OPEN ACCESS

1st World Sustainability Forum
1-30 November 2011

www. wsforum.org

Article, Review, Communication (Type of Paper)

Analysis of Energy Consumption of Change Indoor Fresh Air in Sustainable Residential Buildings

Yueren Wang [1], Nan Wu [1,*], Jing Zhang[1]

[1]Shenyang Jianzhu University/ No.9, Hunnan East Road, Hunnan New District, Shenyang City, Liaoning, P.R.China
E-Mails: hj_wyr@163.com; wunan_0611@163.com; sunflower88869@sina.com

* Author to whom correspondence should be addressed; Postcode: 110168; Tel.: +86-24-24690117; Fax: +86-24-24692696

Received: / Accepted: / Published:

Abstract: Sustainable development is an important symbol of civilization. When people improve the life standards gradually, it becomes a challenge between the energy consumption growth and sustainable development. Due to the important influence of the IAQ in residential building on human body, more and more people pay attention to air exhaust in kitchen and toilet and the supply of fresh air which increase the energy consumption. In this paper, in order to deal with the contradicting problem of energy saving and also keeping IAQ in the residential buildings, we simulated different kinds of operation conditions of air exhaust in kitchen and toilet and fresh air supplement in heating period in a residential building in northern China and analyzed the energy consumption caused by entered outdoor fresh air in different conditions.

Keywords: IAQ; sustainable residential building; energy consumption .

1. Introduction

Within a residential building in northern China, fresh air entering into indoor is from the cracks of doors and windows in winter, and the ventilation air exchange rate is 0.5 times/hour in design calculation. But it is really not enough when kitchen ventilator and toilet exhaust system turn on,

which means to install a fresh air system to control ventilation is necessary. There is no doubt that additional fresh air can improve the room IAQ, but the energy consumption will increase greatly. In order to construct the sustainable residential buildings, we should seek appropriate ways in sustainable use of energy sources.

2. Methods

2.1. Object of Study

In this paper, software DeST-h is used to simulate and analyze the fresh air load consumption in a residential building which hourly changes with the outdoor temperature. The architectural model is one residential building unit in Shenyang, Liaoning province, China. The total construction area is 1185.3 m^2, six-stories, one staircase with two flats. Each flat with area 85.66 m^2 contains two bedrooms and living rooms, one kitchen with area 8.6 m^2 and one toilet with area 8.6 m^2. The building is towards the south, and each floor height is 2.9 m. In the heating period from 1st November to 31st March, all heat transfer coefficients (HTC) of building envelopes are shown in table 1:

Table 1. The HTCs of the envelope structures

Envelope structures	Exterior wall	roof	Exterior door	Exterior window
HTCs [W/m^2 K]	0.45	0.6	1.5	2.2

2.2. Analysis of Ventilation Effect When Kitchen and Toilet Exhaust Units Turn on or off

A sustainable residential building should have perfect indoor air quality. Health ventilation is the minimum standard to ensure good IAQ within the building. Therefore, sanitary ventilation is essential for kitchen and toilet when there is only natural ventilation in the building.

When indoor fresh air is introduced by using a fresh air supplement system, the indoor air stream is organized well, and kitchen and toilet exhaust systems are turned on at the same time, which are helpful for replacement of indoor air with outdoor fresh air, the IAQ within the building is improved adequately. On the contrary, if the exhaust systems switch off, the bedroom air pollutants (the concentration is lower) cannot be discharged out centrally from the kitchen and toilet (the concentrations are higher), and the IAQ in the bedroom deteriorates instead.

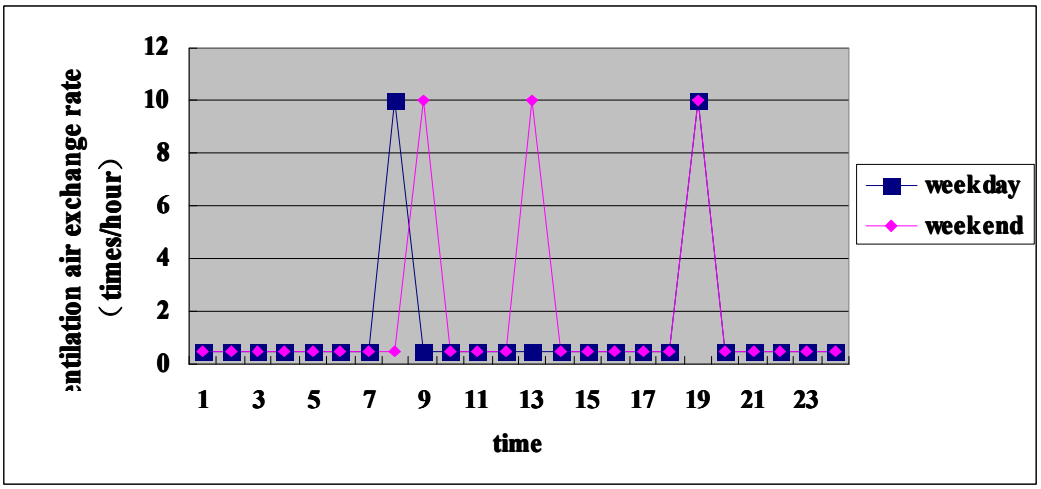
Overall heating load of the building rise up because of the increase of fresh air, if we use whole-heat-recycle fresh air system, the exhaust heat can be recycled effectively in the heating season, and the wasted heat is reused again. In this way, the amount of fresh air heat load in winter is reduced; to the same reason, the cold load in summer. And the fresh air system could save some energy, protect the environment, improve economy and equipment utilization ratio, and reach to functionally sustainable residential building more easily.

Therefore, turning on the kitchen and toilet exhaust systems effectively can ensure the sustainable development of indoor environment in a certain extent.

2.3. Ventilation Schedule When Kitchen and Toilet Exhaust Units Turn on

The ventilation schedule of kitchen ventilator is regular, because occupants commonly choose turn on it in the cooking time. Most cooking times in residential building are at 7am and 6 pm in weekday, and 8 am, 12 am and 6 pm in weekend. At these times, the ventilation air exchange rate of kitchen ventilator is 10 times/hour, at the other time is 0.5 times/hour, the schedule is shown in Fig.1.

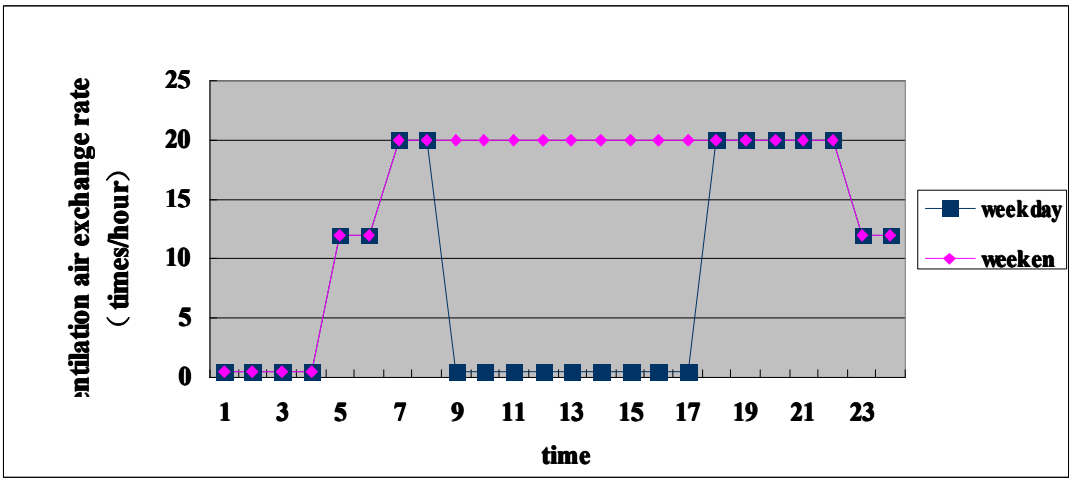
Figure 1. The ventilation schedule of kitchen ventilator



Due to the different living methods of the occupants, the ventilation schedules of toilet are random. People usually set the emission volume 100~250m^3/h which could be converted into ventilation air exchange rate 10~20 times/hour in actual design. In order to guarantee organized emitting the indoor air sufficiently, the turning on time of exhaust unit in toilet confined to the time when occupants use, it is based on occupants' schedules to set the ventilation schedule. We took the following two modes:

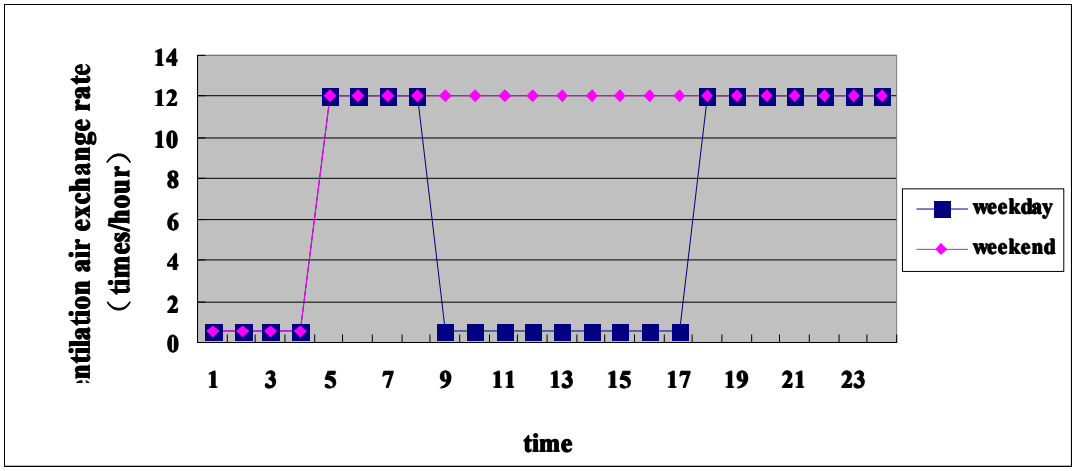
Mode A: When occupants were activity in the room we took maximum ventilation air exchange rate 20 times/h, before and after sleeping 2 h 12 times/h, the others 0.5 times/h, then 24 h fresh air change rate in weekday and weekend were shown in Fig.2:

Figure 2. The ventilation schedule of toilet in Mode A



Mode B: When occupants were activity in the room we the took ventilation air exchange rate 12 times/h, the others 0.5 times/h, then 24 h fresh air change rate in weekday and weekend were shown in Fig.3:

Figure 3. The ventilation schedule of toilet in Mode B



2.4. Analysis of energy consumption of the fresh air load

According to "Residential Building Energy Efficiency Design Standards in Severe-cold and Cold Area" in China, residential building's ventilation air exchange rate in indoor thermal environment of heating in winter is not less than 0.5 times/h[1]. In this paper, the basic ventilation air exchange rate is chosen 0.5 times/h in the study case, the fresh air heat loads of Exhaust Units in different cases in kitchen and toilet are calculated and compared.

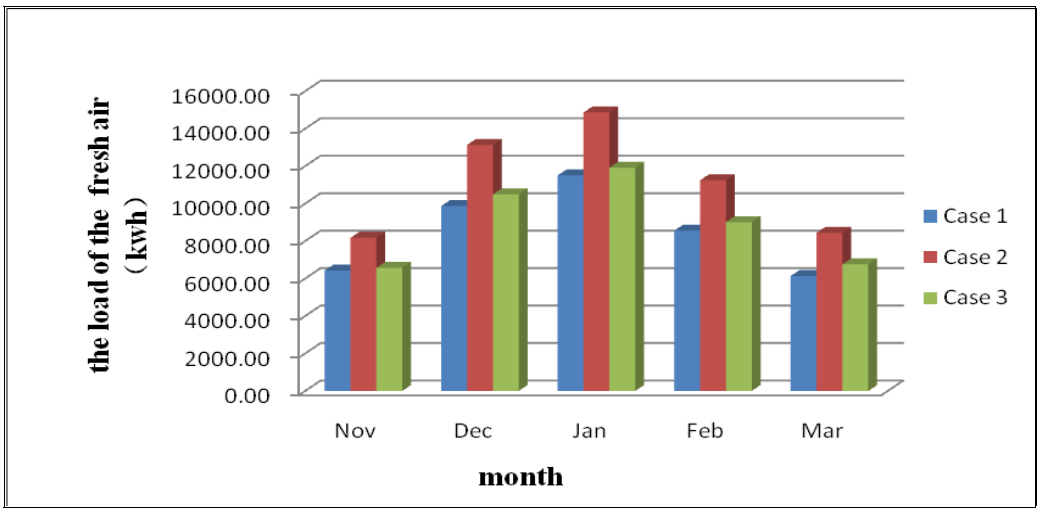
Case 1: when neither the kitchen ventilator nor the toilet exhaust system turns on, the natural ventilation air exchange rate is 0.5 times/h;

Case 2: when both the kitchen ventilator and the toilet exhaust system turn on, toilet exhaust chooses the Model A;

Case 3: when both the kitchen ventilator and the toilet exhaust system turn on, toilet exhaust chooses the Model B;

We calculated the hourly fresh air heat load and accumulated them from month to month in the heating season to each case, the summation are shown in the Fig.4:

Figure 4. The summation of fresh air loads of three cases



The results show that the fresh air load increased obviously when both the kitchen ventilator and the toilet exhaust system turn on, the maximum load is in January.

3. Results and Discussion

We accumulated the fresh air heat load in heating season and compared their relative increase rates among three cases by using equation (1):

$$\eta_i = \frac{q_i - q_1}{q_1} \times 100\% \quad (1)$$

where: η_i —relative increase rate, %;

q_1 —The building fresh air load of Case 1 (basic condition) in heating season, kWh;

q_i —The building fresh air load of Case 2 or Case 3 (i=2,3) in heating season, kWh;

The computation results are as follows：

Case 1: The basic building fresh air load in heating season is 42480.15kwh;

Case 2: The building fresh air load in heating season is 55853.88kwh; the relative increase rate is 31.48%;

Case 3: The building fresh air load in heating season is 44738.39kwh; the relative increase rate is 5.31%.

The calculation shows that: the relative increase rate of the fresh air is 31.48% when we choose Case 1, and 5.31% Case 3. From the comparison we know that the load is not the major problem of the energy consumption in residential building as people thought when we control air intake properly. Outdoor fresh air replace indoor air sufficiently by bringing in fresh air initiatively, the IAQ is improved in this ventilation type which avoids the indoor environment damage and the Sick Building Syndrome as well, in this way the sustainable development of human being and environment is safeguarded essentially.

4. Conclusions

1. For sustainable residential buildings, as the pollution sources are concentrated in kitchen and toilet, it is essential for turning on the kitchen and toilet exhaust systems timely; but the toilet exhaust units' running time to remove the pollutants should be extended a little.

2. Indoor fresh air indraught through a fresh air supplement system, not only could control indoor and outdoor air exchange, but also supple the fresh air in time, so that the exhaust system can discharge hazardous substances produced from furniture, decoration materials, and human activities effectively, ensure indoor health conditions. Although the power consumption increases because of installing fresh air equipment, the air supplement reduces the negative pressure in kitchen and toilet, the pressure head of the fan of the exhaust system will be reduced, so as the system power consumption, both of them can offset some energy consumption. As people consumption demands are diversification, inventing new technology and new products which are safe, energy-saving and environmental safety becomes the necessary means constructing and developing sustainable residential buildings.

3. When the fresh air is supplied in an organized way, its heat load will not make the whole building heat load increase blindly. Physical and mental health of people can benefit from a fresh and clean air in the room. And the supplied fresh air improves IAQ in certain extent, creates a comfortable living environment for occupants. Energy saving should not be pursued at the cost of our healthy and comfortable environment, we should guarantee the basic physical and mental health of people and try to take measures to reduce the energy consumption in fresh air supply systems, it is significant for the mankind to survive and to develop sustainably.

Conflict of Interest

The authors declare no conflict of interest.

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