The Study of Indoor Air Thermal Environment and Energy in Winter

Zhonghua Tang
College of Architecture and Civil Engineering, Southwest University of Science and Technology Mianyang China
tangzhonghua@126.com

Abstract: The paper describe a experiment in the indoor air lab in SWUST (The Southwest University of Science and Technology), it is presumed the lab as a office and measure the data according to the function of the room. In the scale mode experiments, Measure the in-door air temperature, relatively humidity and humidity ratio, air velocity and energy consumption in different air condition. Studies the air distribution and uniformity in the room and calculates the PMV index.

Keywords: Temperature Humidity ; the velocity of wind ; the volume of fresh air ; PMV ; the energy consumption

1. Introduction

The paper combined with climatic characteristics in northern Sichuan, the crowd features and air distribution. This paper analyses the law of thermal environment and the law of energy consumption with different air supply conditions in split air-conditioned room in winter. Provide a reference for future design of HVAC .In particular, providing a basis for the user to install the sub-body conditioning more considerable. And provide the theoretical support for the researchers to select the appropriate energy consumption simulation method. And emphasis the air distribution impact on the indoor thermal environment. It's necessary to use the research of indoor thermal environment onto the engineering.

2. Experimental preparation

2.1. Test room

Experimental test room 3 meters long and 3 meters wide has an area of 9 square meters, (Figure 1) and 2.5 meters height. East opened a 100mm × 190mm door. There is a 1400mm × 1700mm double window in North wall. Wall for the δ = 240mm of masonry structure. Brush cement mortar both inside and outside layer. The lower part of the test room has a 150 × 100mm exhaust duct.

2.2. The duct of independent fresh air

The laboratory has a duct(300 × 300mm) for the independent fresh air, mechanical ventilation, air paths with a centrifugal fan and three multi-leaf off valves. The fresh air supply on the height of 2.5m and the fresh air volume is 50 ~ 200m3 / h.

The concrete measures show in Figure2:

2.3. Analysis

This subject tests by experimental methods. Test the temperature field humidity field, wind speed, and the radiation temperature of the wall in different supply/exhaust way. Then analyze the experimental results obtained the best way of supply air.

Solve the unequal degree with the temperature field, wind speed and humidity field. Using unequal coefficient method [4] to analyze, in details:

Select n measuring points, measured (or calculated) point temperature, wind speed and humidity ratios, find the arithmetic mean of the absolute values is:

$$\bar{t} = \frac{\sum t_i}{n} \qquad \bar{v} = \frac{\sum v_i}{n} \qquad \bar{d} = \frac{\sum d_i}{n}$$

Root mean square deviation is:

$$\sigma_t = \sqrt{\frac{\sum (t_i - \bar{t})^2}{n}} \qquad \sigma_v = \sqrt{\frac{\sum (v_i - \bar{v})^2}{n}}$$

$$\sigma_d = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n}}$$

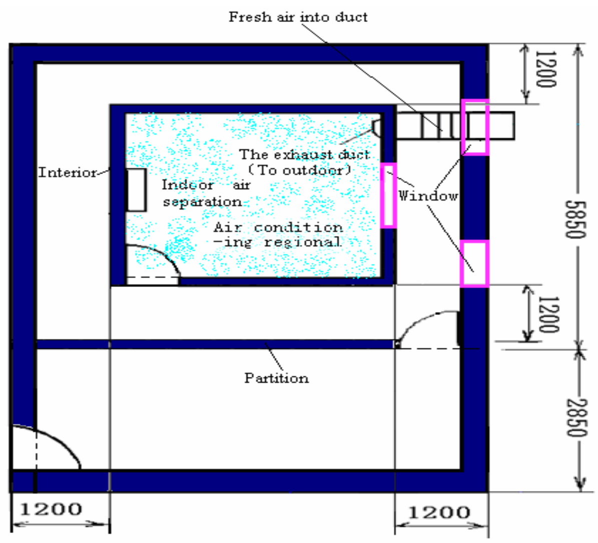

Fig1 the plan drawing of laboratory

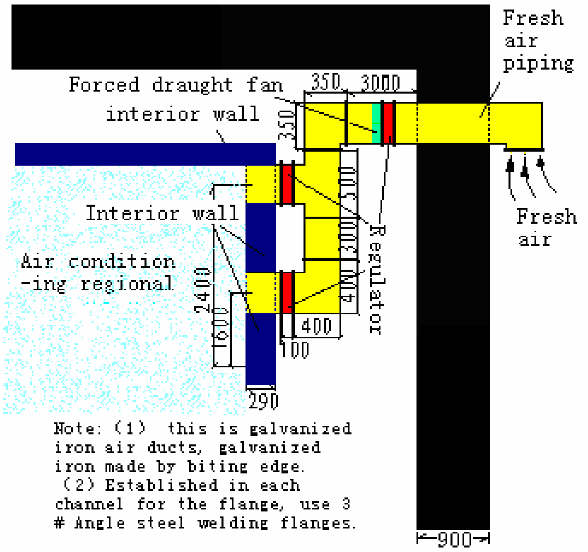

Fig2 the solid drawing of the supply air duct

Unequal coefficient is:

$$k_t = \frac{\sigma_t}{t} \qquad k_v = \frac{\sigma_v}{t} \qquad k_d = \frac{\sigma_d}{t}$$

Obviously, the smaller kt, kv, kd smaller, the better the uniformy.

There are many ways for the evaluation of thermal comfort. This study adopts the PMV-PPD indices from Fanger professor (Technical University of Denmark) to evaluate. PMV is a thermal sensation index get by comfort equation. It will constitute a thermal environment with three types of variables (air dry bulb temperature, relative humidity and air flow rate of a certain body) composition. Let the prediction determined by activity levels and clothing for the average thermal sensation (the average value of seven-point from the thermal sensation of test population) becomes possible. It can be used to evaluate the thermal environment from a general point of view.

2.4. Introduction of measure content

In order to more accurately evaluate the impact on the indoor thermal comfort for different air supply methods. We test indoor air temperature, humidity and wind velocity field in different enter ways of fresh air. One day, we take three representational times to measure, are 9:00 ~ 10:00, 13:00~14:00and17:00 ~ 18:00. We measured the inside and outside temperature, humidity, and wind speed of each measuring point in this three times. Specific test methods and test air date show in Table1.

Table 1 air supply mode and test sheet with test date

Testing time	*Air supply mode*	*Fresh air*	*Testing time*	*Air supply mode*	*Fresh air*
2006.12.5	Mixed large fresh air discharged on high speed	130	2006-12-13	Independent small fresh air discharged under low speed	130
2006.12.8	Mixed large fresh air discharged on low speed	130	2006-12-14	No fresh air in high speed	0
2006.12.9	Mixed small fresh air discharged on low speed	65	2006-12-15	No fresh air in low speed	0
2006.12.10	Mixed small fresh air discharged under high speed	65	2006-12-16	Independent small fresh air discharged on high speed	130
2006.12.11	Mixed large fresh air discharged under high speed	130	2006-12-17	Independent large fresh air discharged on high speed	290
2006.12.	Independent large fresh air discharged under low speed	290	2006-12-18	Exhaust air outdoor machine introduced under high speed	130
2006.12.19	Exhaust air outdoor machine introduced under low-velocity	65			

Note: The introduction of fresh air is the 2.4m height place independent introduction way. The mix introduction is fresh air mixes with the air from the bellower mix and then sent out by the air-conditioner.

With the normal experimental arrange. Independent experimental introduction of fresh air should be 9 groups, but take three main influencing factors into considered: fresh air volume, fresh air inlet mode and the air supply speed of air-conditioning can be fixed level. So it adopts the orthogonal test method. Other fresh air modes use the entire arrangement introduced experimental method.

3. Experimental Analysis

In order to prevent the test results are influenced by the changes of outdoor temperature. The test chamber placed inside the door. Room temperature changes a little. Each indoor measuring point temperature between 11 ℃ ~ 12.5 ℃ without air-conditioning but windows open, the average temperature is 11.5 ℃on Dec. 1.

3.1 Temperature field Distribution

It is well known that the indoor temperature is influenced by the fresh air volume and outdoor air temperature changes. And fresh air supply mode is an important factor for the indoor temperature changes. The indoor temperature of hybrid method has smaller environment temperature difference and the temperature distribution more uniform than the way of independent fresh air supply. Wind velocity is a conditioning running parameter can not be ignored in winter. The bigger wind velocity, the shorter air mix time and the indoor temperature distributions temperature difference is small. For small wind velocity, the opposite is. So just consider the indoor temperature conditions. The hybrid method with large wind velocity is the best air supply mode. The

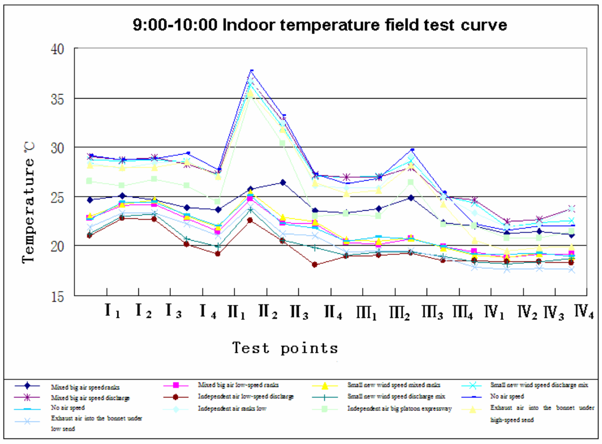

Fig 3 the indoor temperature test curve of 9-10 points

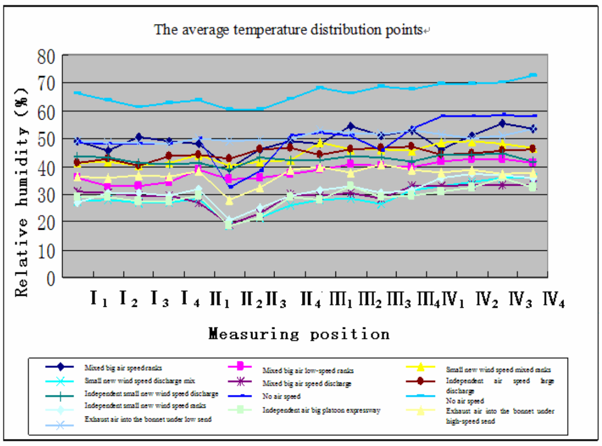

Figure4 the humidity test curve of indoor measur -ing poin

temperature distributions of three times are similar. With the continuous extension of air conditioning time, the indoor temperature decreases, (Figure3).

3.2 Humidity field distribution

Under each kind of air supply mode indoor humidity field distribution very orderly. Whether horizontal or vertical surface relative humidity is almost unanimous, but the relative humidity is very different size. The relative humidity uniformity coefficient has greatly difference. Winter indoor relative humidity at a comfortable between 40% to 60% and the indoor humidity field uniformity is better that means uniformity coefficient less. Mixing large fresh air discharged on high speed, low-speed mixing small fresh, independent on low-speed large fresh air discharged without fresh air into the exhaust of high-speed, outdoor fresh air from downward and feed back from the introduction of high speed, eject air outdoor fresh air from downward and feed back from low speed is the way we choose. No fresh air supply mode of worse indoor air quality not used. Then, according to the size of the uneven coefficient, can choose the best air supply method of relative humidity field. Exhaust air outdoor machine introduced under low-velocity for optimal. Exhaust air outdoor machine introduced under high speed is second, and then are independent large fresh air discharged under low speed, mixing small fresh air discharged on low speed, mixing large fresh air discharged on high speed, (Figure 4).

3.3 Energy Consumption Analysis

Evaluate the pros and cons of air conditioning system from two aspects. One is the comfortable of the air-conditioned environment, and second, the energy consumption of air conditioning systems. With the constant tension in the world energy situation, energy conservation has become one of the world's important issues. Air conditioning energy consumption in today's building energy consumption than the listed high. The energy consumption of air conditioning system analysis has provided an important reference factor for our air conditioning design.

Adopted here no air conditioning with windows open as a reference, the room average temperature is15.9 ℃. The difference air temperature between other air supply way and no air conditioning windows open is as follows Table 2.

Table 2 Comparison of indoor temperature and temperature difference

Air supply mode	*Mixed large fresh air discharged on high speed*	*Mixed large fresh air discharged on low speed*	*Mixed small fresh air discharged on low speed*	*Mixed small fresh air discharged under high speed*	*Mixed large fresh air discharged under low speed*	*Independent large fresh air discharged under low speed*	*Independent small fresh air discharged under low speed*
Average temperature	25.6	21.8	22.2	28.5	28.5	20.5	20.7
temperature difference	9.7	5.9	6.3	12.6	12.6	4.6	4.8

978-1-935068-37-2 © 2010 SciRes.

Air supply mode	*No fresh air in high speed*	*No fresh air in low speed*	*Independent small fresh air discharged on high speed*	*Independent large fresh air discharged on high speed*	*fresh air from downward in high speed*	*fresh air from downward in low speed*
Average temperature	28.5	21.9	27.9	25.6	26.9	20.7
temperature difference	12.6	6	12	9.7	11	4.8

According to the characteristics of the laboratory, the indoor test space, the small changes of indoor temperature and the small heat exchange effect of outdoor unit's. Ignored the influence of the in outdoor temperature changes. Use the average temperature in experimental space as reference temperature. And compare the value of energy consumption increase 1 ℃ per.

The average energy consumption of a variety of air means the following table3:

Table3 The average temperature distribution points

Air supply mode	*Mixed large fresh air discharged on high speed*	*Mixed large fresh air discharged on low speed*	*Mixed small fresh air discharged on low speed*	*Mixed small fresh air discharged under high speed*	*Mixed large fresh air discharged under low speed*	*Independent large fresh air discharged under low speed*	*Independent small fresh air discharged under low speed*
Average energy consumption KW	0.779	0.943	0.970	1.000	1.062	0.97	0.996
Temperature difference ℃	9.7	5.9	6.3	12.6	12.6	4.6	4.8
Unit of energy consumption KW/℃	0.080	0.16	0.154	0.079	0.0843	0.211	0.207
Air supply mode	*No fresh air in high speed*	*No fresh air in low speed*	*Independent small fresh air discharged on high speed*	*Independent large fresh air discharged on high speed*	*fresh air from downward in high speed*	*fresh air from downward in low speed*	
Average energy consumption KW	0.982	1.153	0.987	1.028	0.89	20.7	
Temperature difference ℃	12.6	6	12	9.7	11	4.8	
Unit of energy consumption KW/℃	0.078	0.192	0.082	0.106	0.081	0.206	

1) According to these experiments. We find that low speed of air supply unit energy consumption is much larger than high wind speed of air supply mode without take the energy consumption of fresh air into account and despite the way of air supply/return.
2) The energy consumption of fresh air should not be ignored. The load of fresh air is large. so in satisfies the indoor air quality in the situation to use the smallest fresh air volume in air conditioning designs. Here's the comparative test results confirmed the greater the larger fresh air, the larger energy consumption.
3) Whether the air supply mode is mixing large fresh air with high speed and independent air supply with high speed, mixing large fresh air in low speed and independent air supply in low speed, or mixing small fresh air with high speed and independent air supply in high speed, mixing small fresh air in high speed and independent air supply in low speed. The energy consumption of a mixture of fresh air into the room is lower than an independent fresh air.
4) For the experimental air supply mode, the energy computation of fresh air from downward in high speed or fresh air from downward in low speed with outdoor machine and the other method is similar. Compare with fresh air from downward on low speed and independence large fresh air under the low speed, independence small fresh air under the low speed. The energy computation is little difference between the two.
5) The energy recovery on this air supply mode has no advantage, even not as good as other modes. Why will have such a situation? Here we neglected an important factor, which is the energy computation of fresh air. Therefore, need to analyze the change on for the energy consumption.

4.Conclusion

The results from the analysis above, the indoor state parameters are influenced by many factors, such as: the fresh air volume, fresh air supply mode and the wind velocity and so on. Indoor temperature fields, humidity fields, wind velocity fields, energy consumption analysis and recommended air supply modes, not difficult to find the relationship between them. Winter wind speed, the beginning of this paper has emphasized the influence of the indoor state parameters.

From the analysis of temperature field, the air supply mode with mixing high velocity is the recommended mode. Humidity fields is a low-speed mode with low wind-velocity, and wind-velocity fields is a low-speed mode. Energy consumption is another important indicator of air conditioning system, the requirements of the wind speed is high. It seems that human comfort is contradicted with energy consumption, in fact, air speed, energy consumption and state parameters indoors is also incompatible. One is low wind speed, the other is the high wind speed, the two curves certainly have a crossing point, and this point just is the economic flow.

In order to maintain indoor parameters, the economic reduce energy consumption. The economy is raised in a whole space body, not a single point. Optimum air conditioning system, the rational selection of air supply status points.

References

[1] SunWeihong, based on non-uniform coefficient of water environmental capacity calculation method, this paper probes into the protection of water resources, 2001.2 [J]. (6) : 36-37

[2] YanQisen, ShiWenXing, TianChangQing etc. Air conditioning with refrigeration technology [j]. China architecture &building press,2001.12.

[3] ZhangHongliang, LiuJinPing. Household inverter air condition cold load analysis and energy-saving. Hvac [J], 2003,33 (6) : 119-122.

[4] LiuYanmin [2], HuangPing. Splits the indoor environment with air. Hvac [J], 2004，34 (3) : 69-66.

[5] ShouHuihui, YaoGuoQi. Household central air conditioner system design and engineering examples [M]. Science press, 2005.1.

978-1-935068-37-2 © 2010 SciRes.