SIMULATION FOR THE DEVELOPMENT OF HIGH INSULATED AND AIRTIGHT HOUSES IN JAPAN

Misako Tanoue*, Toshiyuki Watanabe*, Akihito Ozaki** and Shigeki Iwaoka***
*Kyushu University, Fukuoka, Japan
**The University of Kitakyushu, Fukuoka, Japan
*** ATOM Indoor Climate Institute, Morioka, Japan
missa@beel.arch.kyushu-u.ac.jp

ABSTRACT

Most of the recent houses built in Japan have a high performance concerning insulation and air-tightness due to the NGS (Next Generation Standard as a Revision of Japanese Housing Energy Efficiency). NGS highly recommends such performance for energy conservation. Then an energy efficiency of the houses is supposed to estimate in accordance with NGS, however some questions are pointed out as follows.

1. Are the level and specifications of the housing insulation and air-tightness settled in each region in NGS appropriate?

2. Is it possible to judge the energy efficiency by only the Q value (specific heat loss coefficient)?

3. Even in the case that the Q value is used, are the values settled in each region proper to reduce heating and cooling loads?

4. Is the supposition of the sensible heat generation, 16.7 kJ/m^{2}h, and the latent heat generation, 4.2 kJ/m^{2}h, appropriate for the calculation of heating and cooling loads? Both of the heats are supposed to generate constantly in the houses depending on a floor space. Dynamic internal heat generation should be considered.

5. Detailed information on a heating and cooling equipment isn't provided in NGS. The equipments suitable for the houses and regions should be proposed.

We have made predictions about heating and cooling loads using the simulation software "Triple P" (Program for Passive system simulation with Personal computers [1]) to solve the questions mentioned above.

INTRODUCTION

Most of the recent houses built in Japan are highly insulated and air-tightened. The same insulating specifications that had succeeded in the cold regions tend to be applied to all over Japan. It can be easily imagined that the level and specifications of the housing insulation and air-tightness should be changed in each region because of the big differences of climate. **Figure 2** shows the climatic features of Morioka, Yamanashi and Kagoshima (the map of Japan is shown in **Figure 1**). They have different variations of temperature and relative humidity thus the insulation level suitable for each climate should be proposed. Although the Q values are set up for each region in NGS, there are still many items to be examined in detail for saving energy, keeping amenity and durability.

Figure 1 Map of Japan

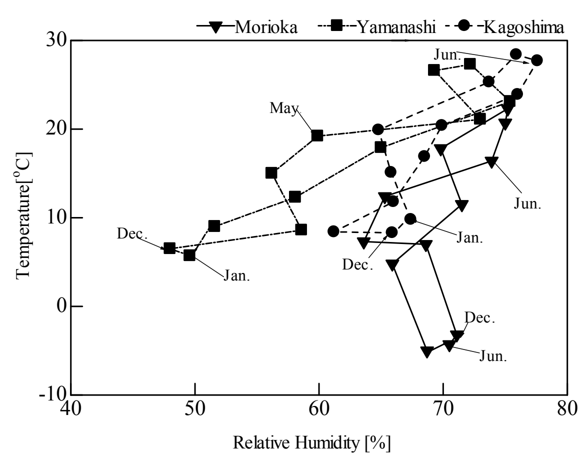

Figure 2 Climatic features of Morioka, Yamanashi and Kagoshima

NGS

In 1980 “The Standard of Japanese Housing Energy Efficiency” was enforced to reduce the energy consumption in houses. It has been strengthened in “New standard” in 1992 and “Next Generation Standard” in 1999. Now we are supposed to evaluate the housing energy efficiency in accordance with NGS. If the energy efficiency is made clear, we can receive various privileges. “What is NGS” is introduced in a chart below. Japanese climates are classified into the six (See **figure 8**) and the standards by NGS are set in each region. We have to choose either of option A-D shown in **figure 3** to evaluate the housing energy efficiency. In the case that a dynamic simulation are chosen, the annual heating and cooling loads of the houses, option A, become the target for evaluation. But almost all builders usually choose an easy way of the Q value calculation (and solar shading coefficient), option B, instead of dynamic simulation.

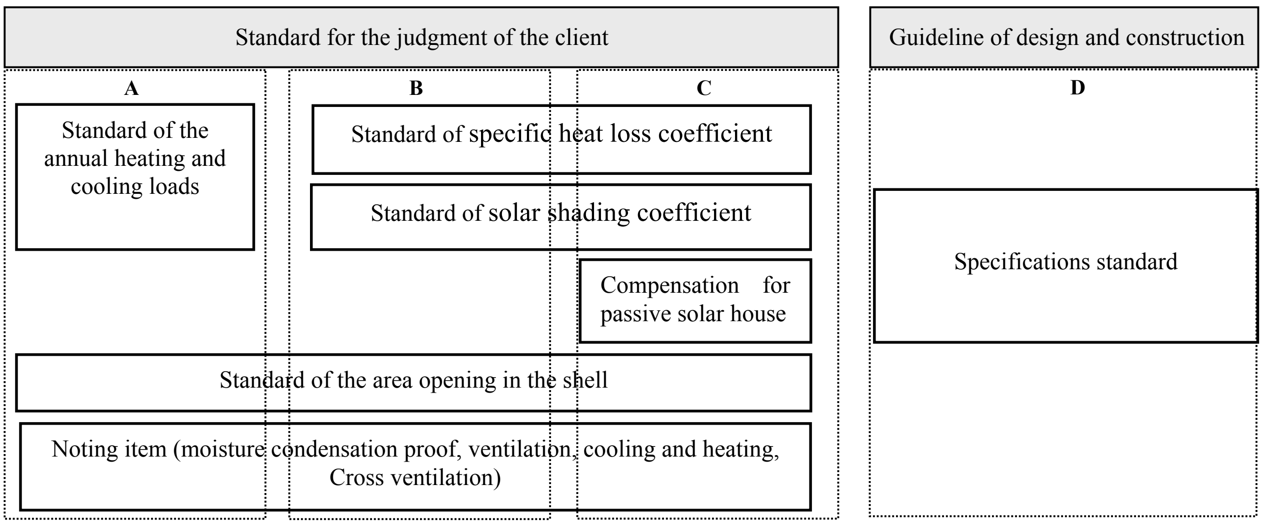

Figure 3 NGS (Next Generation Standard as a Revision of Japanese Housing Energy Efficiency)

OUTLINE OF THE SIMULATION MODEL HOUSES

The four houses shown in **Figure 4 – 7**, these houses have been monitored by authors, are used to conduct simulation studies. **Table 1** shows the floor and window areas of these houses. The Triple P, which has a capability to calculate the heating and cooling loads, temperature and humidity in each zone, requires input data of the floor plan, insulation specifications, internal heat generation and the weather data. Although the different four housing plans are used, the same insulation specifications are adapted to all houses as **Figure 9 - 11**. Then the results of heating and cooling loads caused by the differences of insulation level, internal heat generation and weather data are compared.

Table 1 Floor and window area of the houses

	Floor area (m^2)	Window area (m^2)
House M	237	28.5
House A	132	30.2
House B	135	29.3
House K	125	30.1

Figure 4 Morioka House (House M)

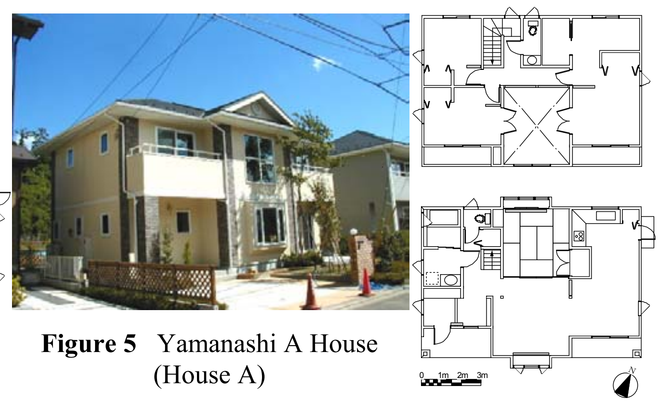

Figure 5 Yamanashi A House (House A)

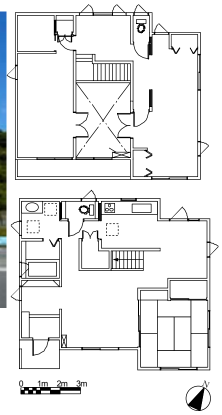

Figure 6 Yamanashi B House (House B)

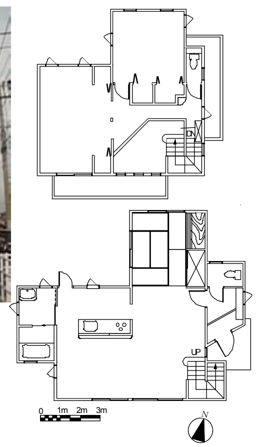

Figure 7 Kagoshima House (House K)

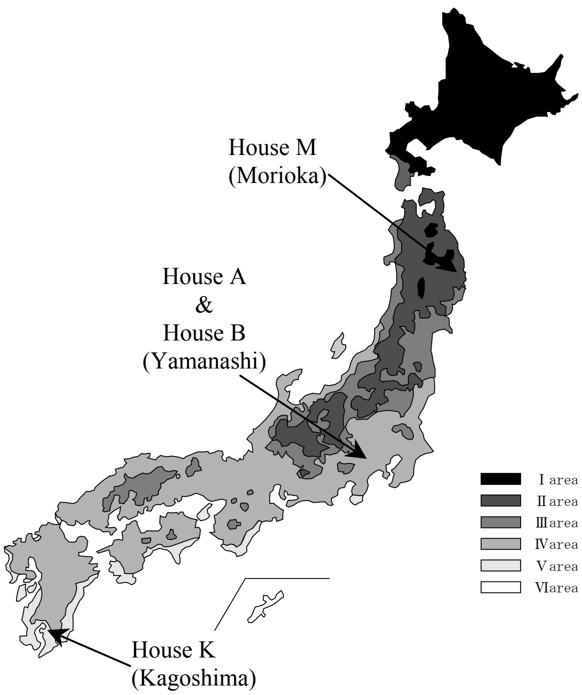

Figure 8 Area of model houses

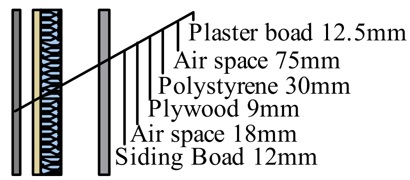

Figure 9 Detail of the Wall

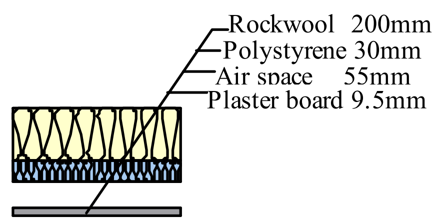

Figure 10 Detail of the Ceiling

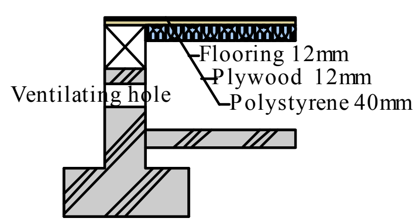

Figure 11 Detail of the Foundation

CONDITIONS FOR THE SIMULATION

The standardized annual outside air temperatures, outside absolute humidity, solar radiation, wind direction, wind velocity and atmospheric radiation in Morioka, Yamanashi and Kagoshima are used as the input weather data.

The heating and cooling periods are fixed on the basis of the average temperature of outside air. In accordance with NGS, the reference temperature for heating and cooling are under and over 15 ^{o}C, respectively. **Table 2** shows the heating and cooling periods at each city.

The target temperature for heating and cooling (all day long) are also settled in NGS as 18^{o}C and 28^{o}C, respectively.

Table 2 Heating and cooling period

	Heating period	Cooling period
Morioka	Sep.30 ～ May 31	Jun.01 ～ Sep.29
Yamanashi	Oct.03 ～ May 03	May 04 ～ Oct.02
Kagoshima	Nov.10 ～ Mar.28	May 29 ～ Nov.09

THE INFLUENCE OF INTERNAL HEAT GENERATION

The internal heat generation has been increased because of the diffusion of the electrical appliances. In summer, high insulation is against for the reduction of the cooling loads because the internal heat is closed. Sensitive analysis concerning the influence of internal heat generation on the heating and cooling loads is performed. The sensible heat generation is fixed 16.7 kJ/m^2h in NGS. No heat generation in Case-1, single in Case-2, one and half in Case-3, double in Case-4 and triple in Case-5 are examined for House A. Kagoshima weather data are used in here because the internal heat more influences on the cooling loads.

The heating loads become smaller and the cooling loads become larger with increase of the internal heat generation. The change of cooling loads caused by the difference of the internal heat generation is bigger than that of heating loads. The internal heat generation reduces the heating loads, thus it seems to be no problem for heating. On the contrary, to reduce the internal heat generation is important for cooling, particularly in hot regions. The internal heat generation should be also include as a regulation in NGS, especially in the hot regions.

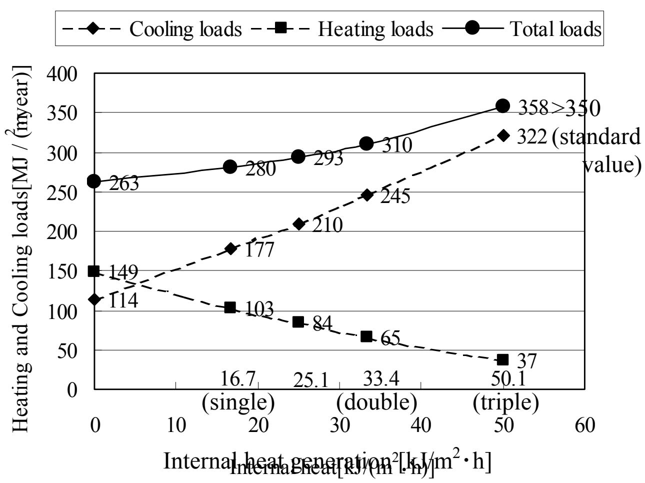

Figure 12 The influence of internal heat generation in Kagoshima

INSULATION PLAN

In the case that the Q value (specific heat loss coefficient) is used as the index for heating loads, it is well known that making the Q value smaller with an increase of insulation leads a proportional reduction of the heating loads. But the effect of insulation greatly differs in the regions. We changed insulation level (the thickness of polystyrene of wall and ceiling, 30mm - 80mm) as shown in **Figure 9-10** to clarify the effect of insulation in Yamanashi and Kagoshima. **Figure 13-14** shows the differences of heating and cooling loads of House A with changing the Q value by thickening the insulation.

Although there is a big difference between Yamanashi and Kagoshima in the quantity of the heating and cooling loads, the tendency of the change of them is almost the same. The heating loads become smaller with increase of insulation. While, the cooling loads shows the smallest value when the Q value is 2.3 $W/(m^2K)$. The high insulation simply leads to reduction of the heating loads, however an excessive insulation causes the increase of cooling loads due to a heat-retention. Even overheat is concerned in the hot regions like Kagoshima. In the hot regions, the climate and internal heat generation should be examined before the insulation performance is decided.

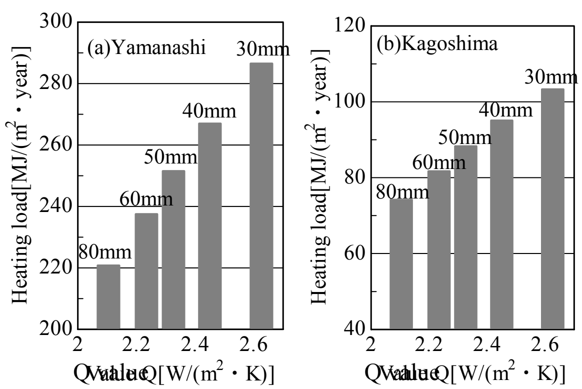

Figure 13 The Q value and Heating load in winter

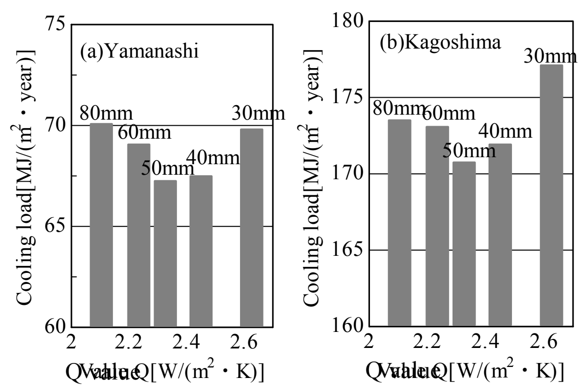

Figure 14 The Q value and Cooling load in summer

THE AREA OF EXTERNAL WALL

In the case that the determined specifications in NGS(see in **Figure 3**) are used, the calculation of the heating and cooling loads and the Q value can be exempted. However if we did not take into account of regional or climatic differences by following NGS regulation, whether insulation level is appropriate is not clear. **Figure 15** shows the heating and cooling loads of House A, B, K and M in Yamanashi. The same insulation specification is applied to all houses and the areas of windows are also assumed to being composed by an external wall due to eliminate the influence through windows as for this analysis. Even if all houses are constructed by the same insulation specification, the heating and cooling loads are fairly different.

It can be recognized that an area of external wall influences the heating and cooling loads. **Figure 16** shows the relation between the heating and cooling loads and the area of external wall. The larger the area of external wall becomes, the more the heating loads increases. The influence of the area of external wall on the cooling loads are less than the heating loads. It means the insulation level should be reinforced, especially in cold region where the heating is mostly demanded, with increase of the area of external wall.

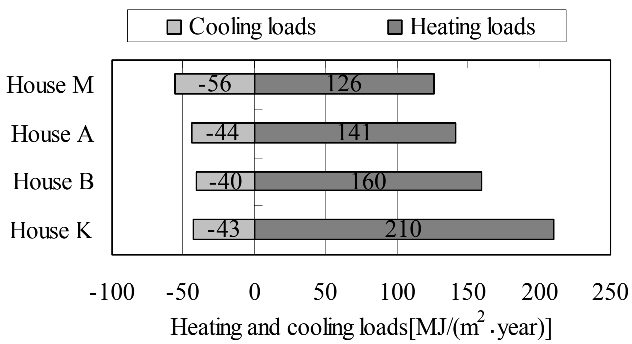

Figure 15 Heating and cooling loads of 4 Houses

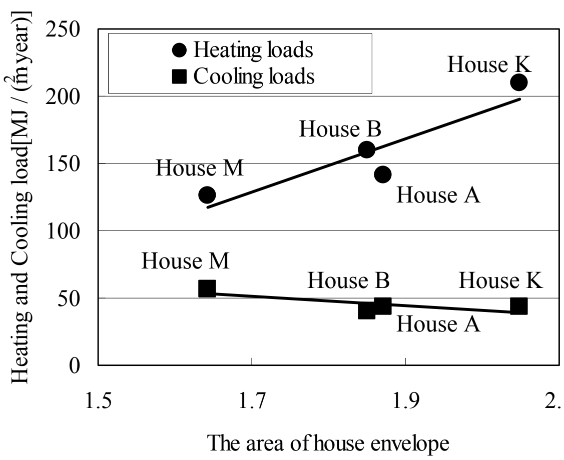

Figure 16 The influence of the area of house envelope

THE CHOICE OF HEATING AND COOLING EQUIPMENT

The heating and cooling in the whole houses have been spread out at the same time with generalizing high insulation and air-tightness. A heating and cooling equipment greatly influences on energy conservation. Thus the choice of the efficient heating and cooling equipment has become important as well as the insulation and air-tightness of houses.

House A and B have the different heating and cooling equipment as shown in **Table 3**. The features of the equipments are shown in **Table 4**. FF heater is an abbreviation of Forced Flue type heater, in which air supply and exhaust over the combustion are done outside of houses.

Figure 17 shows the result of the investigation about comfortableness (the number of respondents was 97) in winter, 1999. Many people felt more comfortable at House B than at House A. Moreover, based on the actual monitoring (see in **Figure 18**), the energy consumption of House B in winter was smaller than House A. There was no difference between these houses in temperatures and humidity. So the adoption of the radiation panel heating is sensibly more efficient than FF heater in winter.

Figure 19 shows the result of investigation about comfortableness (the number of respondents was 92) in summer, 1999. Many people felt uncomfortable about the relative humidity when the radiation panel cooling was adopted. Actually the relative humidity of House B was about 20% higher than House A. Then the dehumidifier was adopted supplementary in House B in 2001 and both houses were monitored again. Although temperature and relative humidity in House A and B became almost the same, the energy consumption of House B was about twice as large as that of House A (see in **figure 20**). It was made clear that an air conditioner was more efficient than the radiation panel cooling in summer.

In future, the accurate simulation on the efficiency of heating and cooling equipments will be demanded. Triple P has a capability to simulate such performance with an analysis of actual building physical phenomena such as multiplex radiation among wall surfaces and equipments and dehumidification with cooling, etc. In here, as an instance, the sensible and latent heat loads of House A are simulated in Morioka, Yamanashi and Kagoshima in order to clarify the influence of the climatic feature (see in **figure 21**). In the hot and humid region (Kagoshima), it can be easily understood that an air-conditioner with high efficiency of dehumidification should be adopted due to the large latent heat loads.

Table 3 Heating and cooling equipment

	House A	House B
Heating	FF heater	Radiation Panel
Cooling	Heat Pump	Radiation Panel

Table 4 Features of the equipments

	FF heater	Heat Pump	Radiation panel (heating)	Radiation panel (cooling)
Capacity (kW)	1.80 ～6.78	0.9～4.4	3.8～4.2	3.6～4.0
Energy consumption (kW)	—	0.24～1.98	2.1～2.4	2.1～2.4
COP	—	2.26～3.75	1.75～1.81	1.67～1.71
Initial cost (US$)	1,300	2,600	18,000	

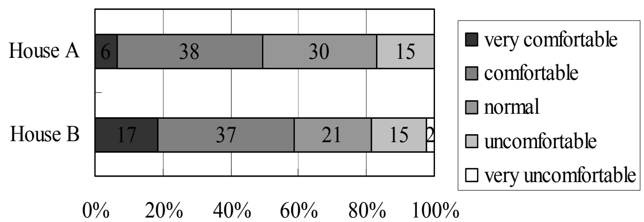

Figure 17 Investigation about comfortableness in winter

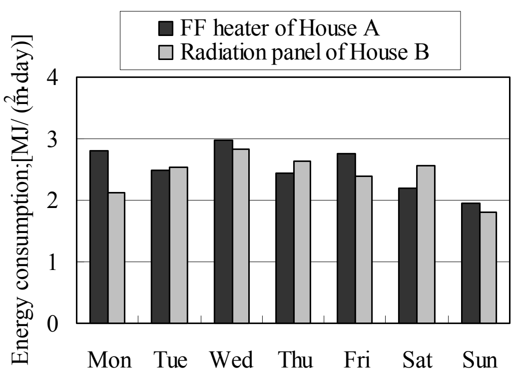

Figure 18 Energy consumption in winter

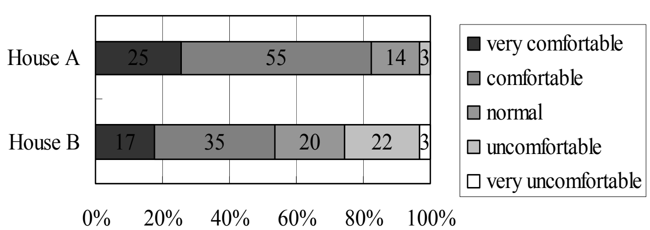

Figure 19 Investigation about comfortableness in summer

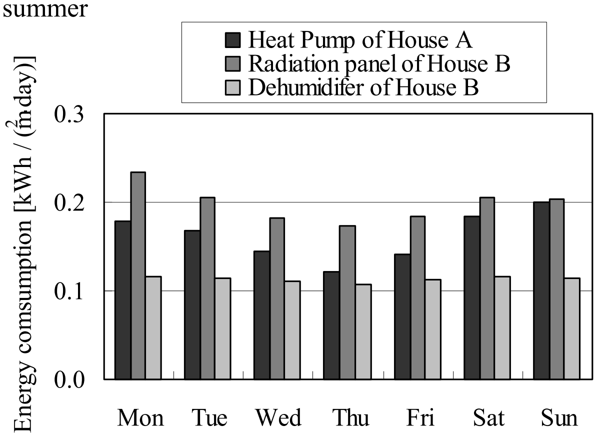

Figure 20 Energy consumption in summer

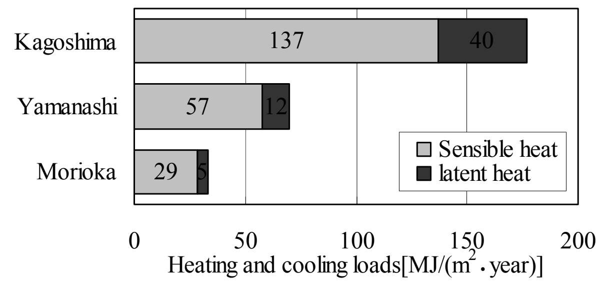

Figure 21 Sensible and latent loads

CONCLUSIONS

1. The internal heat generation increases the cooling loads, especially in the highly insulated and air-tighten houses in the hot and humid regions like Kagoshima, due to a heat-retention.

2. The high insulation simply leads to reduction of the heating loads, however an excessive insulation causes the increase of cooling loads due to a heat-retention. Thus it is difficult to judge energy efficiency by only the Q value (specific heat loss coefficient) in the mild regions where both heating and cooling are demanded.

3. The increase of the area of external wall makes the heating loads larger. The insulation level should be examined, especially in the cold regions where the heating is mostly demanded, depending on the area of external wall.

4. The capability to simulate actual building physical phenomena, such as multiplex radiation among wall surfaces and equipments and dehumidification with cooling, are required due to clarify the efficiency of heating and cooling equipments. For instance, it was made clear that an air-conditioner with high efficiency of dehumidification should be adopted due to the large latent heat loads in the hot and humid regions.

REFERENCES

[1] Hayashi, T. (1992). Development of Thermal Performance Simulation Program for Multi-Space Dwelling Using Personal Computers, Annual

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