Numerical Simulation and Experimental Study on Airflow Characteristics in the Plenum of Underfloor Air Supply[1]

Xiaohua Li Nianping Li Fang Fang Dandan Zhao

Doctoral Candidate Ph.D Professor Master Candidate Master Candidate

College of Civil Engineering, Hunan University, Changsha,

Hunan P.R. China. 410082

xiaohuali72_2005@sohu.com

Abstract: Energy-efficient and cost-effective space conditioning in offices and other commercial buildings usually use the underfloor space for the supply air static-pressure plenum. The airflow in a plenum of the underfloor air supply was simulated by a computational fluid dynamics (CFD) program , and full-scale experiments were conducted to validate the calculation results in May 2005. The results show that the CFD-predicted results in the plenum were in good agreement with the measured results. Two main factors, air velocity and beam height, affect the airflow in the plenum. Pressure loss mainly occurs around the beam. In the underfloor plenum the structural design should reduce the crossbeam height as much as possible, and in operation should reduce air velocity in the plenum.

Key words: airflow, static-pressure plenum, underfloor air supply, experiment, CFD**.**

1 INTRODUCTION

For promising energy-efficient and cost-effective space conditioning in offices and other commercial buildings, it is usually used for the supply air static-pressure plenum among the ceiling-based and the floor-based air conditioning system[1,3,4,5]. Some barriers such as beams or brackets inside the plenum can be a secondary hazard as they hinder the airflow. This increases the initial/running cost of the heat conveyance power, the uneven supply air volume or return air volume due to the uneven pressure at the plenum surface may deteriorate an indoor thermal and air quality environment, and necessity to grasp more accurate pressure loss characteristic inside the plenum was emphasized.

We built up a height 200mm plenum, in which there are two crossbeams(120,140,160mm height and 50,30,10mm thickness, respectively). the airflow characteristics was simulated by computational fluid dynamics(CFD) program , and full—scale experiments were conducted to validate the calculation results in May,2005.[6-7]

2 EXPERIMENT SETUP

Fig.1 presents the installation of experiment. Test rectangle pipe is made from 5mm thickness transparent organic glass, it is 200mm high, 800mm wide and 2000mm long, the front and the back joint 2000mm length and 2mm

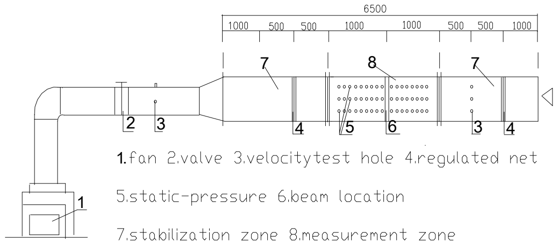

Fig.1 the installation of experiment

thickness zincification aluminum pipe. Respectively, the side of test rectangle pipe felts diameter 4mm and length 50 mm organic grass pipe on which there are 3 rows and each row has 17 static-pressure test holes.

Utilizing Pitot pipe measure dynamic pressure,

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the velocity and flux of airflow can be obtained. In the experiment chooses 1.07 m/s, 1.93 m/s and 2.71 m/s wind velocity, respectively.

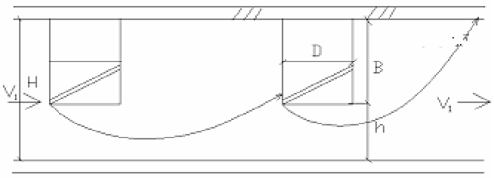


Fig.2 simulated physical model

3 NUMERICAL SIMULATIONS [2, 8, 9]

3.1 Control equation

For distinctly understanding the airflow characteristics of the static pressure in the plenum, we use the commercial software FLUENT6.2 to simulate it, physical model shows as Fig.2.

This paper selected standard *k-ε* model, control equation can choose Reynolds-Averaged Navier—Stokes Equations:

$$\frac{\partial(\rho\Phi)}{\partial t}+div(\rho U\Phi)=div(\Gamma_{\Phi}grad\Phi)+S_{\Phi} \quad (1)$$

there, ρ、U is density and velocity vector; variableφ represents *u, v, w, k,ε*and 1; Γ_{Φ} is valid diffuse factor; and S_{Φ} is source item.

3.2 Boundary condition

1).The inlet: velocity inflow, input real measurement data value (v=1.0m/s). Inlet kinetic energy $k=\frac{3}{2}(T_u u_0)^2$ and $\varepsilon=c_u^{\frac{3}{4}}\frac{k^{\frac{3}{2}}}{L}$; turbulent intensity T_U=5%.

2).outlet: pressure outlet ($\Delta P=0P_a$)

3).solid wall: Standard *k-ε* model need consider inner wall boundary layer to influence on the inner flow.

4 RESULTS ANALYSIS

4.1 experimental results analysis

In experiment $R_e=2.2\times10^4$ ~ 5.5×10^4, the airflow is turbulent in the pipe. Fig3、Fig4 are the real measurement static-pressure distribution curves of the different conditions. Fig3 shows that the crossbeam height B affects the airflow under the same air velocity and crossbeam thickness. The higher the crossbeam height is, the more tempestuously the air flows in the interlayer, the lower the height is, the more placidity the airflow flows, which makes out the local resistance increases along with the crossbeam height increase. So in design should reduce the crossbeam height as possible.

Fig4 shows as the air velocity impacts the airflow under the same crossbeam height and thickness, the higher the air velocity is, the more tempestuously the air flows in the plenum, the lower the air velocity is, the more placidity the air flows, which makes out the local resistance increases along with the air velocity increase. So among system operation should reduce air velocity as possible.

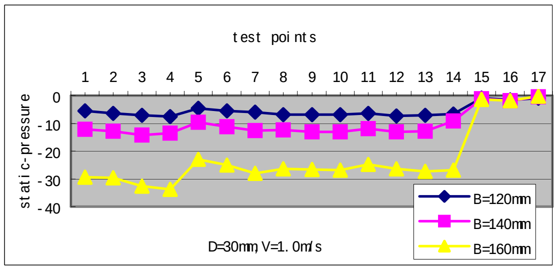


Fig.3 influence of beam height

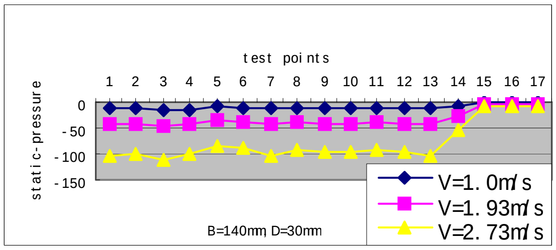


Fig.4 influence of air velocity

The experiment proved the crossbeam thickness has little influence on the airflow in the interlayer. In order to reduce pressure loss may consider increasing crossbeam thickness to reduce crossbeam height when the structure engineer designed the plenum.

Fig.5.shows the photography of the airflow in the plenum. There are many big and small vortexes in the beam corner against velocity direction; Smoke spraying, can be distinctly seen in the shrinkage section of the crossbeam bottom and exists a sticking point in the backward position. The distance

augments along with the velocity and the crossbeam height increasing.

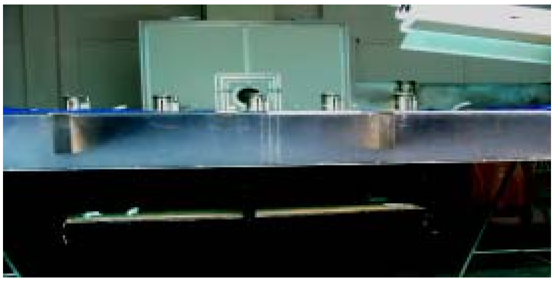


Fig.5 the photography of the interlayer

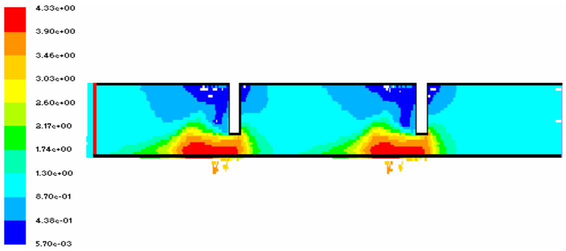
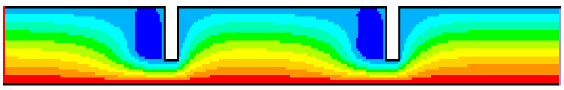


Fig.6 simulated velocity fields(v=1.0m/s)



F g.7 simulated streamlines

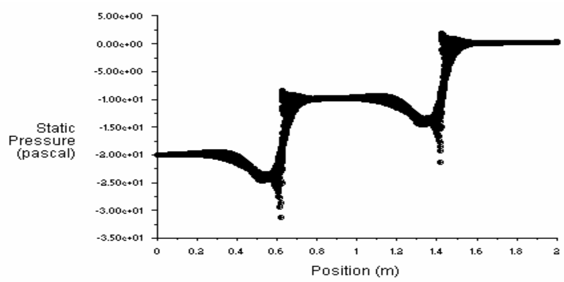


Fig.8 simulated static-pressure distribution

4.2 Numerical simulation results analysis

Fig.6. is the airflow velocity simulated results in the plenum, the velocity of the shrinkage section in the crossbeam bottom is biggest, it is obvious that there are many eddies in the back corner of the crossbeam (against velocity direction). And the velocity changes very great, the velocity in shrinkage section is 4.08m/s while in the eddy 0.034m/s, so if installs the inlets in the eddy region, the supply velocity fields are asymmetry results in the supply fluxes are uneven and worse indoor air quality, so it is not suitable to set the inlet or outlet in the region in practical project design. Fig.7 shows the airflow pressure simulated results; the static pressures around the beam increase sharply, and obviously putting up "static-pressure regain" phenomenon. The pressure loss mostly occurs the bottom of the crossbeam. Vast simulation results prove improving the beam bottom geometry shape may reduce the pressure loss, such as round angle or obtuse angle. Fig8. figures the air streamlines(beam height B=140mm, thickness D=50mm, air velocity V=1.0m/s), the results show that the predicted airflow in the interlayer are in good agreement with real flow.

5 CONCLUSIONS

Through above analysis, following conclusion can be drawn:

1).both CFD results and experiment results are very identical.

2).the airflow flow characteristics are very complex in the interlayer, for realizing uniform supply air and reducing energy loss, in the underfloor plenum structure design should reduce the crossbeam height as possible, and in operation should reduce air velocity in the plenum as possible.

3) the underfloor inlets cant not been set up around the crossbeam regions.

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