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ScienceDirect

Energy Procedia 70 (2015) 699 – 703

Energy Procedia

International Conference on Solar Heating and Cooling for Buildings and Industry, SHC 2014

The application of solar indirect system in passive house in cold region and severe cold region of China

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Abstract

This paper, the future developing prospect of application of passive house in China was provided, solar indirect system combined with fresh air ventilation system with heat recovery was used in designing to provide heat to meet fresh air load in the passive house, taking the Xining city as an example. The aperture areas of solar collector in different conditions were calculated by changing the influence factors such as the tilt angle of the collector and the solar fraction. This paper analyzed the relationship of the solar collector aperture area with the tilt angle of the collector and the solar fraction. On the basis of the analysis, it is safe to draw a conclusion that the program of using solar indirect system combined with fresh air ventilation system with heat recovery in passive house in cold region and severe cold region of China is economically feasible.

Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG

Keywords: passive house; solar indirect systems; heat recovery; tilt angle of solar collector; solar fraction; the aperture area of solar collector

1. The prospect of application of passive house in China

Under satisfied the condition of indoor comfortable thermal, humidity and lighting environment, application of passive house can minimize or even get rid of the dependence on active combustion of fossil fuels for heating and cooling systems.

According to the estimates from Technology and Industrialization Development Center of Ministry of Housing, P. R. China, it can save 3.4billion tons of standard coal, and limit the annual growth of heating energy consumption within 1 million tons of standard coal by 2050, if the new residential buildings in northern heating region are built to passive house standard. If all the existing residential buildings are transformed into passive house standard, the Annual energy consumption of heating can be reduced from 200 million tons to 15 million tons of standard coal.

Peer-review by the scientific conference committee of SHC 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.02.178

The total energy consumption of in northern heating region can be controlled within 50 million tons of standard coal by 2050, if both the new residential buildings and the existing residential buildings are built to passive house standard. It is significant and can help to fulfill China's commitments on the global energy conservation and emission reduction targets in 2020 at The United Nations Climate Change conference.

2. The application of solar energy in passive houses in cold region and severe cold region of China

Solar energy resource is considered the most striking 21st century renewable energy and clean energy. China is a vast country, and only uses the climate responsive low energy consumption building technology, rational utilization of solar energy and other renewable energy can effectively reduce the energy consumption, improve the indoor environment and reduce air pollution. So it has to be in conformity with our strategy of sustainable development and the circular economy policy that the energy demand of passive house can be provided by solar or other renewable energy sources, displacing of traditional energy.

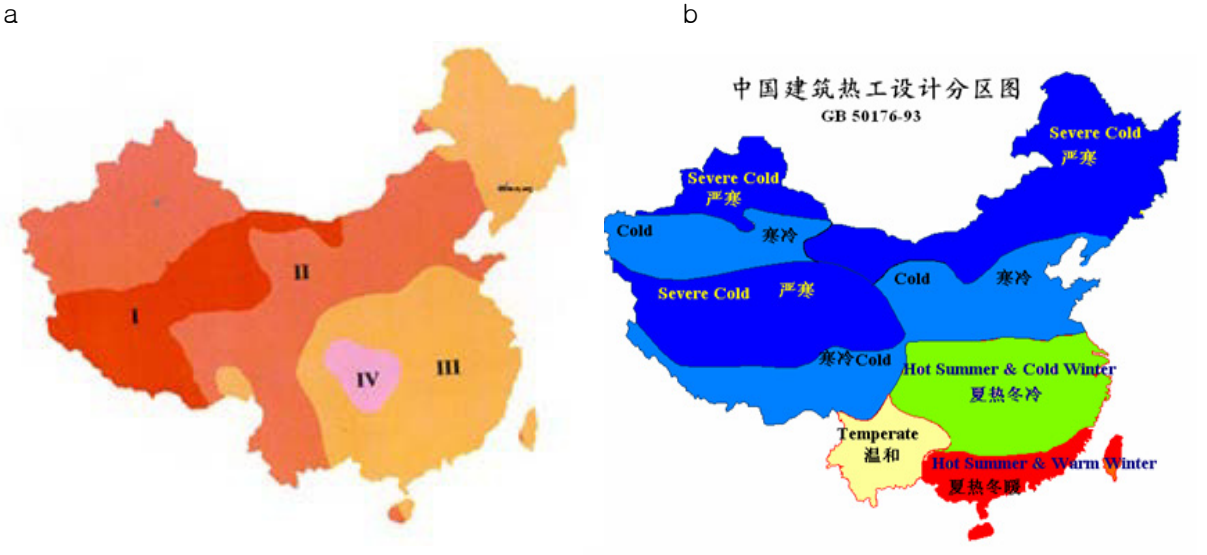

Fig. 1. (a) solar energy resources distribution of China; (b) building thermal design partition map of China

Table 1. Solar energy resources division of China.

Level	The annual sunshine hours （*h*）	Solar irradiation in the horizontal plane （$MJ/m^2 \cdot a$）
Ⅰ	3200～3300	＞6700
Ⅱ	3000～3200	5400～6700
Ⅲ	2200～3000	5000～5400
	1400～2200	4200～5400
Ⅳ	1000～1400	＜4200

By the above figure, it can be known that severe cold region and cold region of China overlaps with the northern and western areas which solar energy resources are quite affluent.

In cold region and severe cold region of China, if all the indicators meet the standard requirements, such as air tightness and other technical measures, only uses the heat gain of architecture can meet the needs of heating. But with the promotion of social development and living level, the higher indoor air quality is required, so fresh air

ventilation system with heat recovery often use to ensure the indoor air clean. When the heat-recovery heat is not enough to meet the fresh air load, renewable energy can be used.

3. The program of using solar indirect system combined with fresh air ventilation system with heat recovery in passive house

Solar indirect system is mainly utilized in passive house, which should combine with fresh air ventilation system with heat recovery to heat fresh air to supply air temperature. The heating area of solar energy resources is rich in China, both abundant solar energy resources and appropriate climate condition in the northern and western areas of China provide advantageous condition to apply the new type of solar indirect system combined with fresh air ventilation system with heat recovery in passive house.

The household system Diagram is as follows:

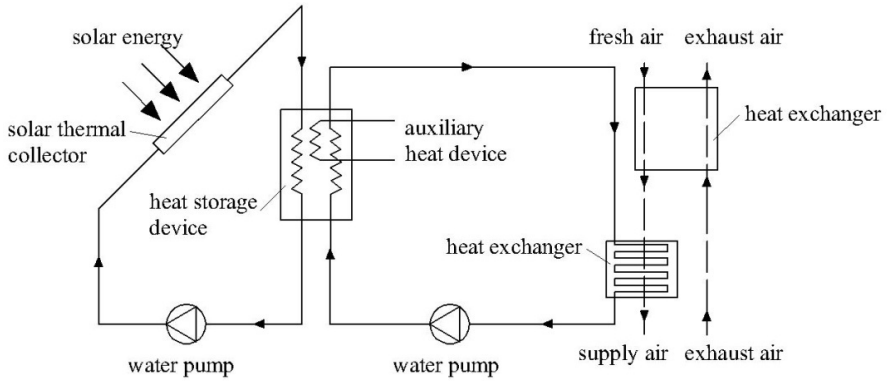

Fig. 2. The household system Diagram

4. Introduction of calculation method

This paper, solar indirect system combined with household fresh air ventilation system with heat recovery was used in designing to provide heat to meet fresh air load in the passive low energy consumption building, taking the Xining city as an example. In cold region and severe cold region of China where the air humidity is low, it is better to adopt sensible heat reclaiming device than total heat reclaiming device. So in this paper, the system used sensible heat reclaiming device, according to the standard of the passive house the sensible heat efficiency is 75%.

Condensation will occur when the fresh air temperature is low, so this increase the fresh air side temperature and the wall temperature of the heat exchanger up to dewing temperature of the indoor air environment, thus prevent the heat exchanger from dewing and corrosion. Considering the complexity of the system, this paper only presented one condition of using solar indirect system to heat the fresh air which after heat-recovery ventilators to the required temperature (according to the standard of the passive house the indoor air temperature is above 20 degrees centigrade)without the preheating.

According to the "urban residential area planning and design specification" household number is 3.2; according to the regulations of the national standard GB/T18883-2002, the fresh air should not be less than 30 m^3 every hour. By the above-mentioned data the quantity of fresh air per household can be calculated.

Local monthly average temperatures were used to calculate monthly fresh air loads, and calculate recyclable heat according to the formula of heat exchange rate in the processes of the exchange of heat .The remaining part of the loads were provided by solar indirect system. Based on these calculations, the aperture areas of solar collector in different conditions were calculated by changing the influence factors such as the tilt angle of collector and the solar fraction.

Using the solar heating optimization design software which developed by China Academy of Building Research to calculate, choose one type of solar thermal collector that efficiency equation as shown below:

$$\eta_i = 0.7318 - 5.68T_i^* \quad (1)$$

5. The calculation results

This paper calculated the aperture area of solar collector in different conditions of each household, and analyzed the relationship of the solar collector aperture area with the tilt angle of collector and the solar fraction, shown in the figure below.

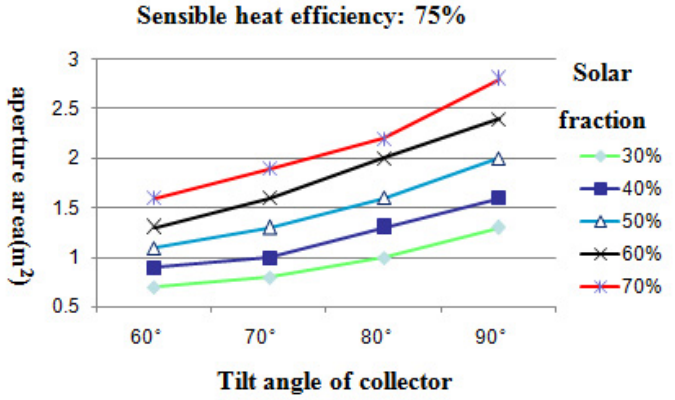

Fig. 3. The calculation results

According to the results, in the case of the solar fraction fixed, with the growth of the tilt angle of the solar collector, the aperture area of solar collector was larger. It attained the largest aperture area of solar collector when the collector was vertical installed facing south i.e. the tilt angle of the solar collector was 90° . In the case of the tilt angle of the solar collector fixed, with the increase of the solar fraction, the aperture area of solar collector was larger. When the solar fraction and the tilt angle of the solar collector were respectively 70% and 90° , the aperture area of solar collector was the largest, which was only 2.8m^2 and was smaller than the regular solar heating system one.

6. Confirmation of the results

In order to verify the calculated feasibility and accuracy, an example is not only computed by the formulas given by the paper, but also simulated by the TRNSYS program. The aperture area of solar collector was set as 2m^2, the rest of the parameters remain the same. According to the result of simulation shows that there is a little distinction between these two kinds of software calculation results is.

7. Conclusion and prospect

In conclusion, the program of using solar indirect system combined with fresh air ventilation system with heat recovery in passive house in cold region and severe cold region of China is economically feasible.

In order to verify the calculated feasibility and accuracy, the TRNSYS program will be used to further deepen the simulation, it indicate that it's feasible to utilize the results to instruct the design of demonstration project of passive house in cold region and severe cold region of China.

Besides, with the construction of the demonstration project, the calculation results can be validated by comparing the design value and the actual value. And the empirical research on the construction of the demonstration project will be carried out.

Acknowledgements

The author wishes to express thanks to Sun Zhifeng and Wang Xuan for the valuable discussion and recommendation.

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