Performance Evaluation of Residences by Dynamic Simulation: Heat Load Based on Changing the Location, Plan and Specification of Residences

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Abstract
The Japanese residential energy saving standard for new house generation was modified in 1999, in which "specification standards" were provided as decision criteria for designers. However, there are several methods for lowering the energy consumption of houses which are not evaluated by these standards.

In this paper, we predict the change in heating and cooling load by difference of location, planning and specification of a model house, which are not evaluated by "the specification standards". We then examine the effectiveness of passive energy methods which are also not considered by the standard.

Keywords: energy saving standard; performance standards; heating and cooling load; specification standards

1. Introduction
The Japanese residential energy saving standard for new house*1 generation was modified in 1999 as an amendment to the residential Energy Conservation Standard established in 1980. The aim of this standard was to control carbon dioxide emissions to mitigate global warming, by lowering the energy consumption of houses.

Within the standard, "specification standards" were provided as decision criteria for designers, and "performance standards" were provided as decision criteria for buyers.

In addition, resident consideration of energy conservation has improved in recent years. Therefore, we consider that the examination of energy saving techniques for houses at the time of designing should also be promoted more diligently hereafter. Generally, we examine floor planning, blinds, insulation thickness and interior specifications, etc. when we design a detached house.

The designer should select the best within the budget, the function and the other demands of the client, etc. When the building is used, heating and cooling load changes primarily affect the residents.

Although there is a standard specifying the thickness of insulation etc., there is neither a concrete numerical value nor criteria for professional judgment when designing a house; for example, how each design element influences the heat load is not indicated by the current standards.

In this paper, we predict the change in heating and cooling load by difference of location, planning and specification of a model house, which are evaluated as the same by "the specification standards". We then examine the effectiveness of passive energy methods which are also not considered by the standard.

We used the Thermal Environment of Residential Buildings "THERB"*2 dynamic simulation software.

1.1 Past studies
A large amount of research has been carried out on passive methods for energy reduction of residences. Mutou and Kodama*3 studied the effect of climate on heat loads. K. Hiwatashi et al.*4 and T. Hagihara et al.*5 focused on the relationship between energy consumption and shape of houses. H. Takeda et al.*6 examined the difference between the new standard and the former standard. Each research was carried out by establishing a model house based on the Energy Conservation Standard; however, none of the research examined the effectiveness of passive energy methods which are not considered by the standard.

2. Outline of the Energy Saving Standard
The energy saving standard has seven areas based on different climates (Fig.1.). Each area has two standards: "specification standards" were provided as decision criteria for the designer, and a "performance standard" was provided as a decision criterion for the client.

Table 1. shows the performance standard of the heating and cooling load of each area.
3. Outline of Calculation

3.1 Building profile of a model house

Table 2. shows the building profile of the model house and Fig.2. shows the plan of the model house.

Table 2. Building profile of the model house

<table>
<thead>
<tr>
<th>Location</th>
<th>Fukuoka Prefecture, Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor area</td>
<td>142.4m²</td>
</tr>
<tr>
<td>Construction</td>
<td>Wood frame</td>
</tr>
<tr>
<td>Number of stories</td>
<td>Two</td>
</tr>
</tbody>
</table>

3.2 Outline of dynamic simulation

We use THERB, which can estimate temperature, humidity, sensible heat, latent heat, and heating/cooling load for a multiple building zone. THERB has the following features:

1) The successive transition method and the trapezoid hold function which can adjust itself to the time-discrete domain.

2) Dimensionless equations are used to calculate convective heat transfer coefficients for every part.

3) The long-wave and short-wave absorption coefficients make it possible to simulate the net absorption of radiant heat and transmitted solar radiation.

4) A multi-layer window model, which defines the overall transmittance, absorptance and reflectance of solar radiation.

5) A network airflow model is used to calculate ventilation quantities.

3.3 Calculation contents

The calculation contents are shown as follows.

1. Initial condition
2. Areas (compare the heat load of 12 points in area IV of the Energy Conservation Standard)
3. Use of buffer zones
4. Modeling for calculation of dynamic simulation
5. Floor (solar absorption and heat capacity)
6. Insulation method
7. Outside screen (east and west sides of house)
8. Thickness of inside insulation

3.4 Simulation conditions

Table 3. shows the conditions of simulation. The set heating and cooling hours were based on a room temperature of under 18°C and over 27°C. Our simulation condition satisfies the energy-saving standard of 1991.

Table 3. Conditions of simulation

<table>
<thead>
<tr>
<th>Location</th>
<th>Fukuoka Prefecture, Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological data</td>
<td>Expansion AMEDAS</td>
</tr>
<tr>
<td>Simulation period</td>
<td>One year</td>
</tr>
<tr>
<td>Rooms</td>
<td>All rooms</td>
</tr>
<tr>
<td>Hours</td>
<td>24 hours/day</td>
</tr>
<tr>
<td>Preset temperature</td>
<td>Cooling: 27°C Heating: 18°C</td>
</tr>
<tr>
<td>Air changes</td>
<td>0.5 times/hour</td>
</tr>
<tr>
<td>Inner heating</td>
<td>16.7kJ/m²/h</td>
</tr>
<tr>
<td>Internal moisture</td>
<td>4.2kJ/m²/h</td>
</tr>
</tbody>
</table>

4. Calculation results and considerations

Some contents which have several features are
The energy saving standard is set to the seven areas based on different climates (Fig.1.). Each area is large and the climate is different. There is a possibility that the heat load is different, even if the area is the same. We examined and compared the heating and cooling load of 12 points in area IV of the Energy Conservation Standard. Table 4. shows calculation points and Fig.3. shows areas of the standard and calculation points.

Table 4. Calculation points

<table>
<thead>
<tr>
<th>Location</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>① Okuchi</td>
<td>⑦ Osaka</td>
</tr>
<tr>
<td>② Kitakyushu</td>
<td>⑧ Kanazawa</td>
</tr>
<tr>
<td>③ Hiroshima</td>
<td>⑨ Nagoya</td>
</tr>
<tr>
<td>④ Matsuyama</td>
<td>⑩ Niigata</td>
</tr>
<tr>
<td>⑤ Tottori</td>
<td>⑪ Tokyo</td>
</tr>
<tr>
<td>⑥ Tokushima</td>
<td>⑫ Hiroo</td>
</tr>
</tbody>
</table>

Fig.4. shows annual heating load and Fig.5. shows the annual cooling load of each area.

In the case of heating load, Niigata is highest at 41.4 (kWh/m²) and Tokushima is lowest at 24.2 (kWh/m²). The heating load of Niigata is about 1.9 times greater than that of Tokushima.

In the case of cooling load, Osaka is the highest at 38.7 (kWh/m²) and Fukushima is the lowest at 15.7 (kWh/m²). The cooling load of Osaka is about 2.5 times greater than that of Fukushima. There is a difference also in the heating and cooling load in the same region.

Fig.6. shows the annual heating and cooling load of each area and the standard of area IV. The heating and cooling load of every point is lower than the standard. The standard has been determined by the total of the highest value of the heating and cooling load. The heating and cooling loads have not been decided for each standard.

4.2 Modeling for calculation of dynamic simulation

We created a calculation plan in order to examine the heat load. Although the interior wall may influence the heat load, the specification and performance standard
The influence on the difference in modeling for calculation is examined and the results of the heating and cooling load of the same house compared. We examine two cases below. The software and calculation conditions are the same.

**Case 1: Detailed model** (the calculation model is close to the actual plan)

**Case 2: Simple model** (only the exterior wall is considered)

Fig.7. shows the detailed model, and Fig.8. shows the simple model.

![Fig.7. Detailed model](image)

![Fig.8. Simple model](image)

Figs.9. and 10. show the heating and cooling load of each case. The annual heating and cooling load of the simple model is 14.2% higher than the detailed model. In the case of "specification standards," the detailed model and simple model are the same, but the results of the calculation of each heating and cooling load are different. We need to construct a detailed model in order to make a strict calculation.

**4.3 Use of buffer zones**

A buffer zone is a closable zone between rooms and the exterior, like a double skin or Japanese "Engawa (Fig.2., Area Nos. 7 and 8). The function of the buffer zone is to ease the influence of solar radiation or outdoor air temperature. There is a possibility that the use of a buffer zone has an influence on the heat load, but the specification and performance standard has been decided concerning the exterior wall only. We examined three cases for Area 7 and 8 and Room 9 (Fig.2.) above, and compared the results. The air exchange rate of airflow between rooms was set at 0 times/hour, and the air exchange rate of airflow between buffer zones and the next room at 0.5 times/hour. Our simulation condition satisfies the energy-saving standard of 1991.

**Case 1: Original** (Room No. 9 includes Area Nos. 7 and 8) All rooms are air-conditioned.

**Case 2: Use of buffer zones** (Area Nos. 7 and 8 are buffer zones). We set shoji (Japanese traditional partitions made of wood and paper) as the boundary between Room No. 9 and Area Nos. 7 and 8. Only Room 9 was air-conditioned.

**Case 3: Use of a buffer zone and ventilation** (ventilate buffer zones while cooling in summer (20 times/hour))

Fig.11. shows the sum of the heating and cooling loads for a year, Fig.12. the heating load of each room for a year and Fig.13. the cooling load of each room for a year. The sum of the heating and cooling load for a year in Case 2 is 0.2% higher than Case 1, while on the contrary, Case 3 is 5.0% lower than Case 1 (Fig.11.). The heating load of Cases 2 and 3 of room No. 9 is
57.7% lower than Case 1 (Fig.12.). The cooling load of Case 2 is 19.5% and Case 3 is 43.7% lower than Case 1 (Fig.13.). Thus, the effectiveness of using the buffer zone increases in cases in which air-conditioners were used based on real life.

**Case 2: Large heat capacity** {flooring + plywood + 100mm reinforced concrete + 100mm polystyrene foam (from the inside to the outside of the room)}

Fig.14. shows the heating load of Room No. 4. In the case of large or small heat capacity, excluding cases where solar radiation absorbance is 0.9, the one room that is the heat reservoir is effective for reducing the heating load.

4.5 **Outside screen and thickness of inside insulation**

The model house has curtains and overhangs for shading. We installed these on the outside screen on the east and west sides of the model house. By changing the thickness of the insulation, we estimated the influence on the heating and cooling load.

Table 5. shows the thickness for calculation of insulation in each case.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Foundation</th>
<th>Wall</th>
<th>Ceiling</th>
<th>Roof (Kitchen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without screen</td>
<td>70</td>
<td>100</td>
<td>180</td>
<td>210</td>
</tr>
<tr>
<td>Screen</td>
<td>70</td>
<td>100</td>
<td>180</td>
<td>210</td>
</tr>
<tr>
<td>Screen + Insulation80%</td>
<td>56</td>
<td>80</td>
<td>144</td>
<td>168</td>
</tr>
<tr>
<td>Screen + Insulation60%</td>
<td>42</td>
<td>60</td>
<td>108</td>
<td>126</td>
</tr>
<tr>
<td>Screen + Insulation40%</td>
<td>28</td>
<td>40</td>
<td>72</td>
<td>84</td>
</tr>
</tbody>
</table>

Fig.15. Annual heating and cooling load
Fig. 15. shows the sum of the heating and cooling loads. The cooling load in the case with a screen is 23.2% lower than the case without a screen.

Fig. 16. shows the sum of the heating and cooling loads. By installing an outside screen, even 40% of the insulation thickness of the specification standards is sufficient to satisfy the performance standards in Fukuoka Prefecture.

5. Conclusion
In this paper we show several passive methods as examples which are not considered by "the specification standards" of the 1999 version of the Japanese Energy Conservation Standard and demonstrate the incommensurability through clarification of their effectiveness. The results are as follows.

- The heating and cooling load of every point is lower than the standard. There is a difference also in the heating and cooling load and the ratio in the same region. The standard has been decided depending on the total of the highest value of the heating and cooling load. The heating load and cooling load have not been decided for each standard. If provided, we can select the method of heat load reduction by dynamic simulation.

- In the case of "specification standards," the detailed model and simple model are the same, but the results of heating and cooling load calculation are different. We need to construct a detailed model in order to make a strict calculation.

- If a buffer space is provided, the heating load of Room No. 9 is 57.7% lower, and the cooling load (ventilate buffer zone while cooling in summer) is 43.7% lower than the initial condition. The effectiveness of the buffer zone increases when we use air-conditioning based on real life.

- Excluding cases in which solar radiation absorption is 0.9, large heat capacity at the floor is effective in decreasing the heat load.

- By installing an outside screen, even 40% of the insulation thickness required by the Specification standards is sufficient to satisfy the performance standards in Fukuoka Prefecture.

References

Notes
*2: It is recognized as a method of evaluating the annual cooling and heating load on the basis of the regulation of four clauses in Article 53 of the law governing the promotion of housing quality reservation. (IBEC_SN0003).