BUILDING USE MODES IMPACT ON SIMULATION RESULTS AND SCHEME EVALUATION

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ABSTRACT

Building use modes are important for energy consumption simulation. But few research concerns building use modes, such as people behavior of opening/closing window, room temperature for air-conditioner running, and air-conditioning space and time. In this paper, a more reasonable and practical use mode approaching the reality is proposed for building performance simulation. And this mode is compared with a 'standard use mode' common used in most simulation tools. Results show different building use modes will influence simulation results—energy and economic evaluation for one scheme.

KEYWORDS

Building use modes; Building thermal simulation; Building air-conditioning energy consumption

INTRODUCTION

Building simulation plays a key role for building energy consumption analysis. More and more, people depend on simulation tools for building envelope design and HVAC system design, such as DOE-2, DeST. With these simulation tools, it is possible to predict energy consumption, after giving the information of climate data, building envelope parameters and building use modes. Above all, it is well known that building energy consumption varies greatly with different climate condition. Usually, climate data used for building performance simulation is typical-year data. Typical-year data can be achieved by the treatment of meteorologic data coming from observatory under some mathematic methods. Secondly, kinds of building envelope parameters are necessary for estimating energy consumption, such as wall configuration, windows surface and its thermal properties. Thermal properties of building envelope are always considered as the most important part for energy efficient building development. So, numerous energy-saving measures are proposed for optimizing building envelope parameters, enhancing building energy efficiency.

But few research concerns building use modes. In most simulation tools for evaluating building annual energy consumption, building use modes are often setting as: air-conditioner runs every hour for each room (continuous air-conditioning), room temperature is 18℃ in winter and 26℃ in summer, fresh air flow rate is fixed at a constant value. These setting conditions are considered as one standard use mode. Under this mode, energy consumption can be compared for evaluating different building envelopes. Furthermore, based on energy consumption under this standard mode, energy and economic scheme of a project is compared. However, this standard use mode is far from use mode actually. In fact, people often regulate room temperature by opening/closing window (particularly in period of transition between winter and summer) rather than by using air-conditioner every hour. If necessary, people only turn on room air-conditioner if people stay in room (intermittent air-conditioning) rather than all rooms air-conditioning every hour (X.L Zhang 2005).

For most people, people often turn on air-conditioner only when they feel hot (for example 29℃ in summer) or cold (for example16℃ in winter) rather than once 18℃ in winter and 26℃ in summer. This point is validated by a survey from more than 1000 families at Shanghai. Certainly, energy consumption under reality use mode has great difference from the standard use mode, so as to energy and economic scheme evaluation. To weaken the influence of these the problem, a more reasonable and practical use mode approaching the reality is necessary for building performance simulation. Evidently it is not possible to have one use mode is same with the reality. But one mode relative close to the reality is our target and will benefit simulation results, also scheme evaluation.

Therefore, some models are developed for approaching the reality in simulation tool DeST. Opening/closing window is modeled by different fresh air flow rate entering room. If fresh air temperature (humidity) is comfortable (relative to room temperature), a higher ventilation rate is used in simulation for modeling the window opening. On the contrary, if fresh air is not comfortable, the window is closing, and a lower ventilation rate is taken for simulation. For every hour in the year, a all-year schedule model simulating if people stay in room hour-by-hour is introduced. Only at the time when some people stay in room, it is possible that the room have to need air-conditioning. A temperature model called "tolerance temperature" (Y.W Jian 2003) is introduced to simulating the temperature limit at which people feel hot or cold.

If room temperature in not in the limit of tolerance temperature, air-conditioner will be turning on.

SIMULATION AND ANALYSES

Model Building Information

A residential building is taken as simulation object, shown in Figure1. This is a typical residential building at Shanghai in China. The building has 12 floors, 2.9m height for each floor, 4 apartments for each floor, 119m^2 for each apartment. One apartment has three bedrooms, one living room, one toilet and one kitchen.

Building use modes setting

According to aforesaid, two building use modes are planed as shown in table1.

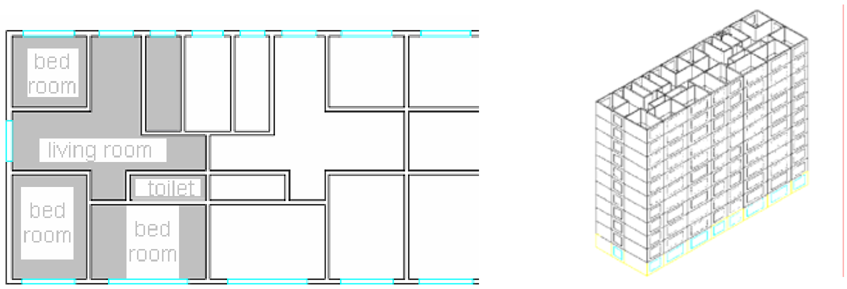

Figure 1 Model building

Table1 building use modes

No.	Ventilation	Tolerance Temperature	Air-conditioning Setting Temperature	Air-conditioning Space and time
Mode 1：	Flow rate is constant: Window closing 0.5 time/h	18-26℃	Summer：26℃ Winter：18℃	All year, every room continuous Running;
Mode 2：	Flow rate is variable Window opened 8 time/h Window closed 0.5 time/h	16-29℃	Summer：26℃ Winter：18℃	Intermittent running Time/space distributing in room Schedule shown as Table 2； No air-conditioner in kitchen and toilet

*Table 2 People Time/Space Distributing in room **

<table>
<tr><td colspan="2"></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td></tr>
<tr><td rowspan="2">Bedroom</td><td>day-on</td><td colspan="8">1</td><td colspan="14">0</td><td colspan="2">1</td></tr>
<tr><td>day-off</td><td colspan="24">1</td></tr>
<tr><td rowspan="2">Living room</td><td>day-on</td><td colspan="18">0</td><td colspan="6">1</td></tr>
<tr><td>day-off</td><td colspan="9">0</td><td colspan="15">1</td></tr>
</table>

* zero in this schedule means not people in room at the hour, vice versa.

Simulation results

Here we analyse firstly the building with traditional envelope. Thermal parameters of model building envelope is brick wall (U=2.0 W /m2·K), concrete roof (U=2.0 W /m2·K), single window (U=6.6 W /m2·K, Shading Coefficient=0.9), Window/Wall surface ratio(South=0.45, North=0.4). Inner heat gain in simulation is supposed as 4.3W/m2

Under different building use modes, Model1 and Mode2, energy consumption is simulated. The results are shown in Figure2. It can be seen from the figure that heating and cooling electricity consumption of Mode1 are 14.7 kWh/m2·year 21.6kWh/m2·year, the same of Mode2 are 11.7 kWh/m2·year,8.1 kWh/m2·year. Comparing the results of Mode1 and Mode2 shows that heating and cooling electricity consumption are different. Particularly, cooling consumption of Mode 2 is much less than that of Mode1, mainly owing to window opening rather than using air-conditioner. Total electricity consumption of Mode1 is nearly 2 time of Mode2.

In Fig.3, two modes are compared in detail by hour in one day of June. It can be seen from Fig.3(a), air-conditioner has to run for maintain room temperature at 26℃ in Mode1, on the country, room temperature is always less than 29 ℃ without air-conditioner running. And from Fig.3 (b), it indicates that window is opened from 0 to 11 clock and 11 to 23 clock in Mode2. Because people would like a cool ambience in summer, window is closed from 11 to 19 clock when outdoor air temperature is higher than room temperature. Ventilation flow rate is 8 time/h and 0.5 time/h for window opened and window closed respectively. However, in Mode1 window is always closed with ventilation flow rate at 0.5 time/h.

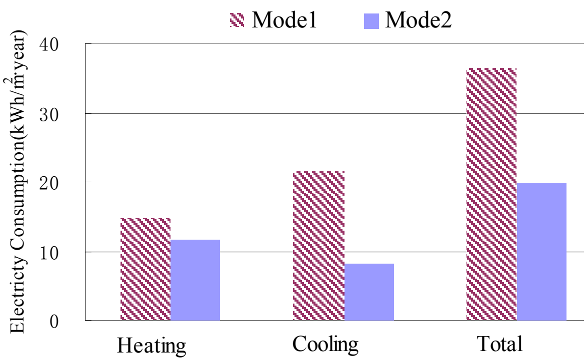

Figure 2 Annual electricity consumption comparisons

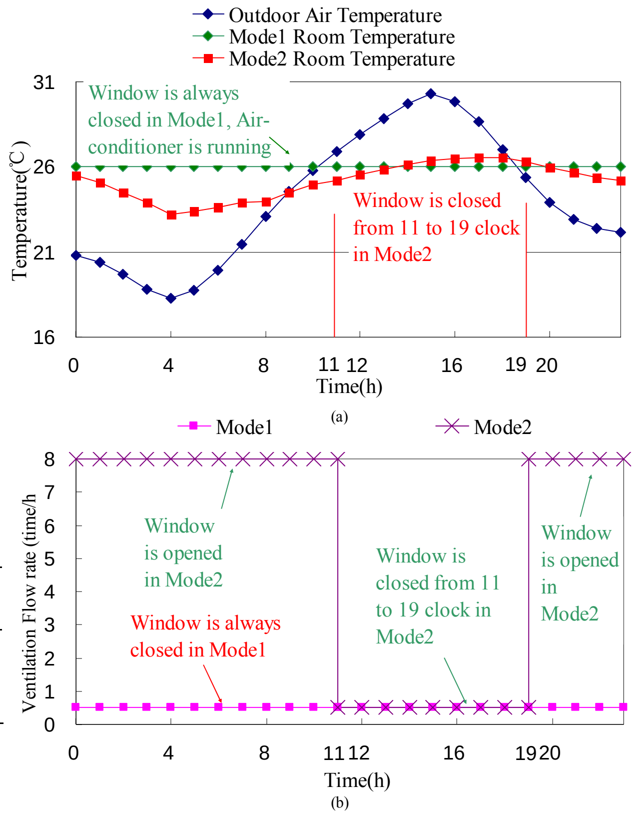

Figure 3 Comparison for temperature and ventilation flow rate

Table3 Envelope thermal parameters

	Traditional envelope	Improved1	Improved2	Improved3
U (Outer wall)	2.0	1.5	1.0	0.7
U (Roof)	2.0	1.0	0.7	0.5

As well known, annual energy consumption is a key and basic data. This value is often considered as benchmark for optional scheme in energy and economic and will be important for scheme optimization design. As mentioned before, annual energy consumption varies with different building use modes setting in simulation. Evidently, the different setting in simulation will influence the choice of optional scheme.

In the following, energy reducing by improvement of envelope is compared under different building use modes. The envelope heat transfer value is the limited index for many country energy efficient building design standard. In certain extent, decreasing envelope heat transfer value will be efficient for reducing energy consumption, particularly for heating consumption.

It is assumed that U value of envelope is divided into 4 grades as Table3. Other traits of the building keep unchanging.

Electricity consumption saving for heating and cooling by improvement of envelope is shown in figure. From this figure, it shows annual electricity consumption saving relative to traditional building envelope increase with the U value decreasing no matter under Mode 1 or Mode 2. And the relative variation rates(RVRs) are different also.

Obviously, annual electricity bills predicted of Mode1 are different from Mode2. For example, to scheme Improved2, annual electricity saving relative to traditional building envelope is 4.5 kWh/m2·year and 3.8 kWh/m2·year, and electricity bill is 7.3Yuan/ m2·year and 8.8 Yuan/ m2·year. The difference electricity saving and bill saving between these two modes are 1.7 kWh/m2·year and 1.5 Yuan/ m2·year respectively. Furthermore, pay-back period of investment for improvement of envelope (20yuan/m2) is nearly 7year and 9year to Mode1 and Mode2.These difference will lead to the different evaluation for envelope improvement. Clearly, relative Mode1, Mode2 is more close to the real mode practiced by Shanghai people. So, scheme evaluation based on Mode2 is more reasonable.

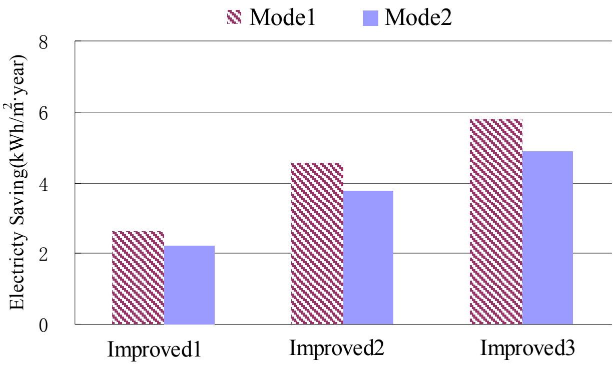

Figure 3 Electricity consumption saving of improved envelope

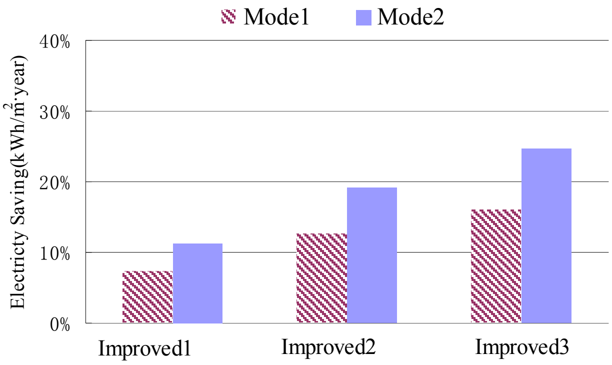

Figure 4 Electricity consumption saving of improved envelope relative to traditional building

CONCLUSION

The importance of this paper is that it reveals, being a setting condition in simulation tool, building use modes will influence simulation results, energy and economic evaluation for one scheme. Therefore, a more reasonable and practical use mode approaching the reality is necessary for building performance simulation. This will benefit simulation results, also scheme evaluation.

REFERENCES

Y.W Jian. Research on evaluation method of thermal performance of residential building：[Ph.D these]. Beijing：Tsinghua University，2003

X.L Zhang. J.ZHU Y.JIAN Residential building simulation case study, 2005