A Study on the Evaluation of Passive and Low Energy Houses Based on Thermal Comfort

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Summary

The purpose of this study is to propose a new evaluation method considering of the resident's adjustment action to the environment. At first, thermal comfort zones to which the resident's conditions and preferences can be reflected are presented. Next, an evaluation method based on these comfort zones is explained and finally case studies to which this method applied are illustrated. Main results are followings.

1. Thermal comfort zones depending on the resident's conditions and preferences are proposed. Changing ET^*, which is the limit of ASHRAE's comfort zone, into SET^* allows the comfort zone to deal with metabolism and quantities of clothes of the resident, as well as wind velocity, as variables.
2. Thermal performance evaluation method considering of the resident's adjustment action to the environment is proposed. In this evaluation method, the resident's environment is evaluated with the comfort zone fitting in with the resident's conditions. If the resident's environment is within the comfort zone, then it is evaluated with CH (the percentage of comfortable hours). If it is out of the zone, then it is evaluated with TD (temperature difference between the comfort zone and the resident's environment).
3. As the results of case studies to which this method applied, it is shown that there is the possibility the effect of natural ventilation is able to evaluate by this method.

1. Introduction

In recent years, passive and low energy houses have been attracting attention and the techniques of them continue to grow. But, which technique is more effective in a certain area and how effective it is are not clear. To make clear them, the evaluation methods are very important.

Taking a general view of the evaluation methods for passive and low energy houses, the efficiency of such houses has been evaluated mostly with the energy consumption or the heat loads or the $LCCO_2$, not with the thermal comfort. However, passive and low energy houses should be comfortable to live in without air conditioning equipment and it should be evaluated not only with the energy consumption or the heat loads but also with the thermal comfort of the residents. In addition, thinking of practical life, it is need to consider that the resident move within the rooms which have different thermal conditions, as well as the residents do some adjustment actions to the environment, such as to change the clothes and to open the window.

In this study, it is the purpose to propose performance evaluation methods for passive and low energy houses based on thermal comfort of the residents.

2. The comfort zone depending on the resident's conditions and preferences

2.1 Expansion of the comfort zone

At present time ASHRAE's comfort zone is used widely. This comfort zone is defined as fundamental

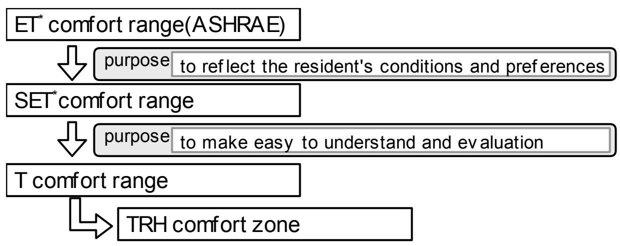

Figure 1 the process and purpose of changing ET^* comfort range into new comfort zone.

condition that the majorities of people are comfort, and is mainly used in design process of the air conditioning system. In this study, this ASHRAE's comfort zone is expanded into the new comfort zone that is able to change by the resident's condition and preferences (the position in the house, metabolism, and quantities of clothes, and wind velocity). Figure1 shows the process and purpose of changing ASHRAE's comfort zone into the new comfort zone. ASHRAE's comfort zone is limited by the ET*, the dew point temperature and the wet-bulb temperature. In this process, at first, from this comfort range by ET^* in winter and in summer (ET^* comfort range for short), the comfort range by SET^*(SET^* comfort range for short) is defined. This change allows us to deal with the resident's condition and preferences, mentioned above, as variables. Figure2 shows the relation between the variable parameters of SET^* comfort range and the parameter of SET^*. Secondly, SET^* comfort range is changed into the comfort ranges of air temperature (T comfort range for short). Finally, the new comfort zones by air temperature and relative humidity (TRH comfort zone for short), as the figure3, are gained from using this T comfort ranges and qualifications for changing ASHRAE's comfort zone into TRH comfort zone, as the table1. Using this comfort zone allows us to understand and evaluate the resident's condition easily.

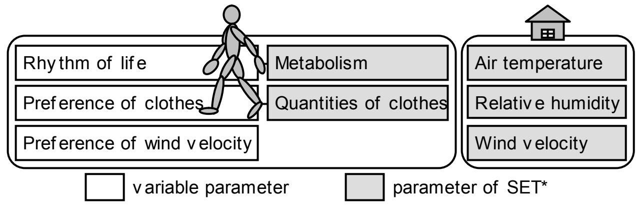

Figure 2 Relation between variable parameters and parameter of SET^*

Table 1 Qualifications for changing ASHRAE's comfort zone into TRH comfort zones.

ASHRAE	summer	winter
ET^*[°C]	22.5-26	20-23.5
T_{wb}[°C]	20	18
T_{dp}[°C]	2.0	

This study	
SET^*[°C]	21.53-25.37
RH[%]	90
T_{wb}[°C]	20
T_{dp}[°C]	2.0

2.2 Examination of calculation condition

Table2 shows the ranges and intervals of valuable parameters to make the new comfort zones. It is decided that the maximum of the wind velocity is 1.0[m/s] and quantities of clothes as the resident's permissible amount are from 0.3[clo] to 1.2[clo], and also, on condition of sleeping in winter, the quantity of clothes is 3.0[clo] [1]. The relation between the resident's act and metabolism is based on the standard life schedules of The Society of Heating, Air-conditioning and Sanitary Engineers of Japan [2].

Table 2 Ranges and intervals of valuable parameters to make the new comfort zones

		Range	Interval
$T_{air}(=T_r)$	°C	10 - 40	0.2
RH	%	10 - 90	5.0
Wind Speed	m/s	0.1 - 1.0	0.1
Clothing	clo	0.3 - 1.2(3.0)	0.1 in winter-sleep : 3.0
Metaboric Rates	Met	0.8 - 2.2	depend on Act
Atomosphic	kPa	101325	fixed

2.3 SET^* comfort range

SET^* comfort range is gained from calculating SET^* values in ET^* comfort range on the condition of ASHRAE's standard (radiation temperature=air temperature, relative humidity: 50[%], metabolic rates: 1.1[Met], wind velocity: 0.15[m/s], quantities of clothes: 0.5[clo] (in summer) · 0.9[clo] (in winter)). It is determined that SET^* comfort zone is from21.53 to 25.37[°C].

2.4 The formation of the new comfort zone by air temperature and relative humidity

T comfort ranges are gained from the air temperatures in SET^* comfort range at every combination of relative humidity and variable parameters. TRH comfort zones are gained from combinations of T comfort zones and the qualifications for changing ASHRAE's comfort zone into TRH comfort zone, shown in the Table1. In order to evaluate throughout the year, these qualifications are determined as follows, referring to the limits of ASHRAE's comfort zone; relative humidity: 90[%], wet-bulb temperature: 20[°C], and dew point temperature: 2.0[°C]. Figure3-A and Figure3-B show examples of difference in quantities of clothes. The wind velocity of them is different (A: 1.0[m/s], B: 0.1[m/s]). Figure3-C shows an example of difference in metabolism. Figure3-D shows an example of difference in movable range (in summer (from April to September), in winter (from January to March and October to December)). A gap of comfortable zone between summer and winter is owing to calculation considering the beddings, 3.0[clo], on the condition of sleeping in winter.

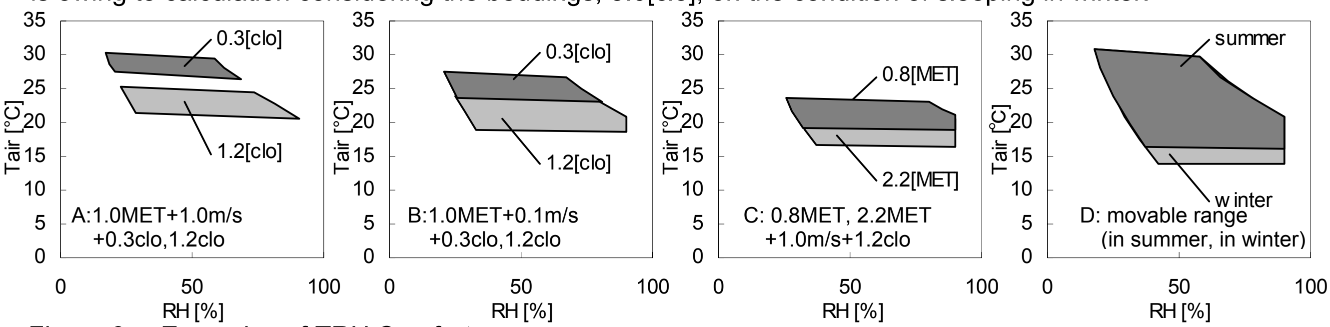

Figure 3 Examples of TRH Comfort zones
A: 1.0MET+1.0m/s+0.3,1.2clo B: 1.0MET+0.1m/s+0.3,1.2clo C: 0.8, 2.2MET +1.0m/s+1.2clo D: movable range (in summer, in winter)

3. Thermal performance evaluation method

The evaluation method proposed by this study bases on the comfort zone depending on the resident's conditions and preferences. This method can evaluate how much time the resident's environment is comfort when the resident doesn't use air conditioner and adjusts oneself to the environment. The elements of indoor climate (the air temperature, the relative humidity and the wind velocity) are used for the evaluation, and therefore it can evaluate the room condition when the resident ventilates the room by opening the windows. Moreover, it is considered that the resident's thermal comfort is different by which room the resident is in and what action the resident does. The room environment in which the resident is (the resident's environment for short) is evaluated with the comfort zone fitting in with the resident's conditions.

3.1 The flow of the thermal performance evaluation method

Figure4 shows the flow of the thermal performance evaluation method in this study. At first, the room environments are calculated by simulation and the resident's environments are selected by the life schedule of the resident from the room environments. If a resident's environment is within the comfort zone, then it is counted among the percentage of comfortable hours (CH for short). And if it is out of the zone, then it is evaluated with temperature difference between comfort zone and the resident's environment (TD for short). These results help us to think what modification is need in order that the house have good thermal environment.

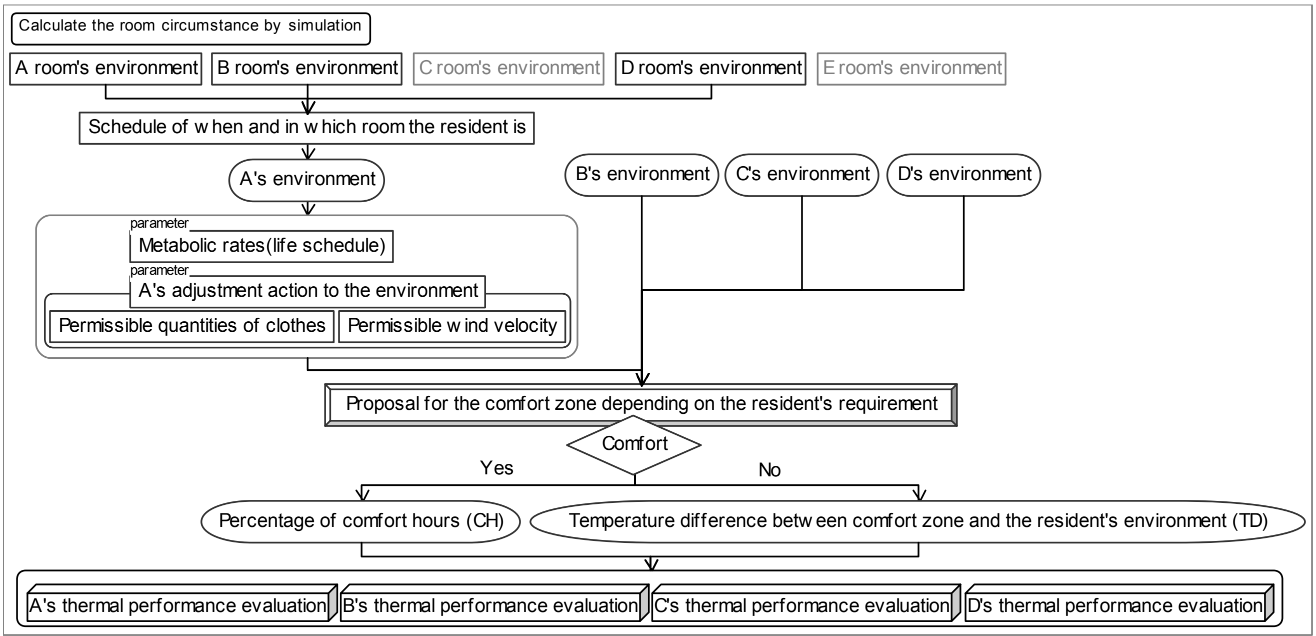

Figure 4 Flow of the thermal performance evaluation method.

3.2 Thermal performance evaluation of a flat model considering of natural ventilation

3.2.1 Outline the flat model

To confirm the evaluation of natural ventilation, we applied this method to a flat model that has three wind-path roots, as figure 5. This model is made by Japanese members of IEA / ECBCS / ANNEX38 / Cooling Group. Table3 shows outline of the building, and table 4 shows the wall construction of the building.

Table 3 Outline of the building

struction / story	RC / 4floor
floor space	126.25[m^2]
number of rooms	25 rooms
member of the family	husband / wife / two children

Table 4 Construction of the wall

name of part	construction of the wall(in-out)
Exterior wall	plaster board / polystyrene / concrete
Party wall	concrete
Interior wall	plaster board / non-seal air space / plaster board
Floor/Ceiling	floorboard(plywood) / plywood / non-seal air space / concrete

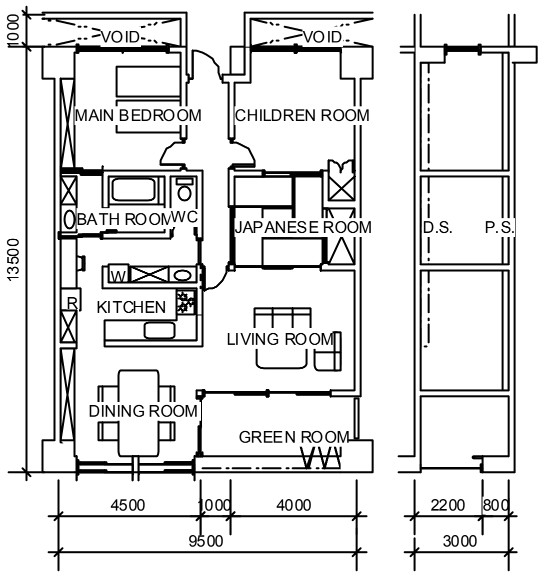

Figure 5 Floor plan / section of the building

3.2.2 Climate data

The climate data of Fuchu-city, Tokyo is used for this evaluation, because it is near to the average value of the heat loads of the 4th region defined by Next Generation Standard as a Revision of Japanese Housing Energy Efficiency, and this city has large population. Meteorological data is referred to MeteoNorm5.0 [3].

3.2.3 Condition of the calculation

TRNSYS and COMIS program are used for the simulation. Number of residents is four, and their life schedules were generated by the life-schedule program of The Society of Heating, Air-conditioning and Sanitary Engineers of Japan [2]. Table5 shows the calculation models. Model_1 is base model with no ventilation and no eaves and other 4 models are combination of conditions of eaves, natural ventilation roots and window area. From model_2 to model_5, if the outside air temperature is over 20[°C], the windows are opened [4].

Table 5 Conditions of the calculation model

	model_1	model_2	model_3	model_4	model_5
the eaves	×		○	×	○
window area	small			big	
course of natural ventilation	1 course			3 courses	
natural ventilation	×	○ if outside air temperature is upper 20[°C]			
GreenROOM	○				

3.2.4 Results of the thermal performance evaluation

Figure 6 and figure 7 show the fluctuation of the monthly average of CH and TD, and the annual average value of them. At first, the annual average of CH for model_2 (with natural ventilation) increases 9.6[%], comparing with model_1. The TD of the model_2 is smaller than that of model_1 in summer, and that means model_2 is cooler than model_1. Secondary, comparing model_2 and model_3, CH of model_3 (with the eaves) increase from June to October owing to the eaves, but that in winter decrease. Third, comparing model_3, model_4 and model_5, they have not much difference. This is considered that the building of this model has large heat capacity and small window area because of the characteristics of flat. Finery, CH of model_2 is the highest among 5 models, and TD is near 0[°C].

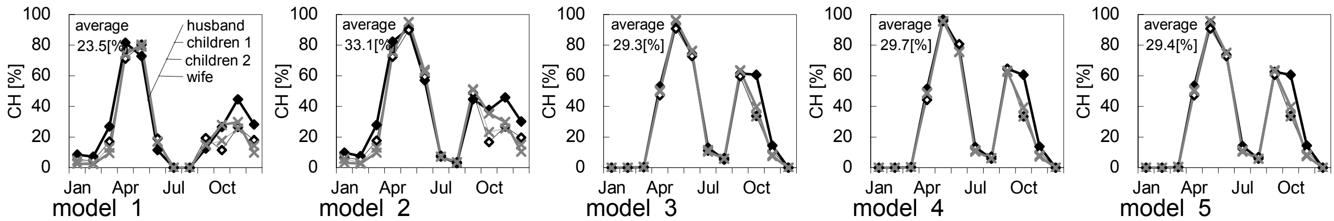

Figure 6 the fluctuation of the monthly average of CH and the annual average value of CH

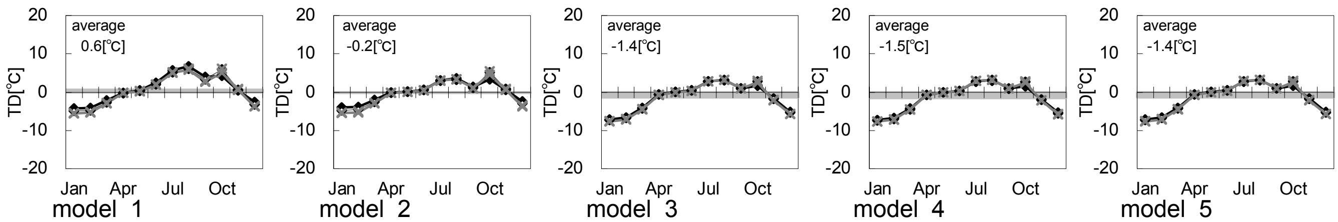

Figure 7 the fluctuation of the monthly average of TD and the annual average value of TD.

4. Conclusion

A thermal performance evaluation method for houses, that can consider the resident's conditions and adjustment actions to the environment, is proposed. This method can deal with metabolism and quantities of clothes of the resident, as well as the wind speed, as variables, and then TRH comfort zones depending on the residents' conditions and preferences are devised. CH and TD allows us to estimate how much time the resident spends in the comfort environment and how thermal environment the resident is exposed. As the results of case studies, it is shown that this method has the possibility to evaluate the effect of natural ventilation, and it is considered that this method is able to apply to the evaluation of the actual house.

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