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The Field Measurements In The Occupied Zones Installed The Under Floor Air Conditioning Systems

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ABSTRACT

Providing sufficient thermal environment without draft in the occupied zone of office buildings is one of the main purposes of air conditioning. Recently, an Under Floor Air-Conditioning system(UFAC) with outlets mounted in raised floor panels has been introduced as a system that is able to obtain both preventing draft and an efficient ventilation in the occupied zone. Evaluating the UFAC system, the indoor climate of offices installed the UFAC were measured in summer. Results of measurements in practical offices with the UFAC shows that this system can sufficiently provide comfortable condition in the occupied zone.

KEYWORD Raised Floor Air-Conditioning, Room Airflow, Field Measurements

INTRODUCTION

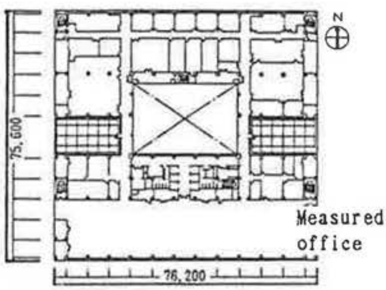
The raised floor system is getting common for new offices now. Together with the raised floor system, the Under Floor Air Conditioning Systems(UFAC) are recently installed in several buildings in Japan. The purpose of present study is to evaluate the UFAC system regarding thermal comfort in connection with the room airflow in practice.

Two types of the UFAC system were introdused and measured. These UFAC systems have outlets with fan and without fan respectively. The main difference between two systems is a stability of airflow coming out from outlet mounted in the floor panel.The UFAC system with outlet's fan is able to keep the airflow constant by the revolution of it.Maintaining stable and constant airflow of the UFAC system without outlet's fan, it is important to keep the static pressure difference between the occupied zone and a chamber of under the raised floor as a pressure plenum constant. The measured items are the room air temperature distribution, the mean air velocity distribution, PMV(Predicted Mean Vote) as a thermal environmental index and the subjective responses to the indoor environment.

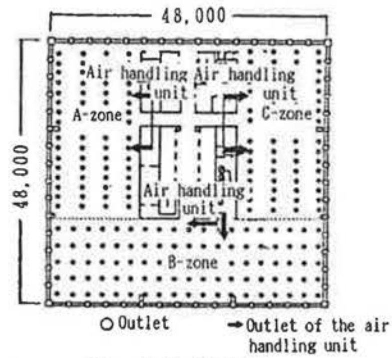
MEASUREMENTS

Outline of measured buildings

Two buildings are measured and used for the offices. Both are located in Tokyo. One is called T-Building and the other is called D-Building. T-Building is nine-storied building and has a total floor area of 45,350㎡. D-Building is sixteen-storied building and has a total floor area of 48,130㎡. The main floor plans are shown in Figure 1a and 1b.



1a T-Building



1b D-Building

Figure 1a and 1b Floor plan of measured buildings

The under floor air conditioning system(UFAC)

Outline of the UFAC

The Under Floor Air-Conditioning system is consisted of floor outlets, an under floor pressure plenum, inlets and air handlers(Figure 2).

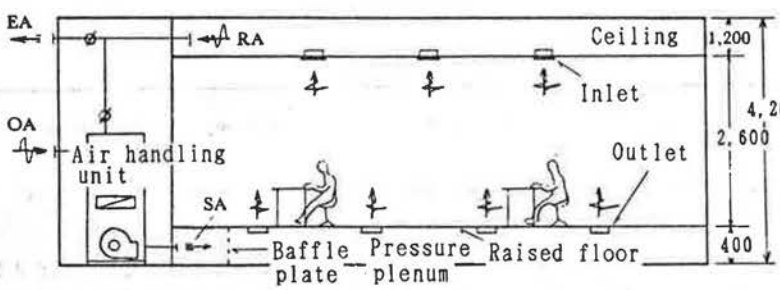


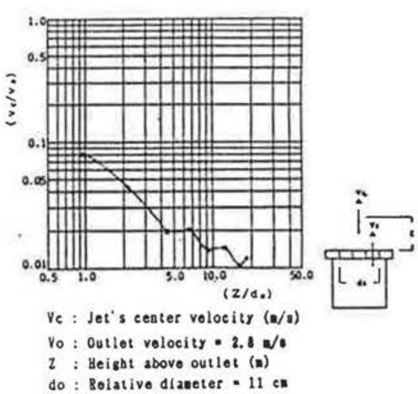
Figure 2 Outline of UFAC(Under Floor Air-Conditioning System)

The characteristics of floor outlets

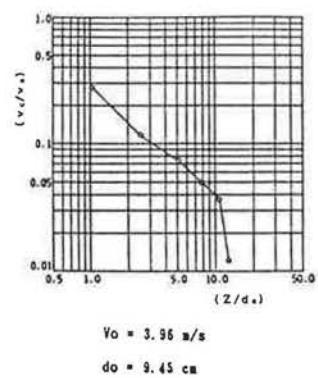
The characteristics of floor outlets set in T-Building and D-Building are with fans and without fan respectively. The specifications of both types of outlet are shown in Table 1. The airflow characteristics of each floor outlets are shown in Figure 3a and 3b. The airflow from the outlet is the swirl flow. The spreading angle of air jet is limited in cirtain degrees for preventing occpants from reaching air jet. The reduction of jet's center velocities versus height from the floor outlet shows a big entrainment ratio and quick reduction of air velocities(Figure 3a and 3b).

Table 1 The specification of outlets

	T-building	D-building
Diameter of grile	200 mm x 2 grile	200 mm
Airflow rate	300 m^3/h	100 m^3/h
Pressure drop	0 mmAq	3 mmAq
Fan power	Turbo 30cm x 50 W	------
Air volume control	Hi 300 m^3/h Mid 225 m^3/h Lo 150 m^3/h by the revolution of fan	0 -- 100 m^3/h by the baket damper



3a T-building



3b D-building

Figure 3a and 3b Reduction of jet's building center velocities of the floor outlets in T-building and D-Building

Measuring items

Main purpose of measurements was evaluating indoor environment with the UFAC systems. The measuring items are the room air temperature distribution, the mean air velocity distribution and the distribution of thermal index called PMV by Fanger. The cooling loads of measured offices were lighting, occupants, computer terminals, personal computers, printers and copy machines.

RESULTS

Results of T-Building

Room air temperature distribution

The air temperature of floor outlets varied from 22.6 to 25.4℃, when the supply air temperature of air handlers was 19℃ (Figure 4). The outlets which had a low airflow rate had higher temperature. The room

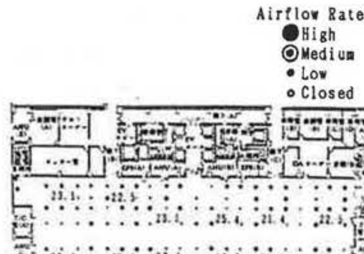


Figure 4 Supply air temp.

air temperature distribution measured at 1.1m above the floor is shown in Figure 6. These temperature varied from 25 to 26℃. The central part of office had a little higher temperature because of having higher outlet temperature. Vertical temperature distribution at 0.1 m, 0.6m, 1.1m and 1.7m and 2.1m above the floor. The vertical temperature difference between 0.1m and 1.7m above the floor was less than one degree C. This difference is enough small for occupants to get thermal comfort.

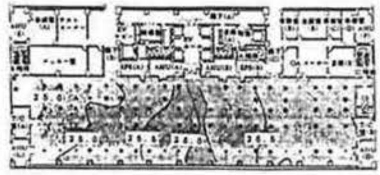


Figure 5 Room air temp.

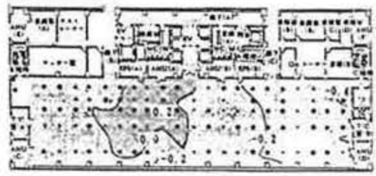


Figure 6 PMV

PMV distribution

PMV in the office varied from -0.4 to 0.2 which are in a limit of a thermal comfort(Figure 6).

Result of D-Building

Room air temperature distribution

The air temperature of outlets varied from 18 to 23℃ in zone A and varied from 19.5 to 24.8℃ in zone B, when the supply air temperature of air handlers was 19℃(Figure 7). The outlets which had a low airflow rate had higher temperature. The room air temperature distribution measured at 1.1m above the floor is shown in Figure 9. These temperature varied from 24.5 to 26℃. Since a set point of room air temperature was 25℃, the room air temperatures satisfied the set point condition.

Figure 7 Supply air temp.

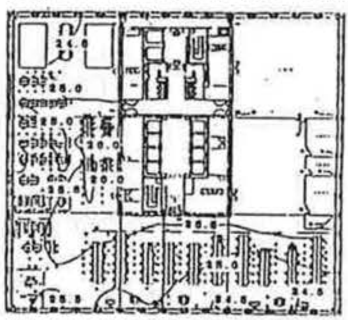


Figure 8 Room air temp.

PMV distribution

PMV in the office varied from -0.4 to 0.2 which are in a limit of thermal comfort (Figure 9).

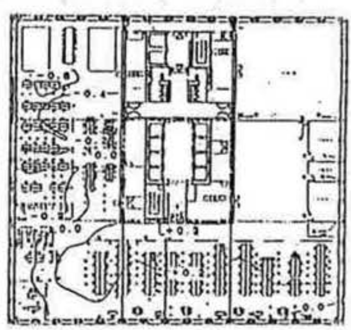


Figure 9 PMV

Room airflow distribution

Since supply air outlets are located close to occupants in the office with the UFAC, the characteristics of airflow near occupants have the significant effect for the thermal comfort. These characteristics are the mean air velocity and the turbulence intensity(i.e. standard deviation of airflow fluctuation devided by a mean air velocity(%)). Figure 10 shows distribution of the turbulence intensities versus the mean air velocities in the D-Building comparing with datas from existing buildings with air outlets mounted in a ceiling. For all datas are within a range of mean velocity between 0.1m/s and 0.2m/s and within a range of turbulence between 30% and 40%, there is no significant difference of room airflow chracteristics in the occupied zone between the office with the UFAC and with the conventional systems. According to draft risk model by Fanger et al., percentage of dissatisfied by the airflow fluctuation around occupants in the measured offices were mostly smaller than 10 %(Table 2 and 3).

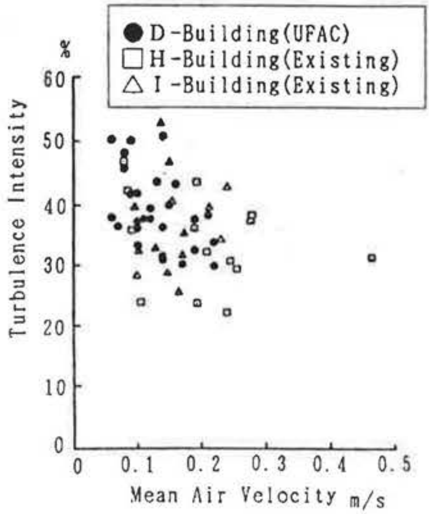


Figure 10 Relationship btween Tu and V

Draft risk model by Fanger et al.

$$PD = (3.143 + 0.3696\ V\ Tu)(34 - Ta)(V - 0.05)^{0.6223}$$

PD : Percentage Dissatisfied (%) Tu : Turbulence Intensity (%)
V : Mean air velocity (m/s) Ta : Room air temperature (℃)

Table 2 Draft risk in the T-Building

Measuring Point	Mean Air Velocity	Turbulence Intensity	Temperature	PD (Percentage of Dissatisfied)
T1	0.08 m/s	32.7 %	25.4℃	4.1%
T2	0.14	29.1	25.0	9.1
T3	0.11	45.5	25.2	7.7
T4	0.07	28.3	25.6	2.5
T5	0.22	48.0	24.4	23.0
T6	0.07	43.8	26.0	3.4
T7	0.12	32.1	25.4	7.7
T8	0.13	36.3	25.9	8.1
T9	0.07	36.6	26.1	2.9
T10	0.09	34.7	26.4	4.5
T11	0.13	54.6	26.1	8.9
T12	0.08	73.6	26.2	4.6
T13	0.12	49.2	25.9	8.2
T14	0.14	33.6	25.6	8.7
T15	0.13	31.1	25.6	8.0
T16	0.11	56.4	25.6	8.0
T17	0.10	80.0	25.6	4.0
T18	0.08	38.8	25.6	3.0
T19	0.14	33.6	25.0	9.5
T20	0.16	31.3	24.8	11.6
T21	0.11	36.7	25.2	6.7
AVE.	--	--	--	7.34%

Results of questionnaire in T-Building

The questionnaire was about air movement and a draft caused by the airflow. 9% among 59 males and 11% among 18 females were feeling draft in the office (Figure 11). Totaly 9% among 77 occupants voted as feeling draft in the measured office. Both results of calculated PD (Percentage of Dissatisfied by draft risk model)(Table 2) and of voted by occupants were close.

Table 3 Draft risk in the D-Building

Measuring Point	Mean Air Velocity	Turbulence Intensity	Temperature	PD (Percentage of Dissatisfied)
D1	0.10 m/s	41.9 %	24 ℃	7.3 %
D2	0.19	37.6	24	17.0
D3	0.09	50.1	24	6.5
D4	0.06	37.9	25	2.0
D5	0.08	48.1	25	4.6
D6	0.08	45.6	25	4.1
D7	0.12	39.5	26	7.5
D8	0.14	31.5	25	9.6
D9	0.15	39.8	26	10.2
AVE.	--	--	--	7.6

Results of questionnaire in D-Building

Although the mean value of PD by draft risk model was less than 10% (Table 3), the result of questinnaire was totaly 20% among 51 workers(i.e. 45 males and 6 females(Figure 12) feeling draft in the office. The cause of this difference would be bigger distribution of the room air temperature and PMV in D-Building than in T-Building.

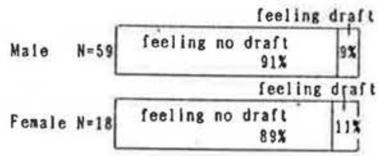


Figure 11 Result of voting in T-Building

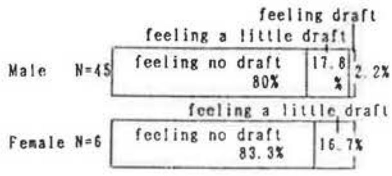


Figure 12 Result of voting in D-Building

CONCLUSIONS

The field measurements were conducted in the offices with UFAC. The measured physical datas showed that a comfortable condition according to the thermal indices. According to draft risk model by Fanger et al., percentage of dissatisfied by the airflow fluctuation around occupants in the measured offices were mostly smaller than 10%. The responses of occupants taken by the questionnaires indicated a almost sufficiently comfortable condition with little draft risk. It is concluded that the UFAC could provide a thermal comfort and is the available air-conditioning system in practice.

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