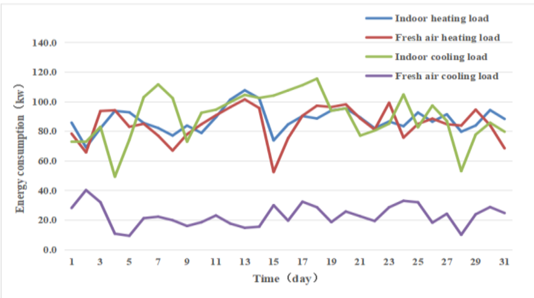

Fig. 4. Represents the monthly building load curve

3.2 Study on energy saving measures

At present, the commonly used fresh air energy saving measures in buildings are to install heat recovery devices, which can be divided into sensible heat recovery and total heat recovery according to the types of energy recovery. In order to clarify the applicability of the two fresh air heat recovery devices, energy and heat recovery calculations were carried out in the heating season and air conditioning season. When accurately calculating the heat recovery efficiency of the system, the increase of fan energy consumption should be considered. And different types of heat recovery devices differ greatly, the actual heat recovery efficiency and rated heat recovery efficiency are also different. In order to simplify the treatment, this paper ignores the increased energy consumption of the fan and only analyzes the change of fresh air load after the heat recovery device is adopted from an ideal perspective. The efficiency of sensible heat recovery device and total heat recovery device was set at 0.6. The heat recovery device in the building can save 5989.91kW • h in the heating season and reduce the building heat load by 32.02%. In the air conditioning season sensible heat recovery device can save energy 131.45kW • h, reduce building cooling load by 1.56%. Total heat recovery device can save energy of 708.73kW • h and reduce cooling load of building by 8.43%. The total heat recovery device is more suitable for this building. The total heat recovery device represents the monthly building load, as shown in Figure 5.

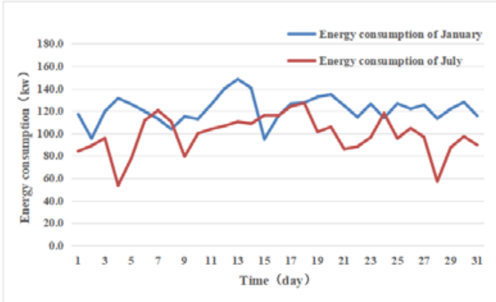

Fig. 5. Building load curve after total heat recovery

The fresh air heat recovery device can be divided into passive and active types according to the working mode. Passive fresh air heat recovery device relies on the energy difference between exhaust air and fresh air to exchange heat, while active fresh air heat recovery device relies on other energy to assist energy exchange. With the development of zero-energy building technology, the demand for fresh air energy consumption is more stringent, and the active fresh air heat recovery device have more space for development. Taking this ultra-low energy consumption building as an example, in addition to the large sensible heat load of fresh air in winter, there is also a high latent cooling load of fresh air in summer, so the installation of active fresh air heat recovery device can achieve more energy saving effect.

In addition, the summer night temperature in cold regions is generally lower than the indoor design temperature, and a reasonable ventilation strategy can greatly reduce the energy consumption of fresh air in buildings. With the development of computer technology, data detection devices can be installed at the entrance and exit of personnel in the future, and the new air volume can be dynamically adjusted according to the number of personnel in the building space to achieve the purpose of energy saving. The density of personnel distribution in the building space is different, and precise air supply according to the concentration of pollutants can better meet the needs of personnel comfort and energy saving. Innovative fresh air energy saving devices are also emerging in an endless stream. Solar preheating, heat pump heat recovery, phase change energy storage and other technologies are used to expand the research ideas for fresh air energy saving.

4 Conclusion

Taking the ultra-low energy consumption building of Shenyang Jianzhu University in severe cold region as a case study, 5 groups of building models were established with different parameters. The annual load simulation was carried out on the models of different envelope structure parameters by simulation software. Through this study, it is clear that the weight change of fresh air energy consumption caused by the increase of thermal insulation of buildings, and combined with the simulation, it gives suggestions on fresh air energy saving measures. The research conclusions are as follows:

(1) The better the insulation performance of building envelope is, the greater the energy saving potential of fresh air load is. The fresh air heat load in Shenyang is sensible heat load, and the fresh air cooling load is dominated by latent cooling load.

(2) From the theoretical perspective, the heat recovery device can reduce the building thermal load by 32.02% in the heating season, the total heat recovery device can reduce the building cooling load by 8.43% in the air conditioning season, and the sensible heat recovery device can reduce the building cooling load by 1.56% in the air conditioning season.

(3) The active total heat recovery device is more suitable for this building, and the methods and ideas of reducing energy consumption of fresh air in low energy consumption buildings are forecasted.

References

1. EERE, editor, The buildings technologies program, energy efficiency and renewable Energy, Building Energy data book, (2008)
2. D. He, et al, Application research and progress of indoor all-heat Fresh Air System for Passive Ultra-low energy Buildings, Shenyang Scientific Academic Annual Conference, (2019)
3. Y. Peng ,W. Chen, Research on Fresh air Load Characteristics of near-zero energy building based on DeST, Energy Conservation, 3(2020)
4. X. Lei et al, A Comparative Study on the Energy Consumption of Air-conditioning with Mechanical Fresh Air Systems and Ventilation by Opening Window, Science Technology and Engineering, 18(2018): 339-345
5. Z Liu, et, Review of energy conservation technologies for fresh air supply in zero energy buildings, Applied Thermal Engineering, 148(2018)
6. Papakostas K T , Slini T , Effects of Climate Change on the Energy Required for the Treatment of Ventilation Fresh Air in HVAC Systems - The Case of Athens and Thessaloniki, Procedia Environmental Sciences, 38(2017):852-859
7. China Engineering Construction Standardization Association, Technical Standard for Ultra-Low Energy Buildings in Public Institutions :T /CECS 713-2020, China Architecture and Architecture Press, (2020)
8. G. Feng, et al, Study on Load characteristics of ultra-low energy Consumption buildings in cold Region [J], Journal of Shenyang Jianzhu University (Natural Science edition) ,37(2021):724-729.