A STUDY ON THE CHARACTERISTICS OF INDOOR ENVIRONMENT AND COMFORT IN OFFICE BUILDING WITH UNDERFLOOR AIR-CONDITIONING(UFAC) SYSTEM

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ABSTRACT

During the last decade, an increasing interest in Underfloor Air-Conditioning(UFAC) systems has emerged. This is due mainly to an increased demand from employees for a greater control over their working environment. And the building and its engineering systems not only have to be designed to achieve the high standards of environmental control at economical cost, but also thermal comfort is an important factor that influences occupants' satisfaction with the indoor office environment.

The purpose of the study is to evaluate comprehensively the environmental performance of office buildings with UFAC system in order to suggest the basic data for developing the design prototype of this system within the possible range. Physical measurements were made of thermal environmental factors, the equivalent sound level of room, the levels of illumination of working plane, and indoor air quality.

INTRODUCTION

Since 1970, the office environment of building has been significantly changed and the office automation for productivity improvement and efficiency has proceeded. According to these trends, the concept of office environment was transited from conventional 'working space' to 'living space' or 'creative space'. While the quality of indoor environment and energy savings has been concerned, air-conditioning has been done on a target for a whole building until 1970s. After then, these air conditioning's targets have been changed into each-floor, area, and zone air-conditioning. In 1990s, UFAC system, also called 'Flexible Space System', was adopted with the times. The system, undoubtedly, will have the potential to affect many of the ways such as thermal comfort of occupant, ventilation efficiency, air quality and productivity, even though only a few examples are buildings with the system in Seoul, KOREA.

The study deals mainly with the physical measurements such as the thermal environmental factors, noise level, levels of illumination, and indoor air quality. Furthermore, the purpose of this study is also to evaluate comprehensively the indoor environmental performance of office building with UFAC system in order to suggest the basic data for developing the design prototype of this system within the possible range.

SYNOPSIS AND FIELD MEASUREMENTS

The measurements in this study were performed at 6th floor of S office building in Seoul, Korea. The building was built in 1993, and 8th story (2nd basement) totally. The area of 6th floor was 178.15 m^2 and 55.4 m^2 in office and conference room, respectively. And, the HVAC system was basically CAV+FCU, except for 6th floor with UFAC system. The UFAC system consists of three main units. They are Conditioned Air Modules(CAM), Underfloor Plenums, and Floor Terminal Units(FTU). A CAM unit blows controlled air into between underfloor baffles. The air is then led into the rooms through FTUs (floor outlets) that mounted on a floor panel. Room air is returned into the underfloor return air grilles located at the opposite side of FTUs. In general, UFAC system can be classified into three types:

- low-pressure plenum system using fan-powered units,
- pressurized plenum system using diffusers,
- a ducted system.

In this study, a low-pressure plenum system using fan-powered units was evaluated. The fan unit consists of a variable-speed fan and two rotating grilles in which the air volume and air direction of the unit can be controlled individually. The fan unit is mounted on a floor panel with outlet, so a regular panel can be replaced by a fan unit panel when the layout is changed.

The measurements were carried out in a S-building located at Seoul, Korea. The field survey was carried out on the building for two days during the cooling season. The synopsis of the building is shown in Table 1. As a remarkable thing, this building uses the overall space underneath the access floor as plenums for passing air, and thus it reduces the story height of building to a certain degree because of not being necessary the duct space of ceiling inside as same as the case of conventional ceiling supply air-conditioning system.

Figure 1 shows the 6th floor plan indicating the positions of FTUs and return air grilles, measuring points, and the shape of FTUs. Physical measurements were made of the thermal environmental factors such as air temperature, relative humidity, air velocity, globe temperature, and the other several environmental factors such as the noise level and the levels of illumination of working plane, etc. Furthermore, the air quality was evaluated by measuring the concentration of suspended particles (dust), carbon monoxide, and carbon dioxide in the room.

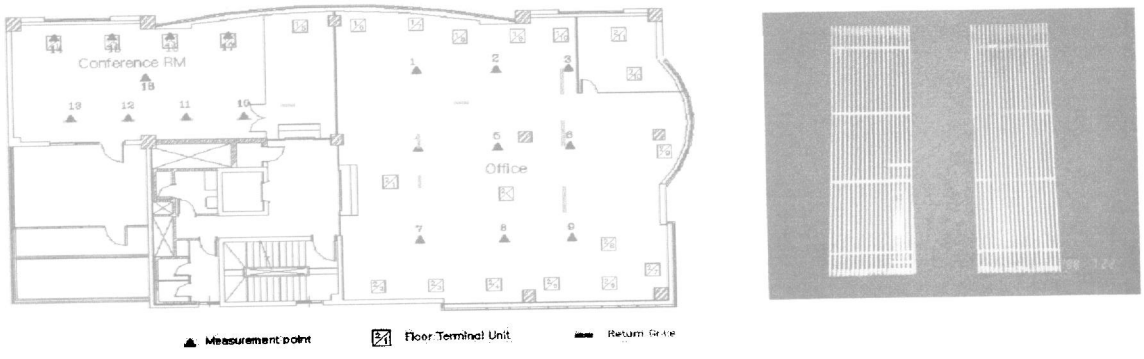


Figure 1. 6th floor plan of an office building and the shape of FTU

Table 1.The synopsis of building and the measuring items including instruments

	Measuring items	Measuring instruments	Position
Thermal environmental factors	Dry-bulb temperature Globe temperature	Assman thermometer Globe thermometer	Centre of room
	Relative humidity Air velocity	Thermometer CTH-990 Anemomaster	Representative points
Air quality	Suspended particles Carbon dioxide	Digital aerosol monitor (P-5H2). Portable CO_2, CO meter (M 8550, TSI)	(9 points)
Lighting	Levels of illumination	Digital lux meter – Lm- 2D(TOPCON)	
Sound	Noise level	Sound level meter (SL-1350)	Centre of room
Occupants	No. of occupants	Counter	N/A

RESULTS AND DISCUSSION

Thermal environment

Thermal Environment was investigated under several conditions. Figure 2 shows the temperature distribution including outside air, room air, and globe temperatures. As shown in the Figure, the outside air temperature ranged from 28.9 to 37.4°C during working hours from nine to five o'clock. The room air temperature of office and conference room ranged from 24.7 to 26.7°C, 23.6 to 26.4°C, respectively. And, the difference of between dry-bulb and globe temperature were 0.6 and -0.4°C, respectively. The average relative humidities of office and conference room were 65.6 and 66.7%, respectively.

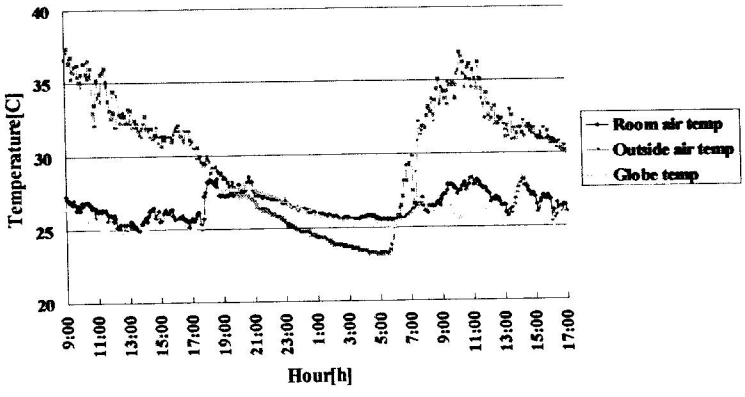


Figure 2. Temperature profile in office during cooling season

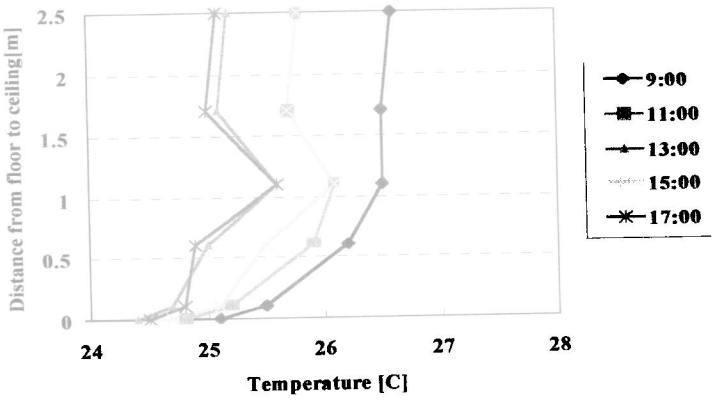
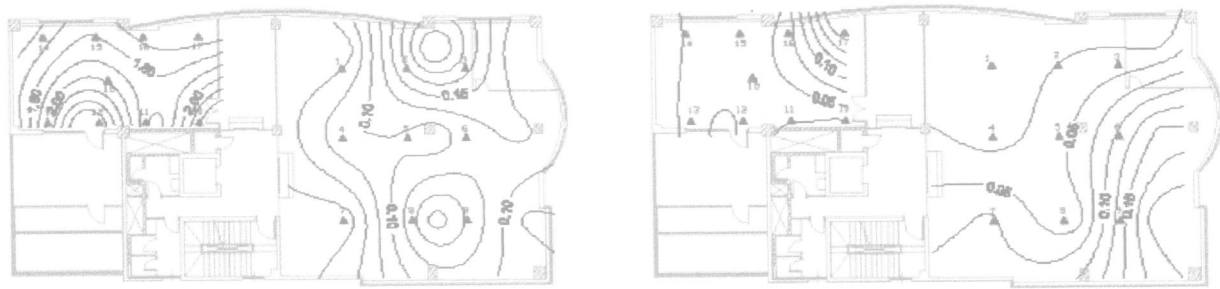


Figure 3. Vertical temperature distribution in office during cooling season

The vertical temperature distributions are shown in Figure 3. The temperature difference of between floor and ceiling has only 0.86°C without reference to the elapsed time. Thus, it is satisfied the fact that the vertical temperature difference of between 10cm and 110cm above floor has to be less than 3°C suggested by ISO recommended criteria for indoor thermal comfort. Figure 4 is a plot of room air velocity. The mean velocity holds up very low with the value of 0.16 and 1.39 m/s in the office and conference room, respectively. With putting all this situations together, it can be seen that indoor thermal environment produces a very comfortable condition and thus the value of building itself is increasing, too.



(a) 14:00 (b) 20:00

Figure 4. The variation of air velocity during cooling season

Sound

Figure 5 plots the equivalent sound level distribution in the office and conference room. As shown in the Figure, that of office ranged from 57.4 to 59.6dB(A), and that of conference room 51.1~60.5dB(A). These values are much greater than 48~58dB(A) and 38~48dB(A) which were the values suggested by Beranek (1988) as the recommended values of both rooms. On the other hand, the mean difference of between the equivalent sound level and the background noise are 12.5 and 11.8dB(A) in both rooms, respectively. These reasons are considered to be due to rather than too much high noise by fan operation in floor outlets to the influence of other factors such as the hammering sound of automatic door being bumped and indirect traffic noise. Because, the equivalent sound level measured in front of CAM(that is, indoor air-conditioner) was less than 46dB(A), even though it was operated at high speed. And, unfortunately, the peripheral conditions at the measuring times were not so desirable.

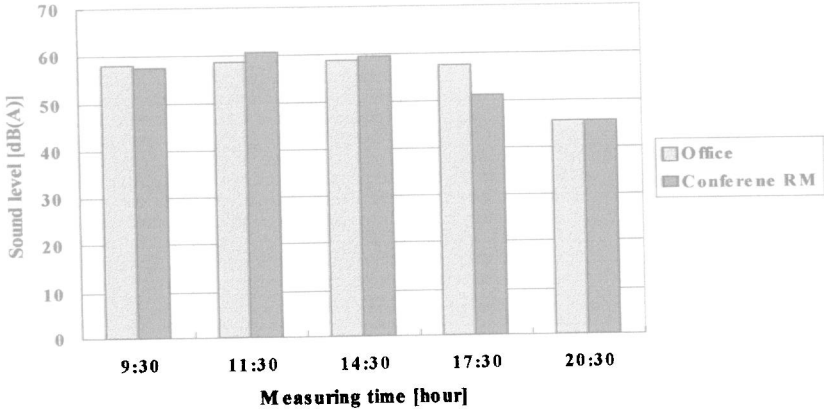


Figure 5. The equivalent sound level distribution in the office and conference room

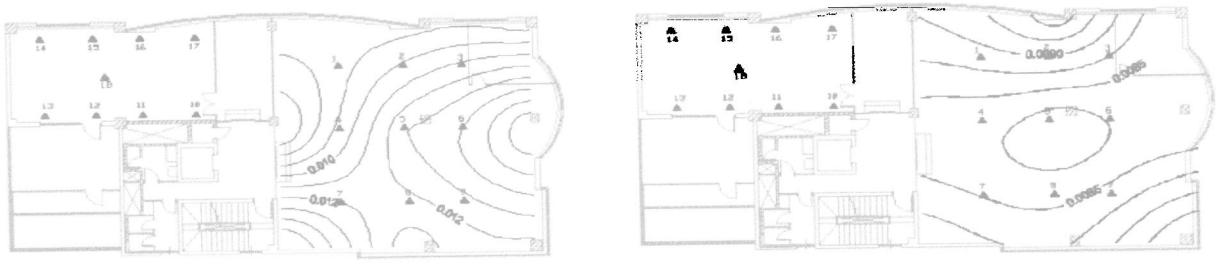
That is to say, it is presumed that the noise levels of office and conference room were increased because of following mixed influences due to:

- the temporary disorder of automatic entrance door in the measuring times,
- the repetition of frequent open and close of the door due to the 6th floor room serving both as a office and a business department,
- and the indirect impact due to the location of this building near the highway.

Therefore, it is considered to be able to be overcome to a certain degree the fact that noise being caused from FTUs using fan-powered units deteriorates indoor environment, if such conditions have been excluded at that measuring times.

Air quality

Figure 6 shows the concentration variation of suspended particles in the office and conference room; both rooms have a very low dust concentration of 0.004~0.01mg/m^3. Figure 7 plots the concentration variation of CO_2 in the same rooms. The means were 646.6 ppm (maximum 707.2 ppm) and 650.1 (maximum 693.5 ppm), respectively. Because the concentration of CO was so low in this pilot measurement, the data were not processed further. The concentration of contaminants, overall, were much lower than in the office with conventional ceiling supply air-conditioning system which were measured by the team of Hanyang University. Thus, it seems that UFAC system produced much better indoor air quality than the conventional ceiling supply air-conditioning system did because of dispersing around dust being piled up at the floor surfaces due to keeping blow air from floor outlets into indoor. In other words, this indicates that UFAC system produces a desirable indoor air quality. In general, UFAC system installed a high efficient filter basically in the inside of CAM, and prevents from recontamination of polluted air because of being able to dust the inside of access floor easily. And, as being proved from many literatures, indoor air quality is also very superior because of filtering room air locally in several places by the dispersed placement of CAMs.



(a) 11:00 (b) 20:00

Figure 6. The concentration variation of suspended particles during cooling season

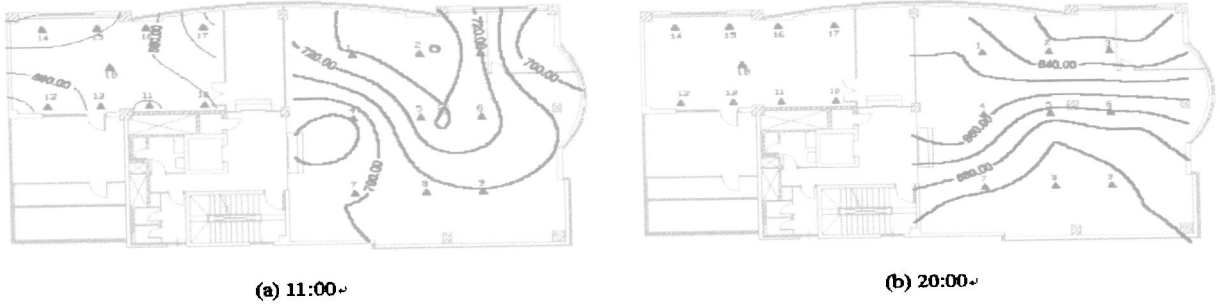


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Figure 7. The concentration variation of carbon dioxide during cooling season

Lighting

The levels of illumination of office and conference room in the morning and afternoon were also investigated with two hours interval. The mean levels of illumination of two rooms are 351 lx and 159.3 lx in the morning, 315.4 lx and 166.1 lx in the afternoon, respectively. The levels of illumination ranged from 306 to 352 lx(mean value is 328 lx) in the office, and from 159 to 166 lx(mean value is 162 lx) in the conference room. In the case of conference room only, the level of illumination was much lower than the recommended level(300 lx) of illumination in Korea. But, the reason is considered to be due to lighting only the two of third of total 48 fluorescent lamps for the purpose of energy saving.

CONCLUSIONS

In order to evaluate comprehensively the indoor environmental performance of office building with UFAC system, the study dealt mainly with the physical measurements such as thermal factors, noise level, illumination, and IAQ. The results were summarized as the following.

- Air velocity was very low with mean values of 0.16 and 1.39 m/s in the office and conference room, respectively. The vertical temperature difference between floor and ceiling was less than the 3°C given in ISO recommended criteria for thermal comfort in both room. Indoor thermal environment produces a very comfortable condition.
- With the values ranged from 57.4 to 59.6dB(A) in office and 51.1~60.5dB(A) in conference room, these equivalent sound levels are much greater than 48~58dB(A) and 38~48dB(A) which were the values suggested by Beranek(1988) as the recommended design values of both rooms. But, the equivalent sound level measured in front of CAM was less than 46dB(A), even though it was operated at high speed. Thus, the noise level of both rooms will be satisfactory and be able to be overcome the fact that noise being caused from FTUs using fan-powered units deteriorates indoor environment, if the peripheral conditions at the measuring times were desirable.
- With the mean values of CO_2 concentration being 646.6 and 650.1 ppm and the very low dust concentration of 0.004~0.01mg/m^3 in office and conference room, respectively, UFAC system produces a desirable indoor air quality.
- The levels of illumination of office and conference room was very favorable owing to lighting only the two of third of total fluorescent lamps for the purpose of energy saving, even though the levels of illumination were much lower than the recommended levels of illumination in Korea, in the case of conference room only.
- The system has the potential to affect many of the ways such as thermal comfort of occupant, ventilation efficiency, air quality and productivity.

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