第 24 回 人間-生活環境系シンポジウム（東京 2000 年 11 月）

Transition and State of Thermal Environment of Ondol(Korean Floor Heating System)

Jang-Yeul Sohn
Hanyang University, Seoul, KOREA

1. Introduction

There are four distinctive seasons in Korea; a continental climate in winter and an oceanic climate in summer, showing a large temperature difference throughout the year. Because of this climate condition, the warm house in winter and the cool house in summer was needed for dwellers and the floor heating system called 'Ondol' was developed for the winter living. Koreans usually sit on the floor without wearing shoes and the body(feet) has a direct contact with the floor surface. Most Korean prefer a warm floor temperature when sitting and lying. Therefore, thermal comfort change according to the variation of the floor surface temperature.

This article deals with the historical transition and some research results about thermal environment in Ondol space.

2. Korean Floor Heating System

2.1 Brief history of Ondol

Ondol has been used for over 1,500 years in Korea. The development of the Ondol system could be categorized into two eras; the era of the traditional Ondol heating system which supply heating air under the floor and the era of using embedded hot water pipes. The fuel of the system used straw, firewood etc. earlier and used coal and oil with development of industry

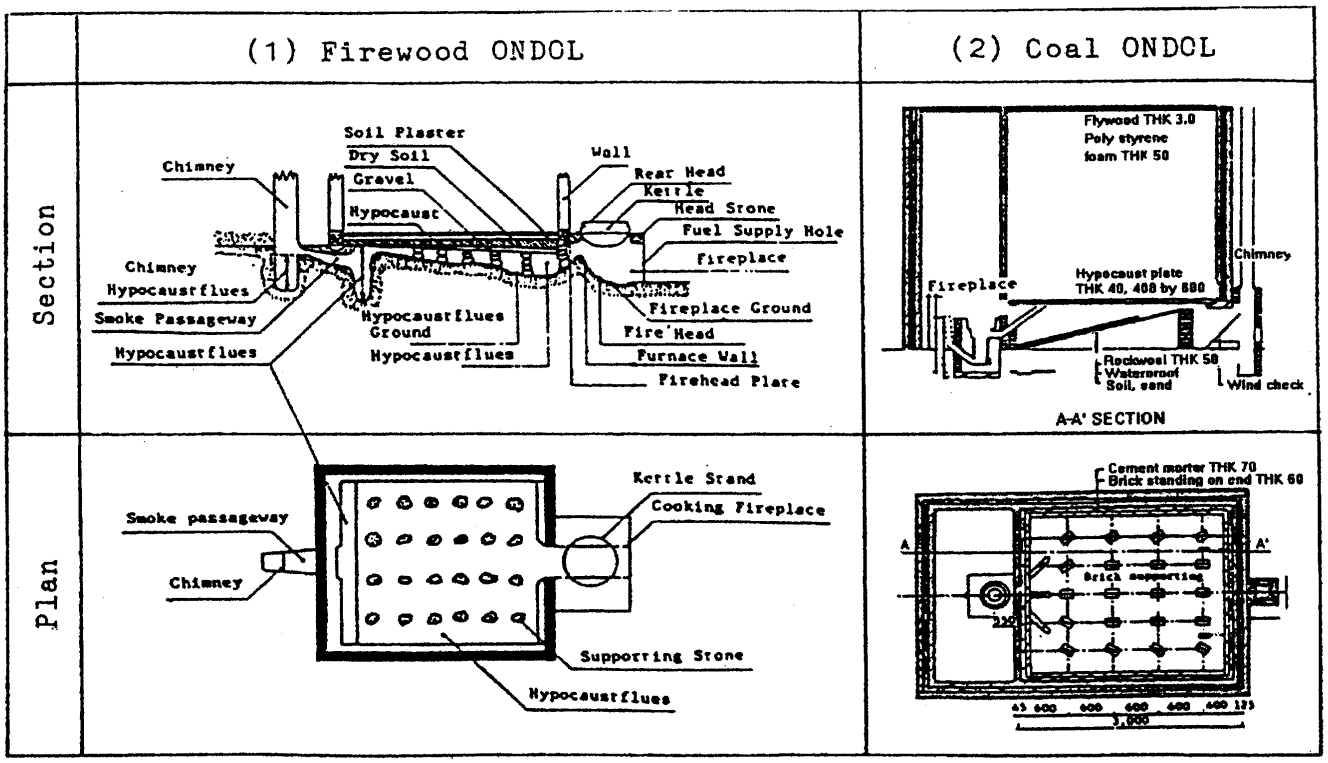

Fig. 1-Conventional Ondol

1) Conventional Ondol

As shown in Fig. 1, the structure of conventional Ondol was one in which heated air passes through a hypocaust flues after combustion and a hypocaust is heated up and then radiates heat into the room space. The temperature of different parts of a room floor varied, thus temperature of the places nearest and farthest to the fireplace were not even. Floor temperature distribution is shown in Fig. 2. Although people were in the same space, the difference of temperature preference existed according to the age of them. The floor temperature was relatively hot because there was an amount of infiltration air in the house.

2) Hot Water Ondol

As the traditional system became modernized, hot water Ondol(See Fig.3) came into use widely. Hot water passes through embedded pipes and heat radiation from the floor surface makes occupants comfortable. It is used in most housing(residences, apartments) as well as some hotels and hospitals. A large- scale heating source of district heating system is adapted in large housing complexes in new towns.

2.2 Present Design criteria

The design criteria of the floor heating system in apartments is "the Code for the Equipment Criteria of Building", established early 1980s, and it prescribes the heating equipment criteria of apartments and the installation criteria of Ondol. The structure of the hot water Ondol is basically divided into a base layer, a heating storage layer and a insulating layer on a concrete slab.(Fig. 4)

Table 1 shows the required performance criteria of Ondol components.

3. Thermal Environment in Ondol

3.1 Thermal comfort in asymmetric thermal radiation

There are problems in applying the comfort criteria which have been used in other countries to Korean without adjusting them because heating methods and thermal sensation are different between Koreans and other countries. As it is known that the V.R.T.(Vector Radiant Temperature) evaluates asymmetric radiation in some researches, V.R.T. was used to describe the environmental quality of these spaces.

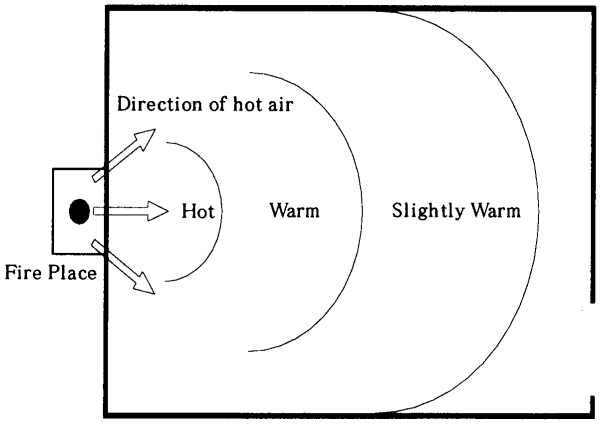

Fig. 2-Floor temperature distribution of traditional Ondol

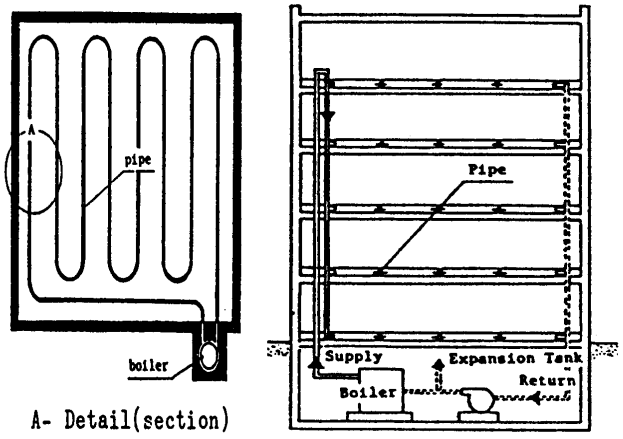

Fig. 3-Hot water Ondol

Table. 1-Composition detail of Ondol

Classification	Korean Building Code	Korea Nat'l Housing Corporation Code
Heat storage layer	aggregate below Thk.40~70, mortar, concrete	gravel(70cm) or macadam
Insulation layer	• the lowest layer : 0.5[kcal/m²h] • middle layer : 1.0[kcal/m²h] • none of insulation rule in the central heating or district heating	—
Finishing layer (coated thickness of pipe upside	15~25mm	22mm mortar
Pipe diameter	diameter : above 15mm	15.88mm bronze pipe
Pipe Pitch	below 150~300 mm	200~250mm
Hot water supply temperature	—	• Unit heating: 60~50℃ • Central heating: 70~60℃ • District heating: 60~45℃
Floor surface temperature	—	—

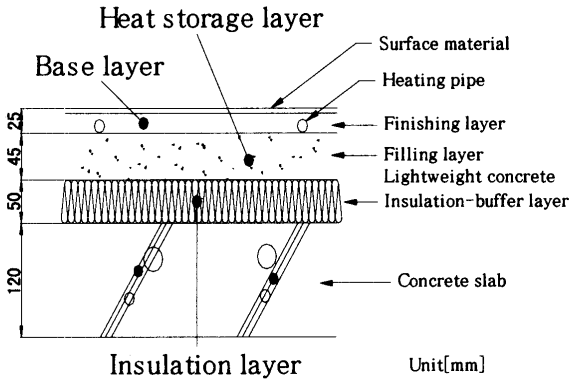

Fig. 4-An example of detail of Ondol Structure

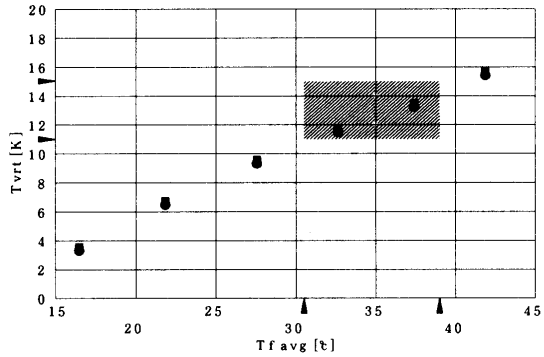

Fig. 5-The scatter diagram of V.R.T. and floor surface temperature

Fig. 5 shows the experimental result on floor surface temperature. Both the upper and lower limits of V.R.T. were defined to determine the optimum comfort limits on the heated floor space. The lined area of Fig. 5 represents the optimum V.R.T. range in a floor heated space. Table 2 shows the standards and research results on floor temperature and V.R.T. in the heating season. Most of the results on floor temperature were established by convective heating systems. Therefore the low limits of floor Temperature are much lower than the results in this article.

3.2 Thermal comfort in the Partial Ondol Heating System

Koreans are familiar with the thermal sensation by contact with the warm floor. Therefore, even though room temperature is within the comfort range, the thermal sensation will be different according to the floor surface temperature. Recently, the heating loads of residential buildings have been reduced owing to the increased thermal insulation and airtightness of the buildings. Consequently, the Ondol floor surface temperature can be maintained lower than the past. The Partial Ondol Heating System is devised to rise the floor surface temperature higher.

The experiment was conducted with a subject in the test room of the Ondol system which can be heated partially was constructed. The comfort zone according to the heating ratios changes shown in Table 3. The range of a comfort zone is changed according to heating ratios. In particular, the comfortable floor temperature is lower than that of a partial heating according to the increase of heating ratios. Fig. 6 shows that the comfort range of a floor temperature and a indoor temperature according to the heating ratio. According to the increasement of the heating ratio, the comfort range of floor temperature falls and that of room temperature rises. But the range of an indoor comfort temperature is lower than the existing comfort range in the case of partial heating because respondents felt comfortable in a high floor temperature in spite of a low indoor temperature.

Table. 2-Standards and results of experiment for optimum comfort

Source	Floor Surface temperature	V.R.T [K]		Indoor air Temperature	Reference
		H	V		
ISO-7730	29 19□26	10	5(ceiling)	OT (20□24)	Floor heating / convective heating (ISO, 1984)
ASHRAE 55-1981	18□29	10	5		(ASHRAE, 1981)
Nevins et al.	23.7□37.8			23.7	(Nevins et al., 1964)
Viesmann	29.4~32.2			15.6~21.1	(Nevins et al., 1964)
McIntyre	29.5		20 (optimum value : 10)		(McIntyre, 1976)
Olesen et al.		10 20			nude, 0.7clo (Olesen, 1985)
Yoon et al.	30.6~38.8		11-15		floor heating

Table. 3-Comfort zone with heating ratio

Indices	PMV range	Heating Ratio	
		60 %	100 %
Room	-0.3~0.3	18.20~20.36℃	18.78~20.70℃
	-1.0~1.0	15.70~22.86℃	16.32~23.07℃
Floor	-0.3~0.3	31.94~34.62℃	25.97~29.73℃
	-1.0~1.0	28.82~37.75℃	21.59~34.12℃
OT	-0.3~0.3	19.00~21.10℃	19.10~21.14℃
	-1.0~1.0	16.55~23.51℃	16.73~23.52℃
MRT	-0.3~0.3	20.00~21.80℃	20.50~22.60℃
	-1.0~1.0	17.68~25.26℃	17.99~25.52℃

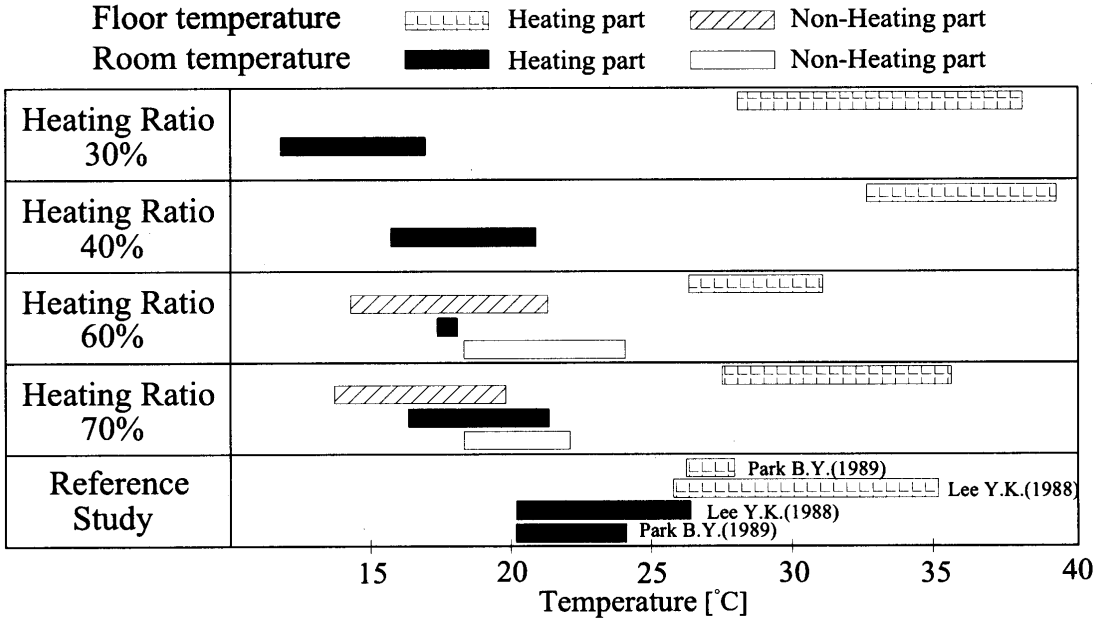

Fig. 6-Comfort range of temperature in partial heating system

references

(1) PARK B.Y. (1989) : Study on the Thermal Comfort Zone in Apartment House(I), Journal of the Architectural Institute of Korea, Vol.5, No.6, pp257-264

(2) LEE O.K. (1988) : Distribution of Thermal Environmental Elements and Neutral condition on each posture of the Human body in an Apartment house, Thesis for master's degree, Hanyang University, Korea

(3) YOON Y.J., PARK S.D., SOHN J.Y. (1992): Optimum Comfort Limits Determination through the Characteristics of Asymmetric Thermal Radiation in a Heated Floor Space, ONDOL, The Annals of Physiological Anthropology Vol.11, No.5, pp517-522

(4) BAIK Y.K., AHN B.W., SOHN J.Y. (1995): The Characteristics of Thermal Environment and Comfort zone under the Partial ONDOL Heating System, The 5th International Symposium on Building and Urban Environmental Engineering and Management, Kumamoto, Japan, pp207-212

(5) SOHN J.Y. (1986) : Ondol in Korea and New Heating Plan, Journal of Heating, Air-Conditioning and Sanitary Engineers of Japan, Vol.61, No.4,

(6) SOHN J.Y. (1986) : The State of Thermal Sensation Researches in Korea and Thermal Comfort in Ondol Space, The 10th Symposium on Man-Thermal Environment system in Tokyo, Japan, pp93-98