Analysis of an under floor air distribution (UFAD) system in a dense occupancy environment

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Introduction & Objectives

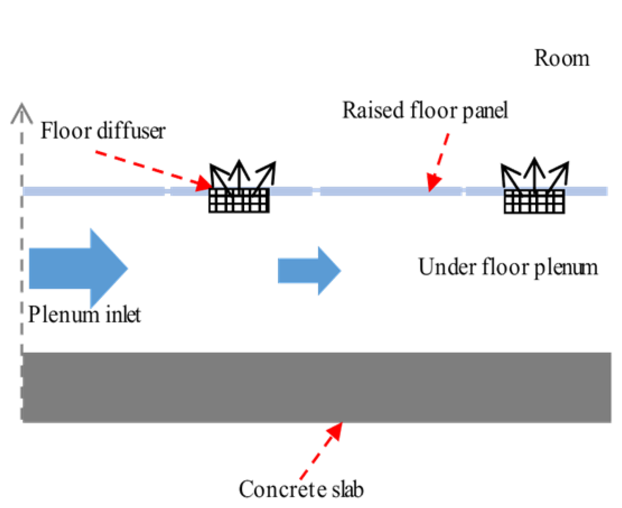
- Under Floor Air Distribution (UFAD) ventilation systems use open spaces (plenums) between the concrete slab and raised access floor to supply conditioned air.
- UFAD system is typically used in a large indoor environment and influence thermal comfort, indoor air quality (IAQ), and energy consumption.

Objective:
Investigate an UFAD system with combined and separate return and exhaust air vents.

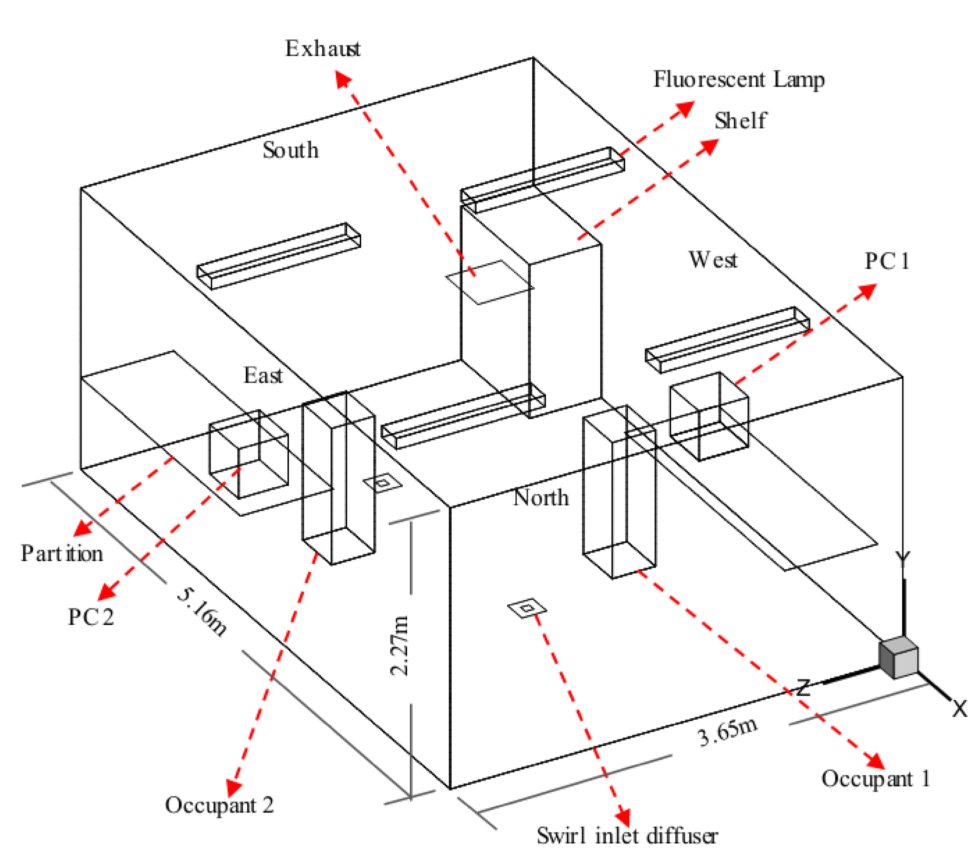
Methodology:
Computational fluid dynamics (CFD) methods are used to predict thermal comfort conditions of occupants, IAQ, and energy consumption.

UFAD Schematic and Validation Geometry

UFAD schematic



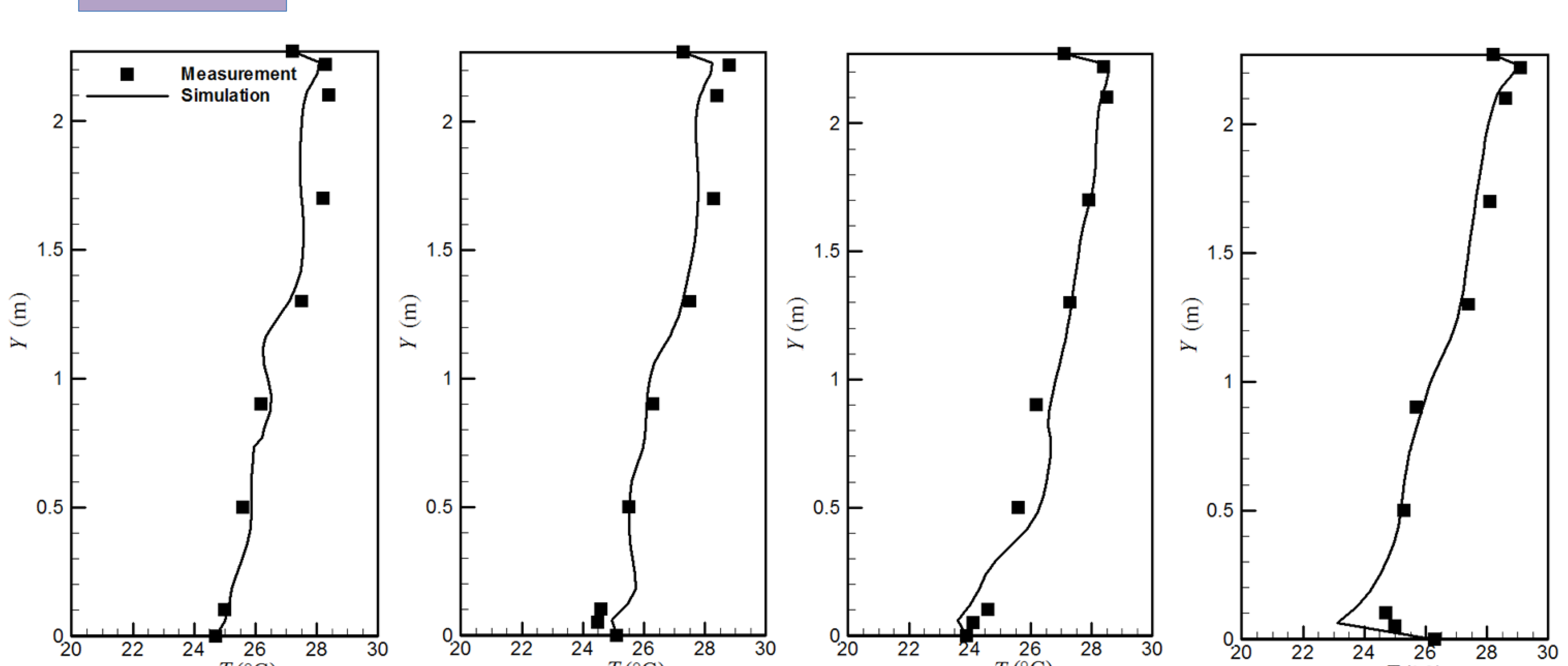
Validation geometry



Modeling assumptions:

- Finite volume approach with structured grid.
- Equations solved numerically using the software “Airpak”.
- **SIMPLE algorithm** to resolve the pressure and velocity coupling.
- **Indoor zero equation** turbulence model.
- One cube model for occupants in the validation procedure.

Validation



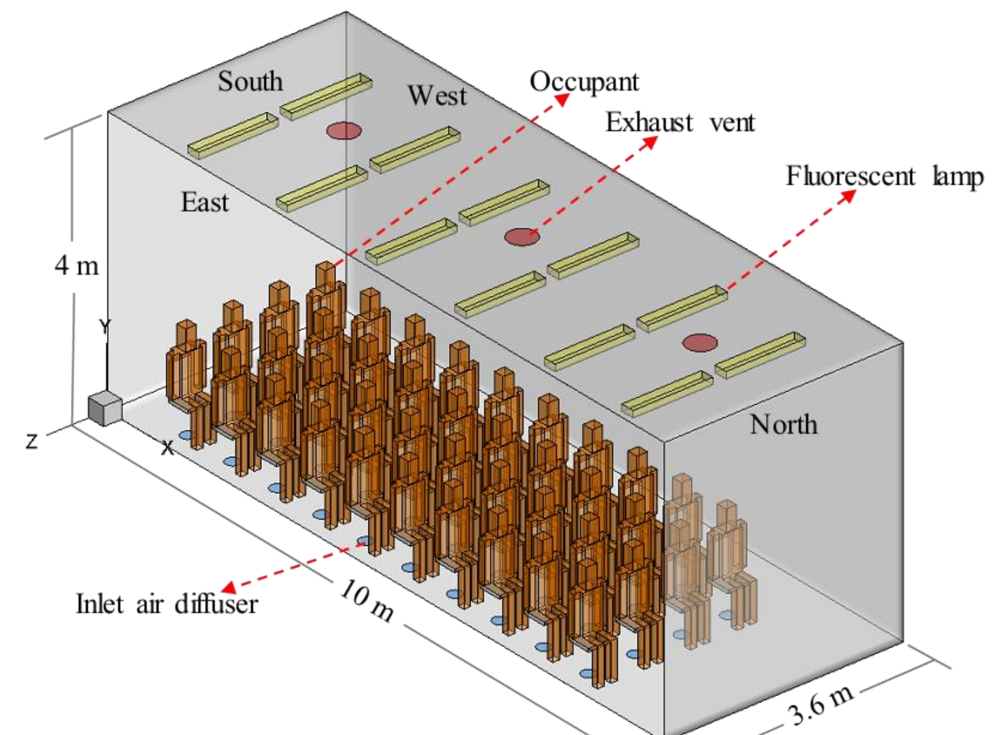
X=-2.58, Z=0.605 X=-2.58, Z=3.045 X=-0.86, Z=1.825 X=-4.3, Z=1.825

Analyzed Space Description

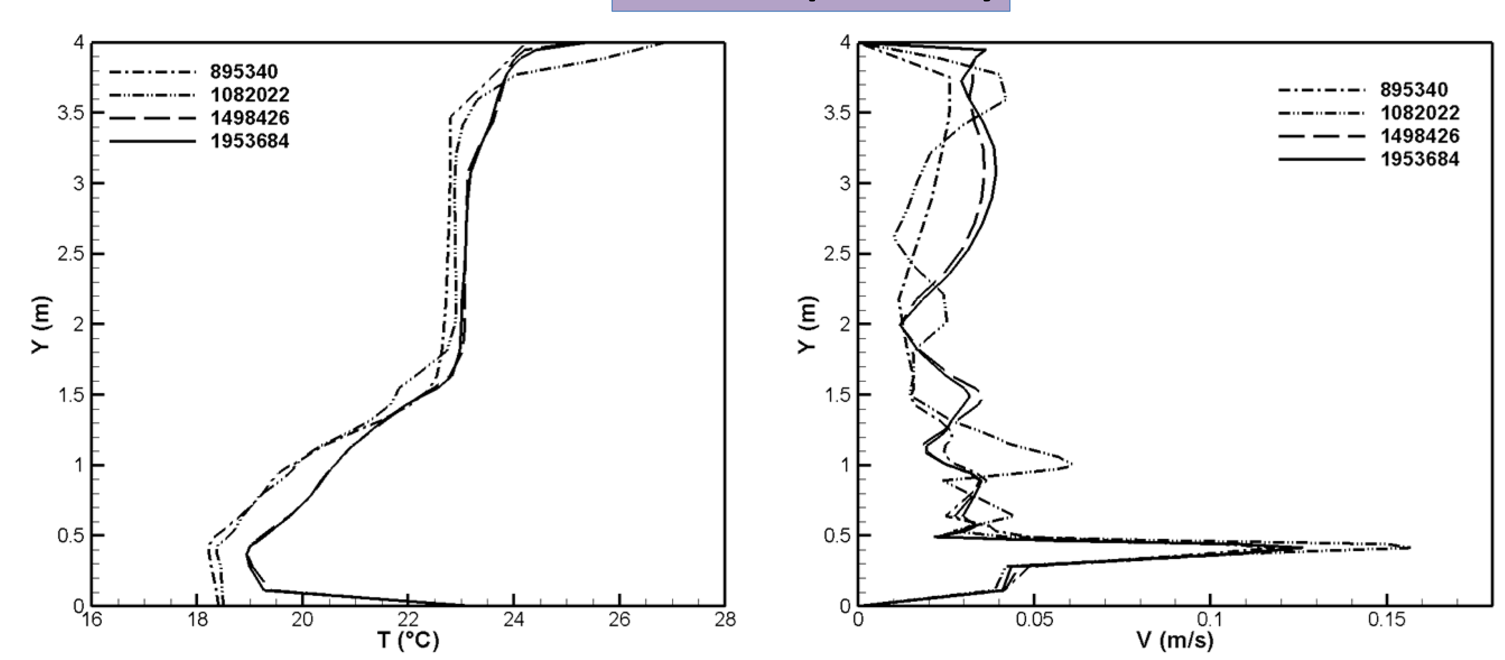
Large indoor space

Model description:

- Total air change rate is equal to 9 ACH (Air Changes per Hour).
- Inlet air temperature is set equal to 21˚C.
- Heat emitted by each lamp is 68 W.
- 40 occupants simulated, and heat emitted by each occupant is 104.7 W.
- East wall is symmetrical

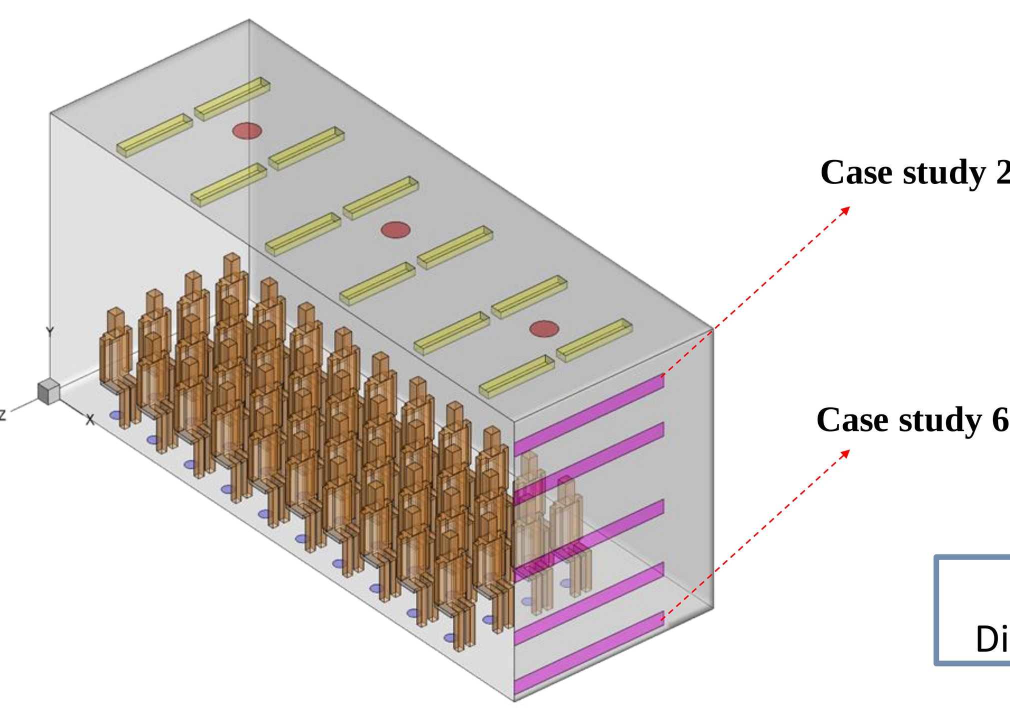


Grid independency



Grid independency:
By altering the grids # from 1,498,426 to 1,953,684, temperature and velocity distribution did not significantly change.

Case Studies Description (return air vent position)



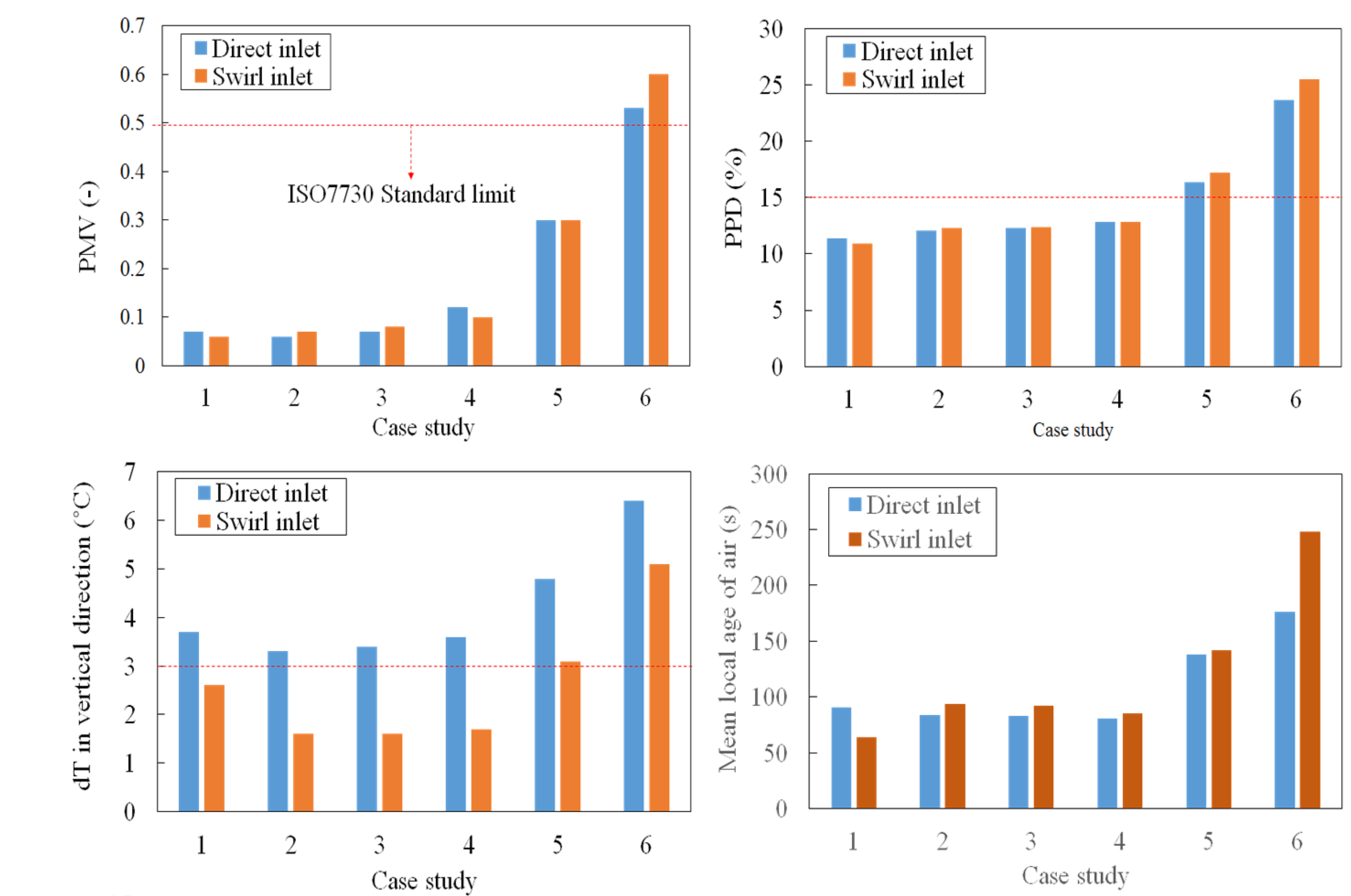
Case study	Return air vent height (m)
1	4.0
2	3.5
3	2.8
4	1.7
5	0.8
6	0.1

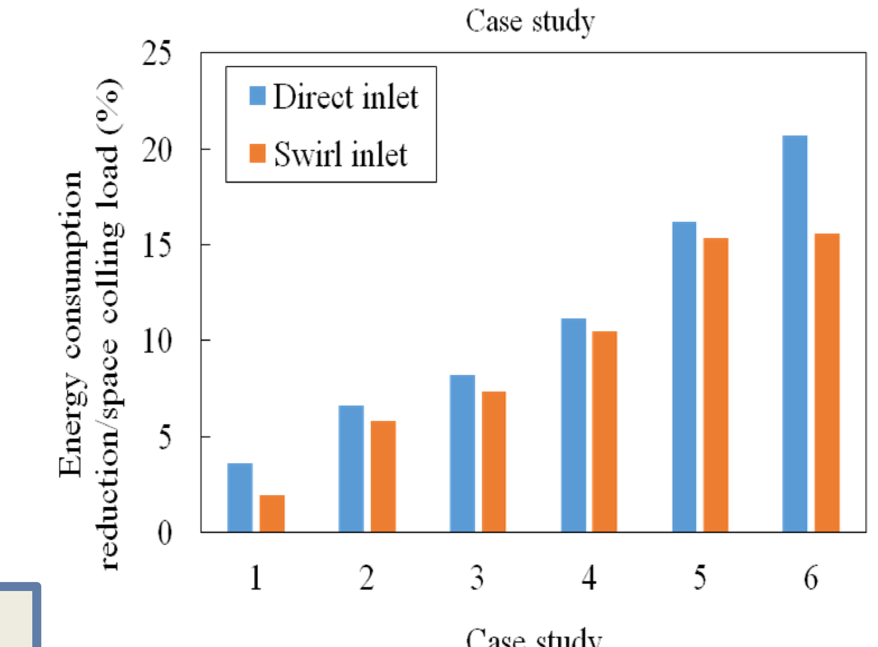
Diffusers:
Direct inlet Swirl inlet

Thermal comfort and IAQ evaluation

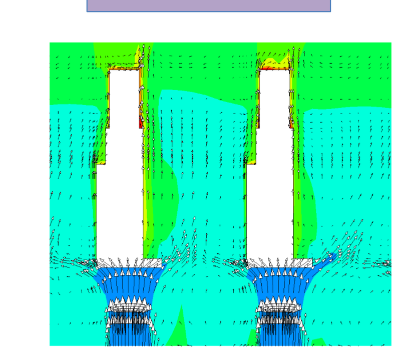
- PMV-PPD (average thermal sensation response - percentage of people dissatisfied) used to survey the thermal comfort conditions of occupants in each case study. PMV-PPD probed in the occupied zone.
- Mean age of air used to survey the IAQ. It is an index for air freshness, and lower values of this index are better for occupants.
- Occupied zone defined as the height of 1.7m from the floor.
- Temperature gradient in vertical direction is used as local thermal discomfort index.

PMV-PPD, Temperature gradient (local thermal discomfort), Mean age of air (IAQ index)

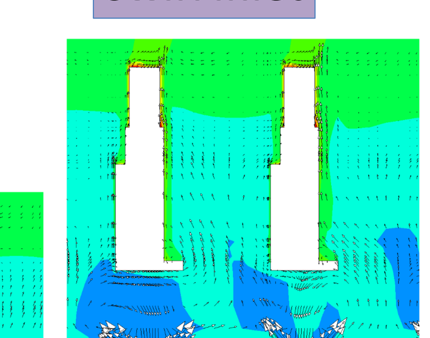




Direct inlet



Swirl inlet



Conclusions

- When the return air vent is in the lower boundary of the occupied zone, the PMV-PPD indices and the temperature gradient in vertical direction exceed the specified range of ISO7730 standard [4] for both types of inlet diffusers (direct and swirl inlet diffusers).
- In direct inlet diffuser, temperature gradient in vertical direction exceeds the allowable range for different locations of return air vent height.

→**IAQ index reaches its best value at the upper boundary of the occupied zone for both of the inlet diffusers, and air flow did not reach local thermal discomfort levels for none of the investigated case studies.**
→**Opting a swirl inlet diffuser with the return air vent position at 1.7m from the floor height causes to the results that can meet both occupants and energy consumption needs.**

References

1. N. Kobayashi, Q. Chen, Floor supply displacement ventilation in a small office, Indoor and Built Environment 12(4) (2003) 281-292.
2. J. Lau, Q. Chen, Floor-supply dispalcement ventilation for workshops, Building and Environment 42 (2007) 1718-1730.
3. M. Fathollahzadeh, G. Heidarinejad, H. Pasdarshahri, Prediction of thermal comfort, IAQ, and energy consumption in a dense occupancy environment with the under floor air distribution, Building and Environment 90 (2015) 96-104.
4. ISO7730, Moderate thermal environments- Determination of the PMV-PPD indices and specification of the conditions for thermal comfort, 1994.