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Experimental Evaluation of the Effect of Supply Air Direction on Air Current and Temperature in a Room with Underfloor Air Distribution System

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ABSTRACT: One of the concerns about the operation of underfloor air distribution systems is the occurrence of local thermal discomfort such as draught and vertical air temperature difference. In the present study, to investigate these discomfort parameters in a room with the mentioned system, the temperature, mean velocity and turbulence intensity for vertical and horizontal supply air diffuser with 16 and 20°C inlet temperatures were evaluated. These parameters were measured at 0, 30 and 60cm distances from the center of diffuser of the underfloor air distribution system at 8 different heights from the floor. Also, by using the Fanger model, thermal sensation, percentage of thermal discomfort and the percentage of thermal discomfort caused by the draught were determined. The results indicated that the amount of thermal discomfort in a room with an underfloor air distribution system is significantly dependent on supply air direction (horizontal/vertical) and, distance from the inlet diffusers. Also, the results showed that by using proper diffusers, while subjects' thermal comfort maintains constant, the supply air temperature can be increased from 16 to 20 °C, which is a major step towards reducing energy consumption.

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1. Introduction

Nowadays, by increasing the importance of thermal comfort due to people spend most of their time in indoor environments, the heating, ventilation, and air conditioning engineers have focused on choosing proper air conditioning systems for the building. Also, improving the occupants' thermal comfort conditions can increase their efficiency and can cause to reduce energy consumption and improve indoor air quality. Therefore, the underfloor air distribution system was quickly considered as an efficient system among engineers by improving comfort and indoor air quality.

In recent years, many studies have been conducted by using numerical and laboratory methods on the underfloor air distribution system. In 2007, Zukowski [1] proposed a new relationship to determine the maximum air velocities from the underfloor air distribution system diffusers to prevent occupants' thermal discomfort. In 2010, Alajmi and El-Amer [2] analyzed underfloor air distribution systems and compared them with overhead systems. According to their results, the use of an underfloor air distribution system can reduce the amount of energy consumption up to 30%. In 2011, Ho et al. [3] studied and compared the overhead ventilation system and the underfloor air distribution system in a laboratory. According to the results, the underfloor air distribution system can achieve better indoor air quality. Also, under constant thermal comfort conditions, the underfloor air distribution system showed a 20 to 30 percent reduction in energy consumption compared to the overhead distribution system. Rahmati et al. [4], in a numerical study in 2018 examined the performance of the personalized ventilation system with the underfloor air distribution system. Based on the results, both systems could cause draught local thermal discomfort in head and foot compartments.

On the other hand, in the underfloor air distribution system, the pattern of temperature and velocity distribution is very important due to supply air diffusers have a direct impact on occupants. Also, these factors are very important in thermal comfort and draught local discomfort. Therefore, in designing this system, in addition to providing thermal comfort conditions, thermal discomfort such as draught and vertical temperature air difference should be avoided. As a result, proper design, proper location of the supply air diffusers, and pattern of inlet airflow into the room is one of the important requirements in the underfloor air distribution system design. There are various approaches to evaluate the performance of ventilation systems and thermal comfort conditions such as numerical, field and laboratory methods.

In this research, an experimental approach has been utilized to investigate the location of supply air diffusers of underfloor air distribution system with subjects as well as the type of diffusers used in this system. Also, by using the Fanger thermal comfort model, thermal comfort conditions, local thermal discomfort, and draught discomfort are predicted and the best case is proposed. For this purpose, in this study, we compared the flow pattern in the vertical and horizontal direction of supply air in the underfloor air distribution system at two temperatures of 16 and 20°C.

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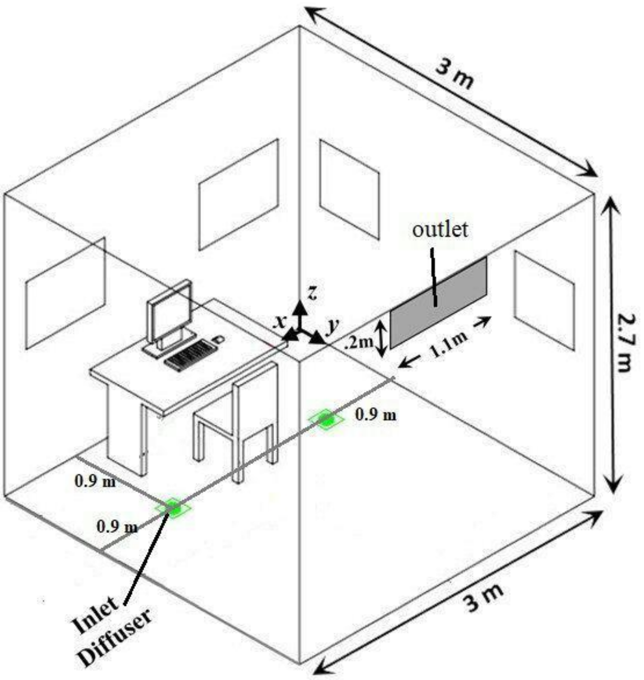


Fig. 1. Climate chamber geometry

2. Methodology

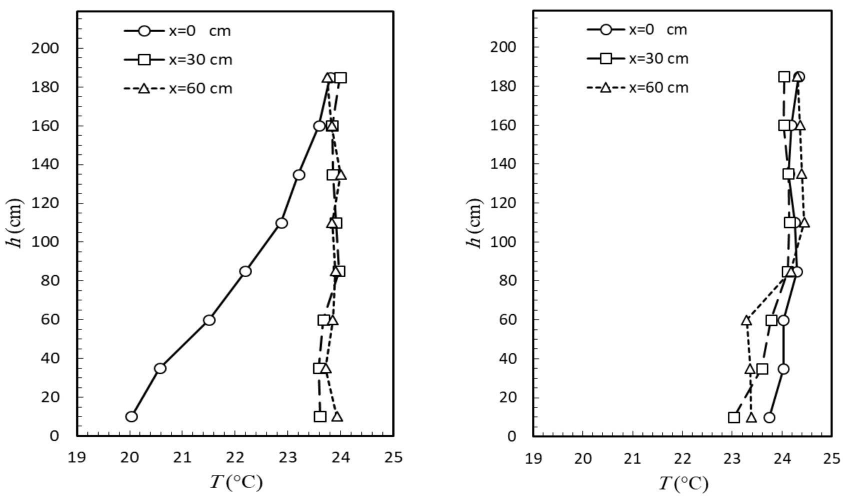
The research was conducted in an experimental climate chamber (Fig. 1.) located in the Thermal Comfort Research laboratory, University of Birjand and it is designed inside a larger chamber and not directly affected by outdoor air conditions and sunshine beams. In this experiment, to maintain the overall room condition based on the general comfort conditions, the room air temperature and relative humidity are maintained at 24 ± 0.5 °C and 25± 2% respectively. The supply air volumetric flow rate from each diffuser is set at 7 lit/s

3. Results and Discussion

Vertical distribution of temperature, velocity, and percentage of people predicted to experience local discomfort in the room on three different vertical lines with 0, 30 and 60 cm distance from the center of the diffuser for case with 16°C temperature, and for (a) vertical and (b) horizontal supply air diffuser showed in Figs. 2, 3, and 4 respectively. Fig. 3 shows that the air temperature on the center of the diffuser has changed from 16 to 20 °C with an increase of 10 cm from the surface of the diffuser. This is due to the sudden increase in temperature, a noticeable decrease in the airflow rate of the supply air diffuser to the test chamber, and a lower indoor air pressure than the supply air pressure. Fig. 4 shows that at a height of 10 cm above the center of the diffuser, the velocity is about 2.2 m/s. As the height from the diffuser surface increased, the velocity decreased and it reached 0.7 m/s at 110 cm. Subsequently, the slope of the variations decreased so that only 0.2 m/s velocity changes were recorded at 185cm. Fig. 4 shows that at the center of the diffuser at a height of 10 to 85 cm, 100% of people feel discomfort with the low temperature of the outlet air and the high velocity of flow, but at 85 to 185 cm from the floor, the percentage of dissatisfaction is greatly reduced and eventually reaches 26%. At 30 and 60cm from the center of the diffuser, the percentages of dissatisfaction are similar to other points and are in the range of 15% to 20%.

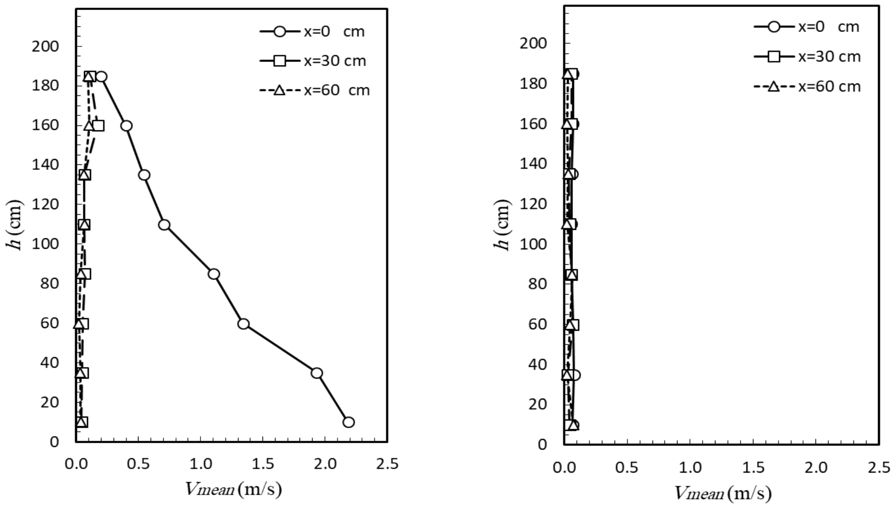
4. Conclusions

Based on the results, in the vertical supply air diffuser by increasing the distance from the center of the diffuser, the percentage of draught local discomfort is greatly reduced and the thermal sensation of subjects increases, but in the horizontal supply air diffuser because of appropriate air mixing, the occupants have better thermal comfort conditions. Also, the results indicated that by changing the inlet temperature from 16 to 20°C, the occupants' thermal comfort conditions have not been changed significantly. This fact can be used to reduce energy consumption. So, by using



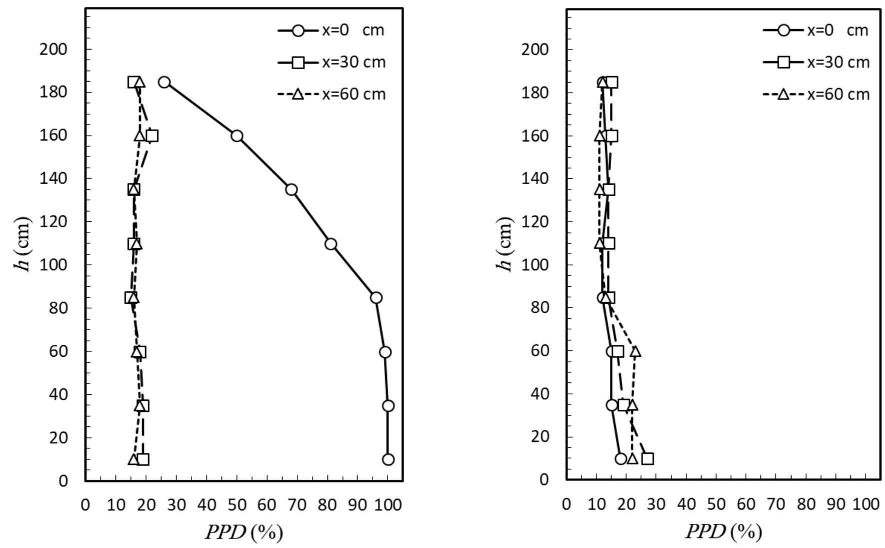
(a) (b)

Fig. 2. Temperature distribution for (a) vertical and (b) horizontal supply air diffuser



(a) (b)

Fig. 3. Velocity distribution for (a) vertical and (b) horizontal supply air diffuser



(a) (b)

Fig. 4. Percentage of people predicted to experience local discomfort distribution for (a) vertical and (b) horizontal supply air diffuser

a proper diffuser and adjusting the temperature of 20 °C to the air in the chamber, the same thermal comfort conditions as the 16°C temperature can be provided.

References

[1] M. Zukowski, “A new formula for determining a minimum recommended value of inlet air velocity from UFAD system to prevent occupants from draught risk,” Building and Environment, 42 (2007) 171-179.

[2] A. Alajmi, W. El-Amer, Saving energy by using underfloor-air-distribution (UFAD) system in commercial buildings, Energy Conversion and Management, 51(8) (2010) 1637-1642.

[3] S.H. Ho, L. Rosario, M.M. Rahman, Comparison of underfloor and overhead air distribution systems in an office environment, Building and Environment, 46(7) (2011) 1415-1427.

[4] B. Rahmati, A. Heidarian, A.M. Jadidi, Investigation in performance of a hybrid under-floor air distribution with improved desk displacement ventilation system in a small office, Applied Thermal Engineering, 138 (2018) 861-872.

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