2015年度日本建築学会
関東支部研究報告集Ⅱ
2016年3月

Investigation of Thermal Comfort and Clothing Insulation in HEMS Managed Residential Building

4.環境工学－10.温熱感

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Residential building HEMS Thermal sensation
Thermal satisfaction Overall comfort Thermal acceptance

1. Introduction

People adapt different behaviors to maintain comfort environment inside the building. An understanding of pattern of behaviors of the occupants to maintain thermal comfort may be very much fruitful to the designers especially to this modern competitive housing world for constructing and maintaining comfortable homes. The adoptive model of the thermal comfort was developed largely on the basis of thermal comfort surveys in European society and American offices, no Japanese data were included. Occupant behavior is different in the office and at home, and thus the existing adaptive models may not be applicable to residences [1]. When working with developing technology, of limiting liability risk; and the wishes of clients who increasingly seek ‘low energy’ buildings for economic and moral reason [2].

Currently, Home Energy Management System (HEMS) has been applied in different residential building for energy saving and creating comfort thermal environment and it is the attraction of occupants while finding a new resident. How the resident occupants adapt to various indoor conditions in HEMS managed building is not fully understood. Generally, people adjust clothing for thermal comfort.

This study is set out to investigate the thermal comfort and clothing trend of the occupants for thermal adjustment. As the residential building selected for this study is HEMS managed so how the occupants maintain thermal comfort and clothing insulation is the focus of this study. This study purposes to find out thermal sensation, thermal comfort and clothing insulation of the occupants of the study building.

2. Outline of the Study Area

The study area Branz City is located in Katsushima of Shinagawa. It has been established with the concept of HEMS. It is one of the unique projects for this study as it is a residential building for 356 families with HEMS. How people maintain comfort temperature and what kinds of clothing are used by the occupants of this building is the concern of this study. The building has been established with the concept of HEMS with unique temperature and lighting management system.

It has launched the concept of ENE-FARM for the first time in the world. ENE-FARM converts gas into electric energy. It has been expected that it will reduce the load of electricity to some extent. While converting gas into electric energy the released back up heat is used for heating water that is used for kitchen, bathroom and floor heating.

Fig. 1 Investigated residential building

3. Investigation methods with field data

This survey is conducted among the occupants of Branz city. A questionnaire related to thermal comfort, clothing etc. was provided to every resident dweller and the votes were collected several times in a day from their smart phones, laptops and iPods. The collected data were classified according to their nature and analyzed. The recorded outdoor temperature is observed from the meteorological station to find out the relation between the trend of the clothing and outdoor temperature.

The clothing insulation was investigated by descriptive method. In this method the clothing insulation was chosen by the occupants of the building from clothing scale. The insulation of male and female clothing was provided by the investigation.

3.1. Subjects

The occupants of the building were selected as the subject of this study. 19 males and 18 females voted 1534 times during the period of the month November 2015. The voting time was not always similar but mostly it was in the morning, day, evening and night.

3.2 Scale of thermal comfort survey

To know the wide range of thermal condition of the study area, 1 to 7 point scale questionnaire was provided as shown in the Table 1. The meaning, relationship, and the evaluation method of the questionnaire were clearly provided to the occupants of the building in advance to obtain the data accurately.

Table 1. Scale of thermal comfort survey

Scale	Thermal sensation	Thermal satisfaction	Overall comfort
1	Very cold	V. unsatisfied	Very uncomfortable
2	Cold	Moderately unsatisfied	Moderately uncomfortable
3	Slightly cold	Slightly unsatisfied	Slightly uncomfortable
4	Neutral	Slightly satisfied	Slightly comfortable
5	Slightly hot	Moderately satisfied	Moderately comfortable
6	Hot	Moderately satisfied	Very comfortable
7	Very hot	Very satisfied	

3.3 Thermal Measurement

To understand the thermal comfort, thermal sensation and clothing patterns of the occupants, a questionnaire method is used. To find out the air temperature, relative humidity and illuminance of the building a device is used (Figure 2). The device records the indoor temperature, relative humidity and illuminance in every 10 minutes interval. However, the measured data by this device has not been analyzed in this paper.

Fig. 2 Air temperature, relative humidity and lighting. recording device.

4. Result and discussion

4.1 Thermal sensation

The thermal sensation of the occupants of the investigated building seems almost satisfactory as around 72% voted neutral. Neutral temperature refers to the air temperature, which on average, a large sample of people would feel “just right” or neutral [3]. The mean sensation is 3.7 on 7 point sensation scale (Figure 3). On the contrary, around 26% voted slightly hot. The result clarifies that the occupants are satisfied with the thermal sensation of the building. Even though the occupants of the building used heating and cooling in some cases but it can be said that they are satisfied with the thermal environment of the building. This might be the cause of the environment created by HEMS and ENE-FARM.

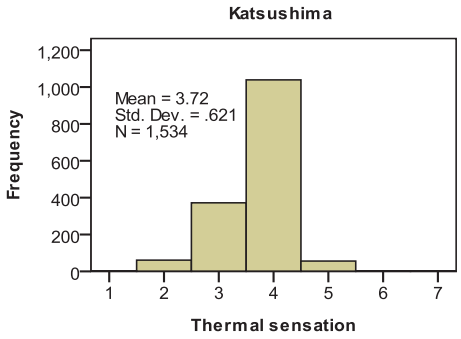

Fig. 3 Distribution of thermal sensation

4.2 Thermal satisfaction

To evaluate the thermal satisfaction of the study area, we have offered a questionnaire of 6 points scale. From figure 4 it can be assumed that occupants are achieving thermal satisfaction by using different appliances and modes of ventilation like opening the window or internal door. The HEMS also played an important role to create comfortable environment. The occupants were able to control the indoor temperature of the house when away from the home. They could adjust the indoor temperature of the house before

reaching home. It may be unfair to use the word very satisfied as the mean thermal satisfaction is 4.3 but they are quite satisfied. The result shows that they have achieved this satisfaction by adopting some behaviors like changing clothing insulation to adjust their thermal satisfaction. Around 10% of the votes answered scale 3 which is slightly unsatisfied. There might be different reason for this result. One might be the body condition to adjust heat or cold and the exercise hours they spent every day. Another might be the age. Regarding to age, we had provided the list of age groups of 5 points age difference scale.

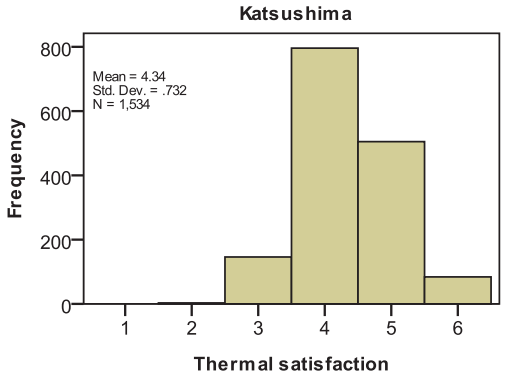

Fig. 4 Distribution of thermal satisfaction

4.3 Guess temperature and temperature setting

To evaluate the feeling of the occupants about the thermal environment, we had also taken their guess temperature and temperature setting. Figure 5 shows close resemblance between their guess temperature and temperature setting. Their guessed temperature was very close to temperature setting. We found that the occupants are very conscious about thermal environment.

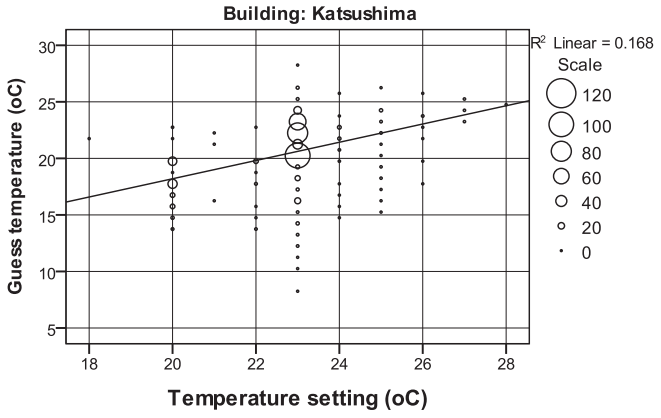

Fig. 5 Relation of guess temperature and temperature setting

4.4 Overall comfort

The mean overall comfort is 4.3. As shown in Figure 6 the highest votes are feeling slightly comfortable. It doesn't mean that they are uncomfortable. The reason could be the slightly changing outdoor environment. As they are satisfied with the overall comfort of the house, they prefer slightly a warmer environment at the end of the month than the beginning of the month. The temperature of Japan gradually decreases from the beginning of November.

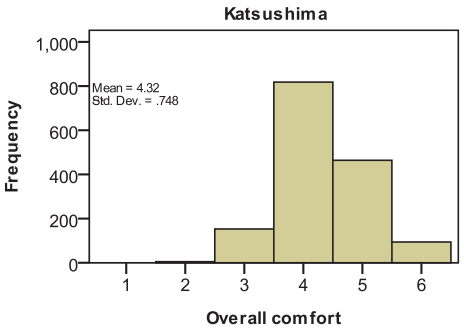

Fig. 6 Overall comfort distribution

4.5 Relation between overall comfort and thermal sensation

Figure 7 shows the relation of thermal sensation and overall comfort. The report shows a very close relation in overall comfort and thermal sensation. When the thermal sensation is neutral the overall comfort is close to moderately comfortable scale. As the sensation level increases or decreases the overall comfort shows uncomfortable.

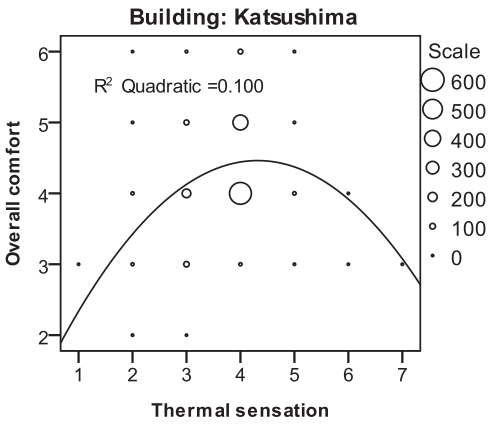

Fig. 7 Relation of thermal sensation and overall comfort.

4.6 Thermal Acceptance

To know the overall comfort of the occupants of the building, we have analyzed their thermal acceptance to the thermal environment

The pie chart shown in Figure 8 shows that most of the

occupants are satisfied with the overall comfort of the building. Answer the question of thermal acceptance at the moment of voting, 91.52% votes accepted the thermal environment.

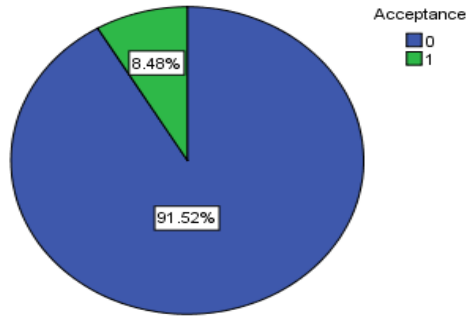

Fig. 8 Thermal acceptance (0=acceptance, 1=unacceptance)

4.7 Clothing insulation

When the mean clothing value was analyzed and compared in the month of November, the mean insulation value seems slightly changing at the end of the month. The result showed that the building occupants slightly increased the insulation of the clothing gradually at the end of the month than the beginning of the month. The mean clothing insulation is 0.7 and the overall comfort is 4.3.

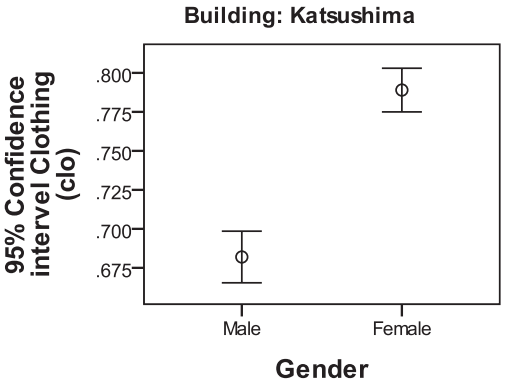

Fig. 9 Clothing insulation male and female.

Figure 9 shows the difference in clothing pattern of male and female of the study building. Females seem using slightly thicker than males. The mean clothing of the male was 0.68 clo whereas the mean clothing of females was 0.78 clo. The reason might be the women seems more sensible to the environment.

Changing clothing is one of the important behavioral adaptations [4]. From the investigation it is also examined that the occupants clothing was significant to the outdoor temperature. As the outdoor temperature changed the insulation of the clothing also changed [4].

5. Conclusions

In this research we conducted a survey on thermal environment, thermal sensation and clothing for thermal adjustment in November. The thermal environment and clothing pattern of the occupants residing in Branz City Shinagawa were investigated. The following results were found.

1. The frequency of thermal sensation and thermal satisfaction is satisfactory. Overall comfort clarifies that the occupants desire slightly warmer environment.at the end of November
2. As the occupants' guess temperature resembles with their temperature setting which proves that they are very much conscious about the thermal environment.
3. The clothing pattern of male and female differs as the insulation of female clothing is slightly higher than male. The clothing and thermal sensation are correlated. The clothing insulation is high when they feel cold and low when they feel hot.
4. The percentage of thermal acceptance is high. The occupants are adapted to the building environment.

Acknowledgements

We would also like to express our gratitude to the occupants of Branz City for answering the questions despite of their busy schedule.

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