A Study on Thermal environment of the Raised-Floor Ondol with a Ventilation System at an Apartment

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ABSTRACT

A radiant heating applied to floor, so called 'Ondol', is a traditional heating method in Korea and has been widely used. The form of the Ondol has been modified so that it can be applied to modern residential buildings. However, the Ondol system has limitation in keeping comfortable indoor-environment, because the Ondol is able to control floor temperature only. Moreover, a Korean government stipulated that new residential buildings are to be 0.7 ACH (Air Change per Hour) to protect indoor air quality from toxic substances emitted form construction materials, furniture and etc.
Therefore, raised-floor Ondol with ventilation that can provide pre-heated fresh outdoor-air was suggested to solve this problem. Under this system, the outdoor air flows through ducts in the cavity between slabs and Ondol panels so that it could be supplied to rooms after it was preheated.
The experiment was carried out at apartment housing under construction in Seoul, 16th~18th February 2008. The following conclusions can be made: (1) An average surface temperature of duct was 9.1 so that is lower than expected value. (2) An average indoor air temperature was 17.4 (Max. 19.9) which could satisfy with the rage of thermal comfort for indoor air (17~22) taking sensor's tolerance into consideration. (3) The surface temperature of floor swung between 22 and 32 .

1. INTRODUCTION

A radiant heating applied to floor, so called 'Ondol', is a traditional heating method in Korea and has been widely used. The form of the Ondol has been modified so that is can be applied to modern residential buildings. However, in light of indoor environment side, the Ondol system has limitation in keeping comfortable indoor environment, because the Ondol is able to control floor temperature only. The controlling ventilation is needed to meet good indoor environment. Houses built many years ago achieved natural ventilation through infiltration. But modern buildings built recently are so airtight that it is hard to be occurred natural ventilation well. Moreover, a Korean government stipulated that newly constructed residential buildings are to be 0.7 ACH (Air Change per Hour) to protect indoor air quality from toxic substances emitted form construction materials, furniture and etc.
Therefore the Upgraded Ondol system has been developed to fulfill a relate standard and provide comfortable indoor environment for occupants. The principle of this system was proved through two experiments; chamber experiment and house experiment. In these experiments, performance and field application of this system were studied. However, the study on apartment housing applying this system has not been carried out. Apartment housing accounts for more 54% of dwelling house in

Korea. The purpose of the present paper is:

1) to introduce the concept of raised-floor ondol with a ventilation system

2) to experimentally investigate its thermal performance and applied feasibility at apartment housing; and

3) to provide experimental data for modeling and simulating such system.

2. THE CONCEPT OF A NEW SYSTEM

2-1. Raised-floor Ondol with a ventilation system

Ondol is divided into two-types, which are pipe-burying heating system (wet-type) and prefabricated Ondol system (dry-type). Other system is double-bottomed Ondol system, which has a characteristic of decreasing floor impact sound as well as the advantage of prefabricated Ondol system (dry-type).(Sung, 2007) This kind of Ondol system is called "Floating floor Ondol system" The raised-floor Ondol with a ventilation system was developed base on Floating floor Ondol system. Under this system, outdoor-air flows through ducts in the cavity between Ondol panels and slab so that it could be supplied to rooms after it was heated. The principle of raised-floor Ondol with a ventilation system is shown in Figure 1 and the composition and materials of an experimental floor is shown in Figure 2 respectively. The experimental floor was composed 5 layers; 20 mm-thick Particle board, 12 mm-thick Improved wood, 12 mm-thick Ondol panel (within 10 mm-thick heating pipe), 5 mm-thick plywood.

2-2. Results of former studies and the range of thermal comfort for Ondol

Two experiments adopt this system was performed. The first experiment was performed at a full-scale model in a chamber and cavity was as a plenum type. The second experiment

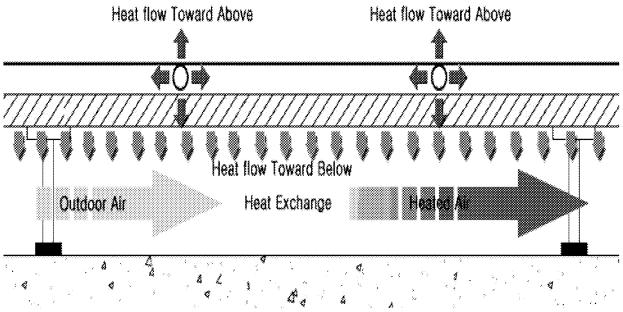


Figure 1: The principle of raised-floor Ondol with ventilation system

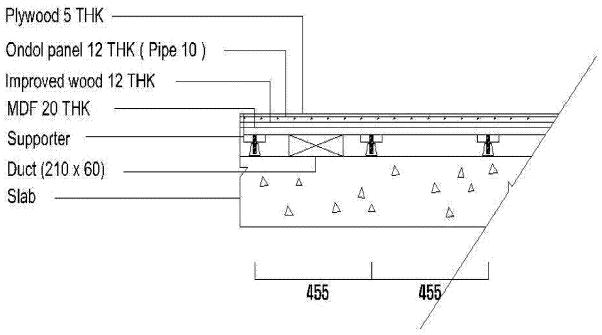


Figure 2: The composition and materials of an experimental floor

was performed at the one room of residential house and cavity was used as a duct type. In a chamber experiment, indoor air temperature satisfied with the rage of thermal comfort in spite of lower supply-water temperature. It is seem that surround environment didn't affect much on experimental model in a chamber. However, in the second experiment, the supply-water temperature had to be high to achieve adequate temperature of out-let air, and thus the temperature of inner surface of floor was too high to satisfy with the rage of comfort temperature for it. In case of studies performed in America or Europe, thermal comfort was checked during human standing or sitting on a chair, but Korean spend their time with themselves set on a floor. Therefore, the rage of thermal comfort for Ondol heating system was needed, and studies about this have been con ducted many times. The results of former studies and thermal comfort under Ondol heating system were shown in Table 1 and 2 respectively.

Table 1: The results of former studies

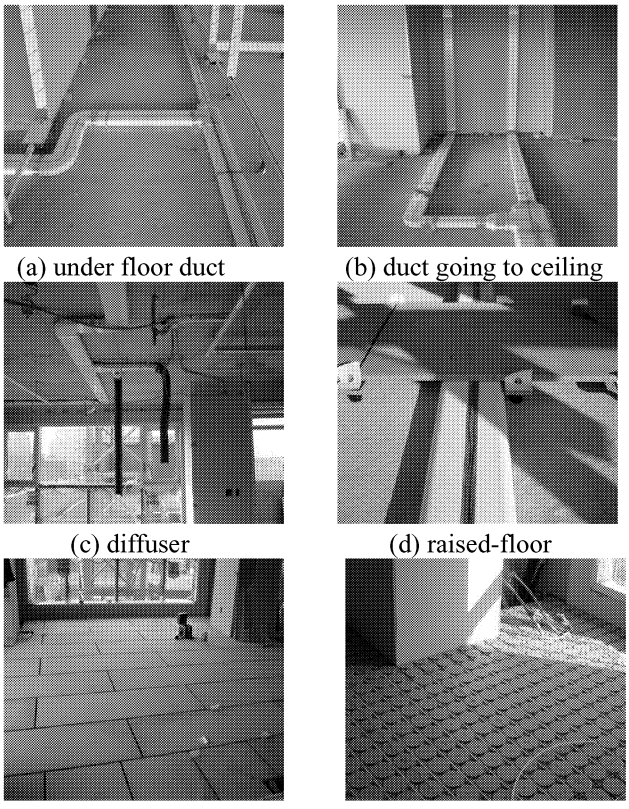
		1st experiment (in a chamber) 2006	2nd experiment (in a house) 2007
Condition of experiment	The dimensions of experimental house(model)	5m(L)×5m(D)×2.5m(H)	4.45m(L)×3.35m(D)×2.85m(H)
	Composition of floor	Ondol panel (20THK) Panel board (20THK) Cavity(Plenum 60THK) Slab	Finishing (10THK) Ondol panel (20THK) Insulation (18THK) Panel board (20THK) Cavity (Duct 60THK) Insulation (30THK) Slab
	ACH	0.86	0.74
	Ambient air temp. (Aver.)	1.39	-1.96
	Boiler controlling (Supply hot water)	Full operation (39.92)	1 hour on / 1 hour off (60)
Results	Indoor air temp.	Ave.:26.12 Min. :23.59 Max. :27.95	Ave. : 21.25 Min. : 19.26 Max. : 23.45
	Surface temp. of floor	Ave.: 31.26 Min. : 25.69 Max. : 34.28	Ave.: 38.52 Min. : 32.91 Max. : 44.14

Table 2: Thermal comfort under Ondol heating system

Title and author of paper	Rage of thermal comport
A Study on Thermal Comfort Requirements of Low Temperature Floor Heating System( ) (Yoon, 1991)	Comport Indoor air temp. - 18 ~ 21 Comport surface temp. for floor - 1 min. : 28 ~ 33 - 20 min. : 27 ~ 31.4
Indoor Thermal Characteristics and Comfort Zone under the Differential Ondol Heating System (Baik, 1994)	Comport Indoor air temp. - whole heating: 13 ~ 17 Comport surface temp. for floor - whole heating: 22 ~29
Establishment of Optimum Floor Surface Temperature Floor in Ondol Heating System (Kong, 1995)	Comport Indoor air temp. - 18 ~ 21 Comport surface temp. for floor - floor contact : 29 ~ 34 - non-contact : 27 ~ 38

3. MEASURING METHOD

The experiment was carried out at an apartment under construction in Seoul, 16th~18th February 2008, and the area of experimental unit house was 144.6 square meters. Mechanical ventilation was used for induce and exhaust, and the diameter of diffuser stolen at each rooms was 100 mm. Measuring points were follows ; 19 points for inside of duct, 5 points for diffusers, 5points for each layer of floor, 10 points for indoor air temperature (at the center of each room 0.5 high and 1.5 high). Copper-constantan thermal couples (□0.3mm, T-Type) were used to measure temperature and date stored every one minute. The temperature of supply hot water was set on 60 and a boiler was turned on for 90 minutes and off for 30 minutes. When the experiment was performed, inner-walls were not built and ceiling finishing was not done yet. Figure 3, 4, 5 and 6 show construction of system, floor plan of experiment house, measuring points and temperature of supply hot water and return water respectively.



(a) under floor duct (b) duct going to ceiling

(c) diffuser (d) raised-floor

e) finishied raised-floor (f) Ondol panels

Figure 3: Construction of system

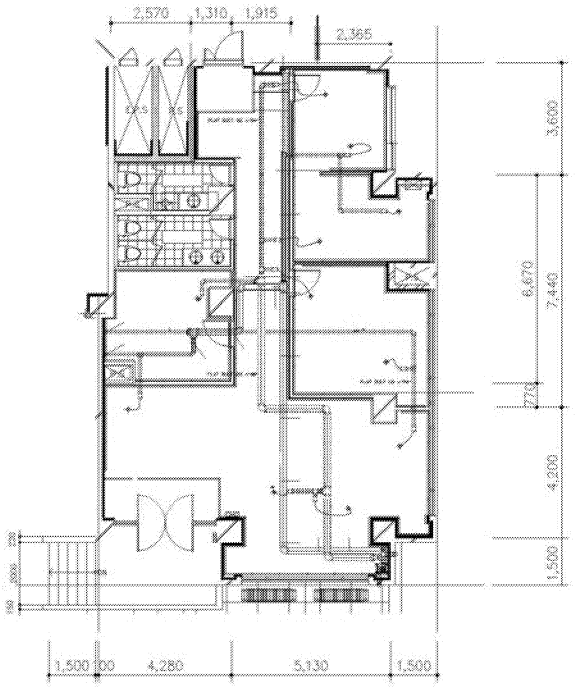


Figure 4: Floor plan of experiment house

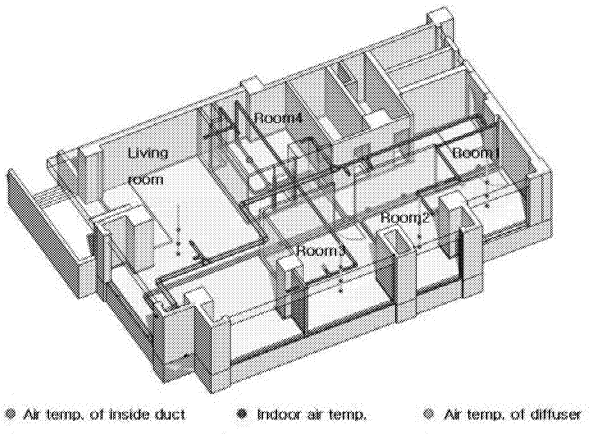


Figure 5: Measuring points

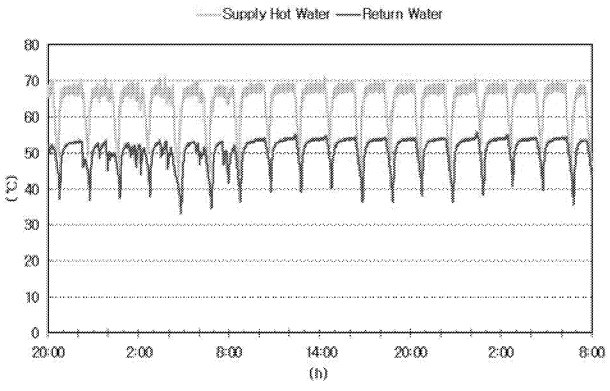


Figure 6: Temperature of supply hot water and return water

4. RESULTS

4.1 The temperature of ducts

To know the temperature of duct and its circumstance, surfaces and inside of duct and cavity temperature were measured at D16 point. Figure 7 indicates measuring points of duct and Table 3 shows average temperature of each points. The average surface temperature of duct was 9 , and inside of duct was 11.4 . And the average air temperature of cavity was higher than duct as 12.8 . Hence, it is seemed that low temperature of slab affected duct which contacts with surface of slab

4.2 Supply air temperature

Figure 8 shows that the outdoor air was heated during it flew through dust, and the swing of supply air temperature was smaller than the swing of out door air temperature. The maximum value of average air temperature was diffuser of room2 with 15.9 and of temperature difference between out door air and supply air was 18.3 .

4.3 Indoor air temperature

Figure 9 shows the indoor air temperature at 1.5m high. The average indoor air temperature was 17.4 which could satisfy with the rage of thermal comfort for indoor air (17~22) taking sensor's tolerance into consideration. There was no temperature difference among three measuring points because inner walls were not built.

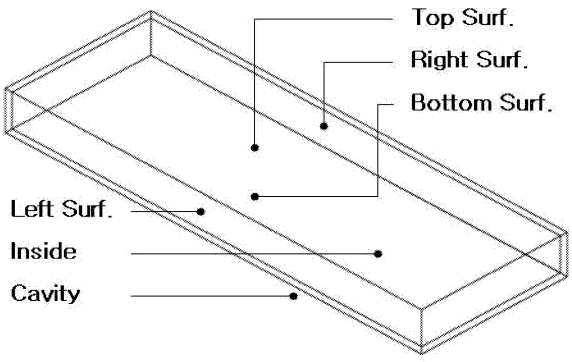


Figure 7: Measuring points of duct

Table 3: Average temperature of each point

Measuring Point	Average Temp. (℃)
Top Surface	9.23
Bottom Surface	9.27
Right Surface	8.89
Left Surface	8.97
Inside	11.4
Cavity	12.8

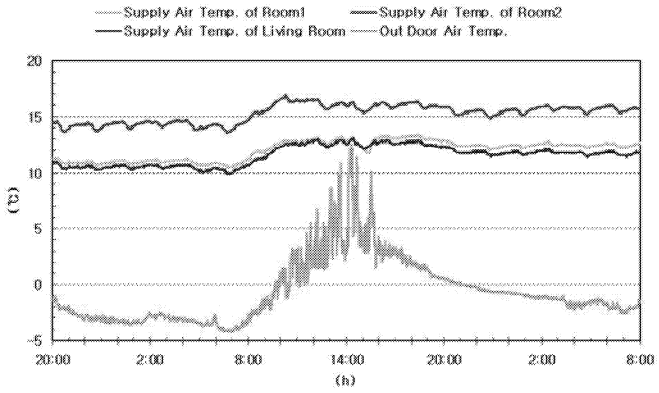


Figure 8: Supply air temperature of diffusers

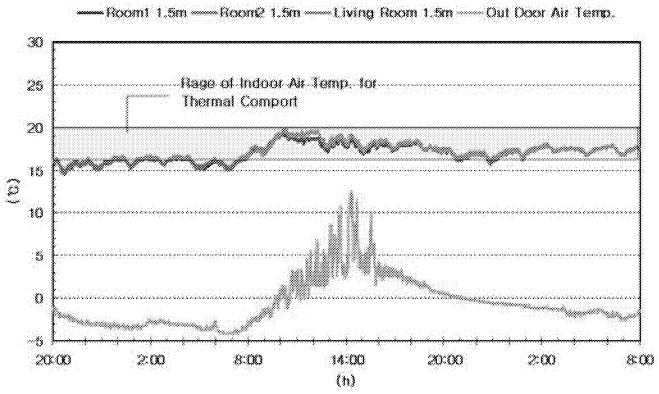


Figure 9: Indoor air temperature

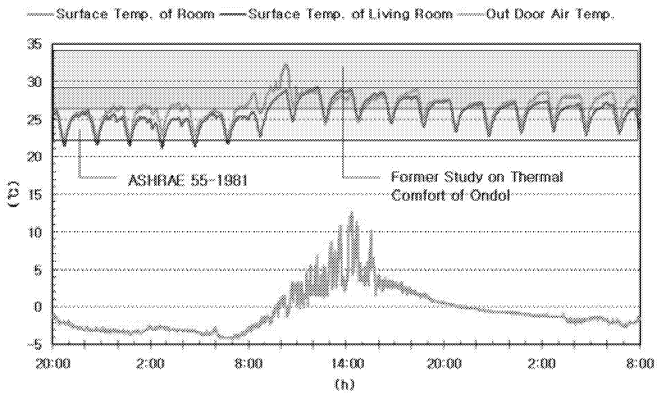


Figure 10: Surface temperature of floor

4.4 Surface temperature of a floor

Figure 10 shows that the surface temperature of a floor swung between 22 and 32 . In ASHRAE standard 55-1981, it is provided that the thermal environment condition for human occupancy is 18~29 for floor surface temperature except for a bare foot (ASHRAE 1981). However, it is hard to apply ASHRAE standard to this result strictly because of a different lifestyle in Korea. Therefore, the rage of thermal comfort for Ondol heating system should be applied to this study. Former studies about this indicated that the comfort surface temperature for floor is 27~34 . The surface temperature of floor swung within the ASHRAE standard. However, when the rage of former studies is applied in this result, the surface temperature of floor during boiler was stopped was lower than 27 .

5. CONCLUSIONS

A new structure of raised-floor Ondol with a ventilation system was put in an apartment for this study. And the experimental results testified the feasibislity and good performance of the heating system. The following conclusions can be made:

(1) The average surface temperature of duct was 9.1 so that is lower than expected value. It is seemed that low temperature of slab affected duct which contacts with the surface of a slab. Therefore, it is estimated that an insulation layer should be put between duct and slab to protect conduction.

(2) Outdoor air temperature increased during air flew through ducts and the maximum temperature difference between outdoor air and diffuser was 18.3 . An average indoor air temperature was 17.4 (Max. 19.9) which could satisfy with the rage of thermal comfort for indoor air (17~22) taking sensor's tolerance into consideration. And it is expected that indoor air temperature will be raised more because of inner heat gain for using.

(3) The surface temperature of floor swung between 22 and 32 . During heating period, the temperature was too high to achieve the rage for comfort (27~34). However, after turned boiler off, the temperature went down below 27 so that it is seemed that occupants will be able to feel uncomfortable.

The experiment was performed in an under construction site. Therefore, it is required that a measurement should be performed once more after the apartment was occupied. And to determine energy consumption of using this system, additional study must be conducted.

ACKNOWLEDGEMENTS

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