A Study on the Suggestion of Thermal Comfort Range in Radiant Floor Ondol Heating System

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ABSTRACT: The purpose of this study is to investigate the characteristics of thermal comfort index and to present the thermal comfort range through regression analyses and experiment in a radiant floor heating system laboratory. The results were compared to the comfort zone of ISO-7730, and the applicability of the thermal comfort index to a radiant floor heating system was studied. On comparing the sedentary posture on the floor to sitting on the chair, the comfort zone and the neutral point of comfort index showed different values. It is considered that the influence of conduction from floor to the human is sufficient. Moreover, we could find a correlation between the thermal sensation votes of subjects, and the comfort indexes were lower than those by calculation.

1. Introduction

It is necessary to set up a range of thermal comfort for different peoples and countries, since their thermal sensation varies according to their sex, race, age, health and weather conditions. The thermal environmental indices proposed up to now have been calculated in the space where HVAC systems were used. Therefore, it is not acceptable to apply the values to Korean peoples who are used to sedentary ways of living especially in residential buildings.[1]

Proper thermal environmental indices applicable to the indoor thermal environment should be set up in order to establish a comfortable living environment. It is important to investigate the correlation between the peoples' thermal sensation and the physical environment in indoor space. Computing the characteristics of thermal environmental indices and comfort range for each index, this research aims at providing necessary fundamental data to develop a new thermal comfort index and a strategy in the radiant floor heating space.[2]

In order to provide a thermal comfort range of environmental indices, field surveys were performed in a floor-heated mock-up test space. The difference between thermal sensation vote (TSV) by the subjects' reply and the predicted mean vote (PMV) by calculations was analyzed.

2. Experiment and test procedure

2.1 Outlines and conditions of experiments

The experiments were performed from 12 January 2001 to 20 January 2001 in a mock-up test room located in Seoul National University of Technology and 16 subjects participated in the experiments. Eight of them were females and the rest of them were males. The surveys for thermal comfort were performed and the subjective thermal sensation replies were col-

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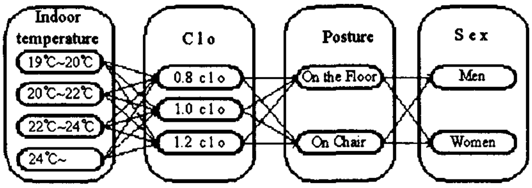


Fig. 1 Experimental conditions.

lected. Figure 1 shows the experimental conditions. In total, 48 cases were examined.

2.2 Experiment space & measurement items

The dimension of a mock-up test room was 4.5×3.0×2.1 m and it had a preparation room with the same dimensions. Figure 2 shows a mock-up test room used in this research. In order to investigate the physical thermal environmental elements that affect peoples' thermal sensation, indoor temperature, globe temperature, relative humidity, air velocity and operative temperature (OT) were measured in a mock-up test room.

2.3 Skin temperature measurement and questionnaire for thermal comfort sensation

Skin temperatures were measured for two female and two male subjects. The mean skin temperature (MST) was calculated by the 7 points method. The metabolism was approximately 1 Met. The thermal resistance values for the clothes the subjects wore were 0.8, 1.0 and 1.2 clo. Questionnaires about thermal sensation were given to the subjects.

The questionnaires and replies from the subjects provided details of thermal sensation about the indoor environment. The 'Physiological-Psychological 7 scales' proposed by ASHRAE Standard 55-81 was used for the thermal sensation.[3,4]

3. Results and discussion

3.1 OT and thermal sensation

Figure 3 provides the TSV by subjects' re-

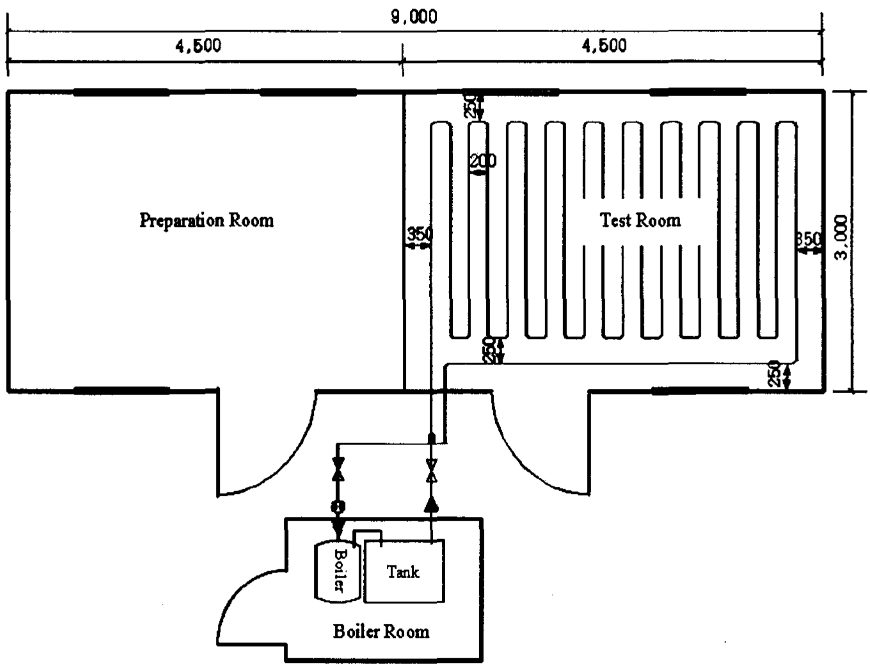
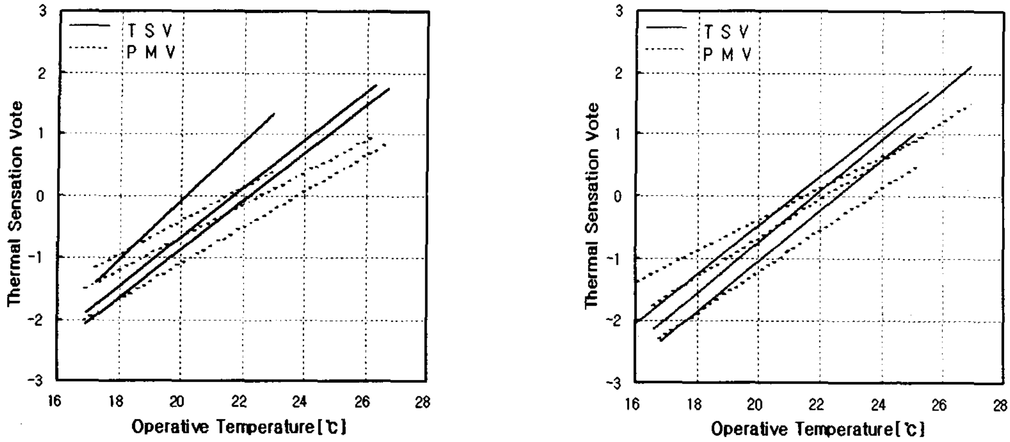


Fig. 2 Mock-up test room.



(a) Sitting on the floor (b) Sitting on the chair

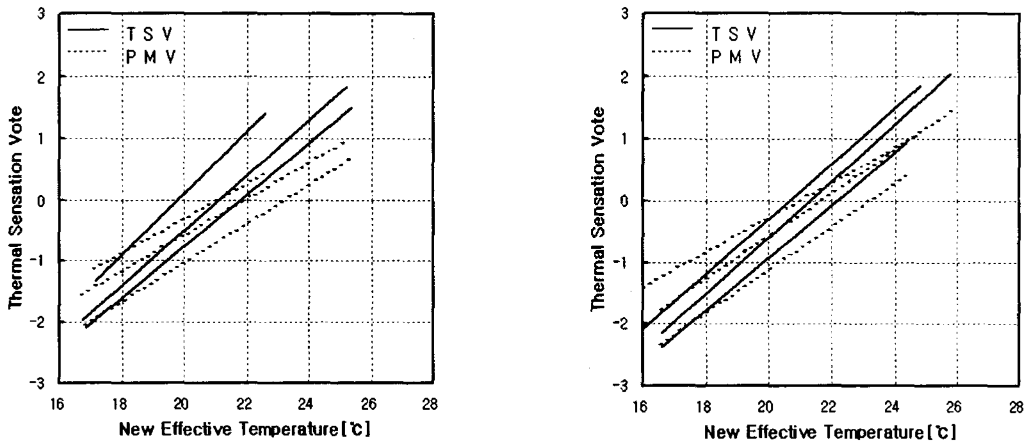
Fig. 3 TSV and PMV in terms of OT.

ply and PMV by theoretical calculation in terms of OT. As the temperature increased, TSV increased more significantly than PMV.

When the subjects sat on the floor, the thermal comfort range derived by regression formulas were 19.12~23.50℃ for TSV and 19.65~25.46℃ for PMV. When the subjects sat on the chair, the thermal comfort range derived by the regression formula was 19.89~23.79℃ for TSV and 19.47~25.10℃ for PMV. The TSV comfort range was lower than that of PMV. The thermal neutral points of TSV were lower than that of PMV by 0.81℃ for sitting on the floor and 0.65℃ for sitting on the chair. It was because OT lacks the elements that express the conduction heat exchange between the subjects and the floor. The TSV by OT showed a lower value than that of PMV.

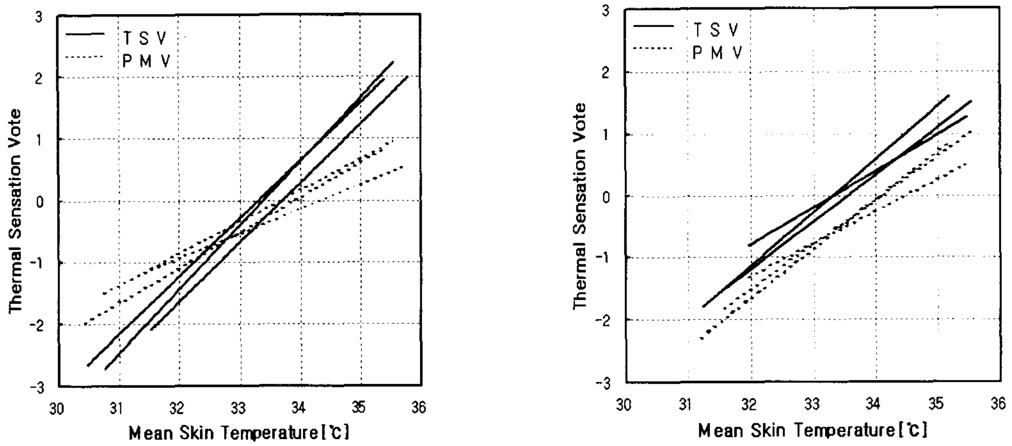
3.2 New effective temperature and thermal sensation

Figure 4 provides the comparison between PMV and TSV by subjects according to the



(a) Sitting on the floor (b) Sitting on the chair

Fig. 4 TSV and PMV in terms of ET*.



(a) Sitting on the floor (b) Sitting on the chair

Fig. 5 TSV and PMV in terms of MST.

new effective temperature. The thermal comfort ranges calculated using regression formulas were 19.54~23.34℃ for TSV and 19.18~24.56℃ for PMV when the subjects were sitting on the chair. The range for TSV was narrower than that of PMV. The thermal neutral points for TSV were lower than those of PMV by 0.77~1.7℃ and 0.28~0.99℃ for the cases of sitting on floor and chair, respectively. It was because of the fact that the new effective temperature lacks the conduction effect since it represents one temperature index synthesizing temperature and vapour pressure.

3.3 Mean skin temperature and thermal sensation

Figure 5 shows the comparison between PMV and TSV. The thermal neutral points for TSV and PMV were 33.5 and 34.1℃, respectively, when the subjects were sitting on the floor. The thermal neutral points for TSV and PMV were 33.9 and 34.3℃, respectively, when the subjects were sitting on the chair. The difference was 0.6℃ for sitting on the floor and 0.4℃ for sitting on the chair. The difference between TSV and PMV for sitting on floor was larger than while sitting on the chair. So, we suggest that the calculation of the mean skin temperature in the floor heated space should be expressed according to the contacted area ratio between the floor and the subjects.

3.4 Thermal sensation according to questionnaires and model formulas

Table 1 shows the PMV ranges calculated by the regression formulas. They ranged from

Table 1 Comparison of this study with ISO-7730

		Regression formulas	Thermal comfort range (−0.5<TSV<0.5)	Neutral point (TSV=0)
ISO-7730			−0.50<PMV<+0.50	PMV=0
This study	Sitting on the floor	TSV=1.3643 PMV+0.4834 (R2=0.6996)	−0.72<PMV<+0.01	PMV=−0.35
	Sitting on the chair	TSV=1.2729 PMV+0.2391 (R2=0.7028)	−0.58<PMV<+0.20	PMV=−0.19

−0.72 to 0.01 for the case of sitting on the floor, and from 0.58 to 0.2 for the case of sitting on the chair.

As shown in the table, the range of TSV changes according to the PMV ranges. When PMV varied between −0.5 and 0.5, TSV changed from −0.2 to 1.17 for the case of sitting on the floor, and from −0.4 to 0.88 for the case of sitting on the chair. This implies that the thermal comfort sensation for sitting on the floor showed the significant change.

4. Conclusions

(1) The comfort range, the thermal neutral point for temperature and new effective temperature showed the significant difference when the subjects sat on the floor and the chairs. We can think that it was because the elements representing conduction heat exchange between the subjects and the floor were deficient. The correlation by TSV showed a lower pattern than that of PMV.

(2) Regarding the neutral point of the mean skin temperature, the difference range between TSV and PMV were 0.37~0.76 when the subjects sat on the floor and 0.25~0.4 when the subjects sat on the chairs. We suggest that the calculation of mean skin temperature in the floor heated space should be performed according to the contacted area between floor and the bodies of subjects.

(3) Within the PMV range from −0.5 to 0.5, TSV changed from −0.2 to 1.17 for the case of sitting on the floor, and varied from 0.4 to 0.88 for the case of sitting on the chairs. We noticed that the TSV for sitting on the floor showed the big difference compared to the case of sitting on the chairs as the thermal comfort range moved from lower to higher temperatures. We can conclude that this was because the partial thermal comfort caused by contact between the floor and the parts of thigh, calves and feet of the subjects affected the entire thermal sensation of subjects as the floor temperature increased.

Acknowledgement

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