VENTILATION REQUIREMENTS FOR RAISED FLOOR HVAC SYSTEM

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ABSTRACT

In a room with a raised floor HVAC system (RF system), the vertical temperature gradient became an important factor in relation to the ventilation requirement to maintain a vertical temperature difference within a comfort standard such as ASHRAE Standard 55-1992. A series of detailed laboratory experiments were carried out to obtain the design ventilation requirements with various conditions of ventilation rates, cooling loads, and types of floor outlets. The main results are shown as follows. (1) From measurements it is clear that the vertical temperature gradient is strongly dependent on the throw contributed to supply air volume, cooling load and type of floor outlet. (2) The relationship of the vertical temperature difference in an occupied zone to cooling loads, and ventilation rates was obtained and the design ventilation requirements for the RF system were recommended.

INTRODUCTION

Since the RF system has been introduced to general office buildings, many papers on thermal comfort have been published. From field investigations, it has been shown that temperature distributes almost uniformly both vertically and spatially in a room. In laboratory experiments, principal effects on vertical temperature gradient of the angle of floor outlets, cooling loads, supply air volume have been qualitatively investigated. As mentioned above, it is important to obtain the design ventilation requirements to maintain the vertical temperature difference within the acceptable limits.

A primary goal of this study is to quantify the relationship between the ventilation rate and vertical temperature difference in an occupied zone and to recommend the design ventilation requirements for the RF system.

METHODS

Experiments were performed in a full-scale test room with L=5.4m, W=4.3ı H=3.6m. Fig.1 shows the layout of floor outlets, locations of internal cooling loa and measurement points.

Four different ventilation rates (3.1 h^{-1}, 5.5 h^{-1}, 7.2 h^{-1}, 9.1 h^{-1}), three intern cooling loads (35W/m^2, 52W/m^2, 70W/m^2) and two types (A,B) of floor outlets we used for the experiments. These give altogether 24 measuring situations.

Cooling loads were obtained by using heaters, lighting and person simulators. Tl vane angle of type A and type B is 72° , 60° from a horizontal plane respectivel Air temperature was measured at 0m, 0.2m, 0.4m, 0.6m, 0.8m, 1.0m, 1.2m, 1.4ı 1.6m, 1.8m, 2.0m, 2.2m, 2.4m, 2.6m, 3.0m, 3.4m, 3.6m above floor level at locatic A, B, C, D. Supply/return air temperature, surface temperature of walls, ceilin and floor was also measured. With the above mentioned measurement points gives altogether 90 points for the temperature measurements. In addition, a cases were carried out under a steady thermal state and heat loses were less tha 5W/m^2 in each case.

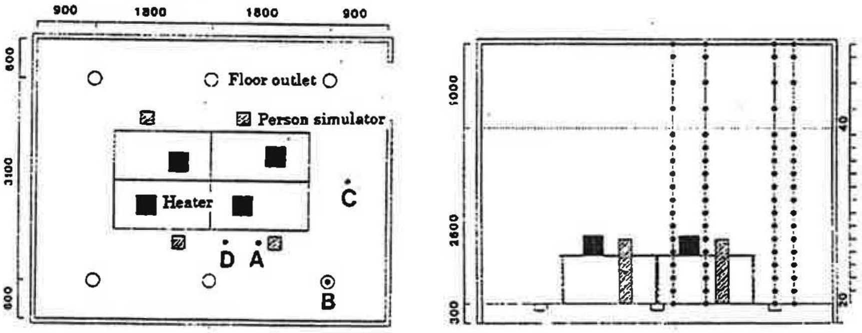

Fig.1 Sketch of the test room with the layout of measurement point

RESULTS

Effects on the Vertical Temperature Gradient under Various Conditions

Measurement Location: Fig.2 shows the vertical temperature profiles at differen measurement locations. Beside the area which is close to the floor outlet a position B, where the thermal condition is dominated by the supply air, th temperature difference is less pronounced at locations. The height, at whicl temperature above floor outlet is equal to that at another location, is called th throw in this paper and the velocity at that point is about 0.2 m/s. So that th following results are districted at location C.

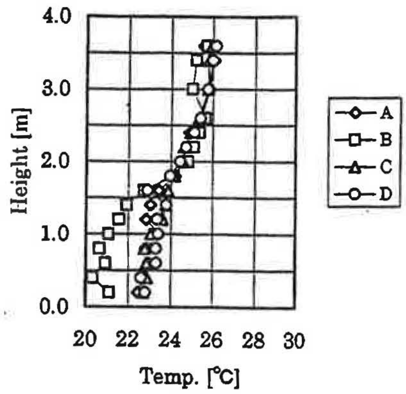

Fig.2 Temperature profiles versus height at difference locations at cooling load 54W/m², ventilation rate 7.2 h-1, floor outlet type A

Ventilation Rates: Fig.3 shows the vertical temperature profiles at different ventilation rates. The more the ventilation rate, the smaller the vertical air temperature difference. Furthermore, vertical temperature is almost relatively uniform up to the height called throw, and the area below this height can be seen the complete mixing region. On the other hand, the vertical temperature increases slowly as the ventilation rate subsides slowly.

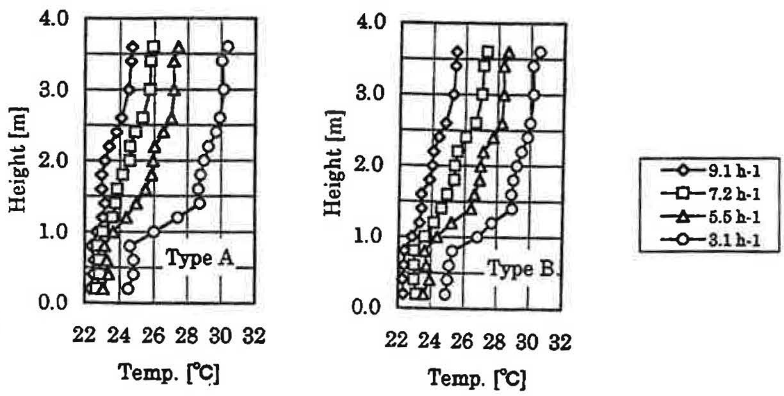

Fig.3 Temperature profiles versus height at difference ventilation rates at cooling load 54W/m²

Cooling Loads: The degree of the effect of cooling load on the vertical temperature difference is almost equal to that of the ventilation rate. The greater the cooling loads, the higher the vertical temperature difference and temperature.

Outlets: The vertical temperature difference is 1℃ greater at type B than at type A. This result can also be explained by the throw of supply air.

Design Ventilation Requirements

Fig.4,5 show the relations among the supply-return air temperature difference, vertical temperature difference and supply air temperature difference obtained from experiments. Any correlation coefficient is larger than 0.93 and the regression equations are also shown in the figures.

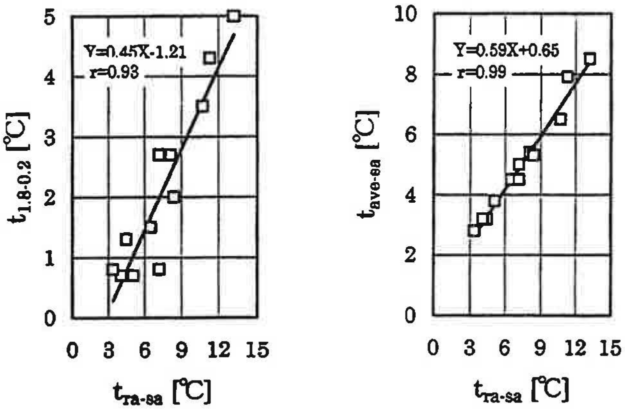

Fig.4 Relations among the supply-return air temperature difference, vertical temperature difference and supply air temperature difference (air outlet typeA)

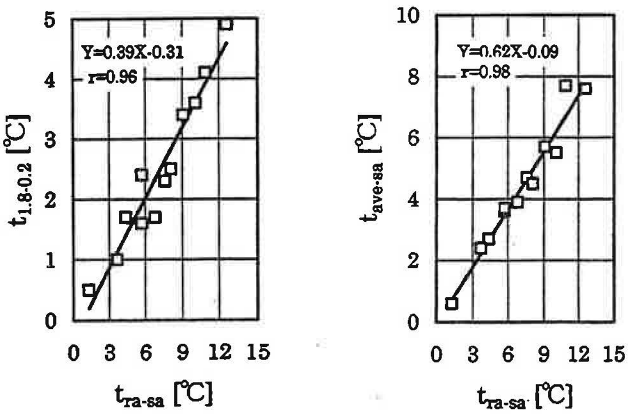

Fig.5 Relations among the supply-return air temperature difference, vertical temperature difference and supply air temperature difference (air outlet type B)

Fig.6 shows the relationship of the ratio of cooling to ventilation rates, vertical temperature difference, and supply air temperature difference. From that we can obtain the design ventilation requirements by the given cooling loads. Tab.1 shows the regression equations

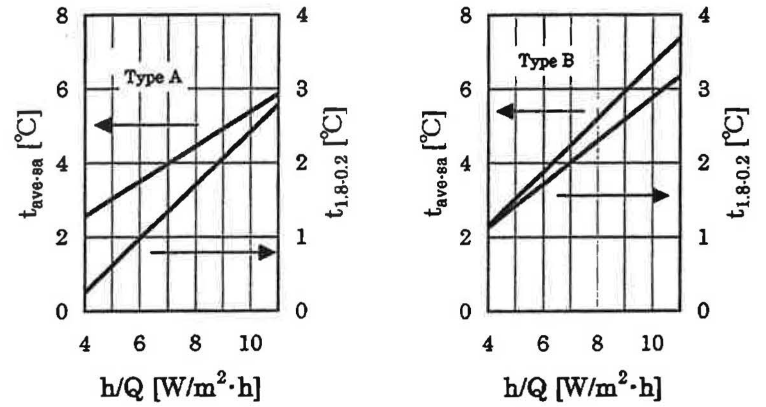

Fig.6 Relations of the ratio of cooling to ventilation rates, vertical temperature difference, and supply air temperature difference

Tab.1 Regression equations (h: W/m², Q: h⁻¹)

Air outlet	Regression equation
A	$t_{1.8\text{-}0.2}=0.36\times[h/Q]-1.21$ $t_{ave-sa}=0.47\times[h/Q]+0.66$
B	$t_{1.8\text{-}0.2}=0.36\times[h/Q]-0.31$ $t_{ave-sa}=0.58\times[h/Q]+0.09$

DISSCUSSION

Effects on Vertical Temperature Gradient of Various Conditions

It is suggested that room space can be divided vertically into two regions called complete mixing region and piston flow from floor up to ceiling. The height of complete mixing region strongly influences the vertical temperature difference in the occupied zone which is contributed to ventilation rates and cooling loads. A greater vertical temperature difference appeared along with greater cooling loads and smaller ventilation rates.

The difference of vertical temperature difference in the occupied zone between two types of air outlets is about 1 ℃. It can be considered that the throw of supply air is different one from another with different vane angle.

Design Ventilation Requirements

The design ventilation requirements recommended in this study take into account not only the internal cooling loads but also the vertical air temperature difference in the occupied zone. A stronger correlation coefficient larger than 0.93 between return-supply air temperature difference and vertical temperature difference was obtained from the experiments. Accordingly, the relationship between ventilation rates and vertical temperature difference in occupied zone has been quantified. The regression equation shown in Tab.1 indicates that the contribution of ventilation rates to the vertical temperature difference is equivalent to that of cooling loads.

On the other hand, when an unsuitable floor outlet is used, for example type B, approximately 20～30% of ventilation rate should be added for getting a complacent thermal condition. From the regression equation, both of design ventilation requirements and supply temperature can be determined.

CONCLUTIONS

The effects on vertical temperature difference in a room with RF system have been revealed and the design ventilation requirements for RF system has been recommended. The results from this study are shown as follows.

(1) It is suggested that room space be divided vertically into two regions called complete mixing region and piston flow region from floor up to ceiling. The vertical air temperature difference is strongly dependent on the throw contributed to ventilation rate, cooling load and floor outlet.

(2) Among the two types of floor outlets used in this study, the vertical temperature difference between two types of floor outlets is about 1 ℃. Therefore, it is important to select the floor outlet in order to decrease the vertical temperature difference.

(3) This study quantified the relationship between the ratio of the cooling load to the ventilation rate and vertical temperature difference. Accordingly, the ventilation rate can meet not only the given internal cooling load but the acceptable thermal limits.