INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211

Experimental Analysis Of Diffuse Ceiling Ventilation

Jitendra Raghuwanshi
M.Tech. scholar

Dr. V.N. Bartaria
Professor & Head of department LNCT BHOPAL, India

Abstract:

HVAC engineers have never stopped developing air distribution systems that are able to provide the occupants with high air quality and optimal thermal comfort. One of the critical problems regarding the thermal comfort is draught risk, especially when ventilation system is operated at a high flow rate. A new air distribution system using the entire ceiling as the air inlet is used in the livestock house. However in term of indoor space occupied by human being, the research is limited. This work endeavours to describe and testify the performance of a diffuse ceiling ventilation system in a typical office room. The overall objective is to investigate the possibility of using the diffuse ceiling as an air distribution system in an office building. A full scale measurement is conducted in a climate chamber to analyze the performance of diffuse ceiling ventilation system used in an office room. Air temperature, air velocity, surface temperature, pressure loss and ventilation effectiveness are measured under different test conditions

Introduction

Ventilation is a process of supplying fresh air and removing exhaust air to and from a space by natural or mechanical means. A good design of air distribution system requires not only supplying clean air with correct temperature and flow rate to the occupants, but also it is important that the system is designed in an energy efficient way to provide the occupants with high air quality and thermal comfort in occupied zone. A typical consequence of bad air distribution design is Sick Building Syndrome (SBS). SBS often results in headache, fatigue, problems to concentrate and think clearly, etc. Studies [1] in European, Asian and US buildings shows: 20 – 40% of occupants with health symptoms and 10-60% of occupants find the indoor environmental quality unacceptable even though the existing ventilation standards are met. On the other hand 35% of energy use in Europe [1] is already spent for creating indoor climate. Therefore it is an important task to improve the design of air distribution system with minimum cost of energy and installation and maximum comfort. Major ventilation principles used in practices are natural ventilation, mechanical ventilation and hybrid ventilation. Though natural or hybrid ventilation has showed a large potential energy saving in operating buildings, mechanical ventilation still plays an irreplaceable role to provide occupants with conditioned climate. Major air distribution principle used in mechanical ventilation is mixing and displacement ventilation. The mixing principle dilutes the indoor pollution concentration, while the displacement principle supply the air from lower level of occupied zone to separate stale air from fresh air. An alternative ventilation principle for room air distribution system is downward ventilation or diffuse ceiling ventilation (DCV). The main design principle of DCV is that the fresh air is supplied through ducts or direct opening from façade or ductless opening from rear wall into a pressured plenum. As there is small pressure difference between the plenum and occupied zone, the fresh air penetrates through the entire acoustic ceiling into the occupied zone. The concept is particularly known in special applications like the clean room industry where the air flow resembles piston flow [2]. In Denmark, this application is extensively used in the livestock buildings. However in term of indoor space occupied by the human being, the research is limited and the results are preliminary [2]. Due to the characteristic of this type of air distribution, it has the potential of more widespread utilization such as open office room, school, and indoor sport hall etc, especially when high thermal load presents.

Experiment Results

The main results of experiments are presented in two parts: ventilation effectiveness and thermal environment. Ventilation effectiveness is calculated by the different concentration measured at steady state condition in different scenarios. Air temperatures and velocities are measured at the selected points in the occupied zone. PMV/PPD is calculated to represent the overall thermal satisfaction and local thermal comfort is presented by the draught rating. The main results and key values are presented in the report, while detail temperature and velocity data can be seen in App.B – App.G.

Air Temperature And Air Velocity Measurement

Air temperature and air velocity are measured spontaneously in each spot, and measured spots test location.. Vertical air temperature and velocity are compared for the air change of 3.5 and 5.1 times per hours. Inlet and return temperature are 16.7°C and 24.2°C respectively in the first scenario and 17.2°C and 25.5°C respectively in the second scenario. The temperature data can be seen in App. B and C. Local air velocity data can be seen in App. F andG.

Vertical Air Temperature Profile

A uniform temperature distribution is obersved in two scenarios, see Figure 1 and Figure 2. The average of vertical air temperature difference, $\Delta T_{a,v}$ is also always less than 1 K. The highest temperature gradiant is found at spot A3 in the first scenario. Despite of spot A3 in the first scnario, the small temperature gradient above 1m indiates a good mixing in the upper occupied zone. This results agrees with the cooling case in P.V. Nielsen's experiment.

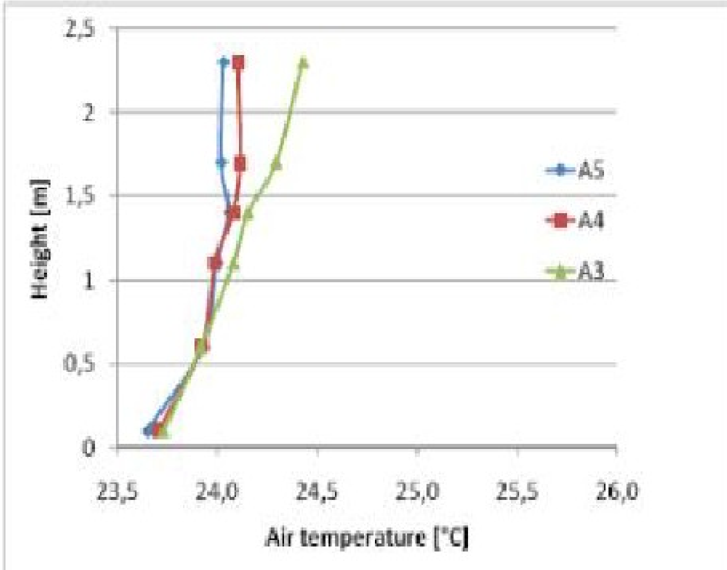

Figure 1: Vertical air temperature profile ACH =3.5

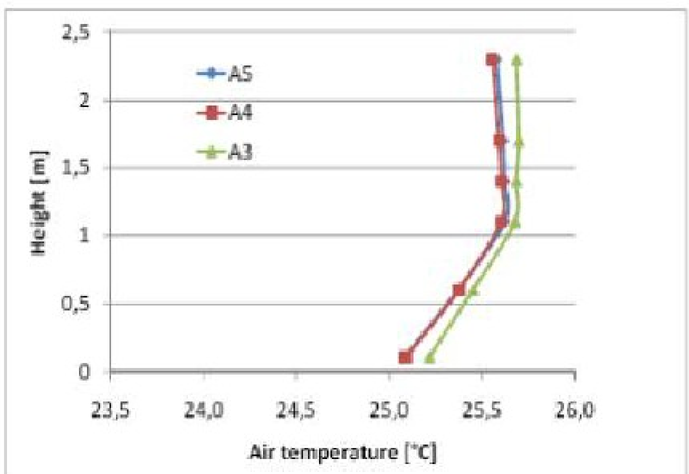

Figure 2: Vertical air temperature profile for ACH =5.1

Vertical Air Velocity Profile

Air velocity is measured at three heights: 0.1 m, 1.1 m, 1.7 m, which represents respectively ankle, abdomen, and head level for a person at five different points. A1 and A2 are closed to both occupants and heated folie. A3 is on the other side of occupant toward the outlet. A4 and A5 are placed away from the heat source. The location of each spot can be seen in Figure 3 shows the vertical air velocity distribution when ACH is 3.5 h-1. All measured velocities are less or equal to 0.1 m/s and the difference from ankle to head are within 0.04 m/s. Higher velocity is found at the ankle level at the spot A4 and

A5, and the velocity is quite stable from floor up till 1 m, and decreasing till head level. Due to the lack of velocity sensors, it is not possible to find how the velocity changed from 1.0m to 1.7m. On the other hand the velocity at spot A1, A2, and A3 are increasing from 0.1 m to 1.1m and become quite different above 1.1m. The possible reason can be that despite the measuring uncertainty, all the heated source are placed above 1m. The convective flow counteracting with downward cold air may result in an unstable air movement in the upper occupied zone around the heat source.

Figure 4 shows another vertical velocity profile when air flow increases to 5.1 h-1. All five spots have the same trend that the velocity increases from head level to ankle level. The highest velocity is found at the ankle level, up to 0.15 m/s in A4 and A5. The reason can be caused by the high reverse flow coming along from the wall toward occupants, especially the extra heated source is placed near the spot A4 ad A5.This value is also happen to be the limit of "flow element", urm ,which P.V. Nielsen used in his design chart.

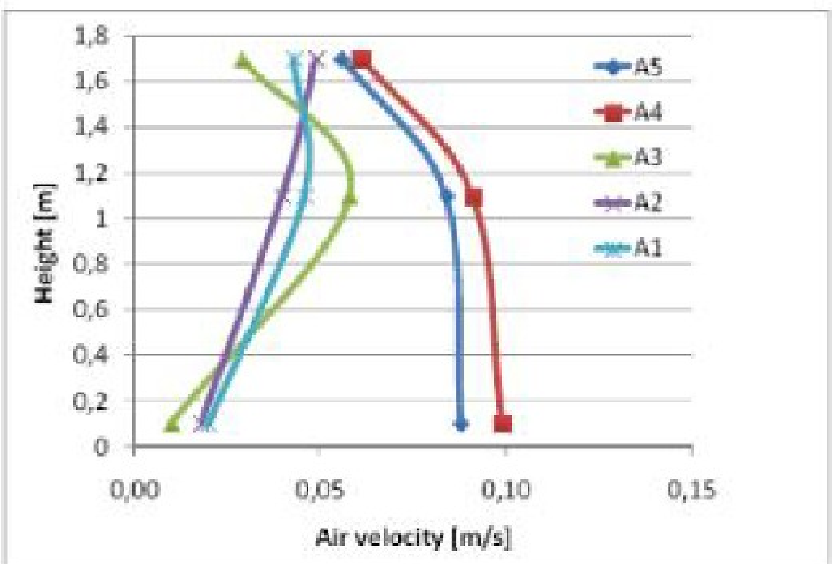

Figure 3: Vertical air velocity profile for ACH = 3.5

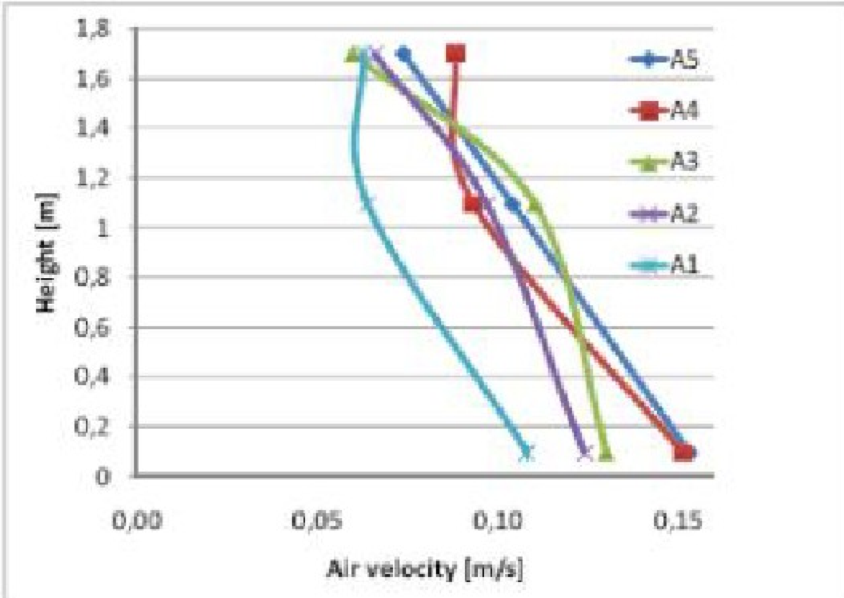

Figure 4: Vertical air velocity profile for ACH =5.1

Measurement Of Pressure Drop Across The Ceiling

Another advantage of diffuse ceiling as the air inlet is documented in Nielsen et . al [3]. The very low pressure drop across the ceiling has a positive impact on the energy consumption. Five different flow rates are tested in the chamber and pressure drop across the ceiling are documented in Table 1 and Figure 5

Ach	Flow M^3/S	Flow	Pressur Inlet (Pa)	Pressure Outlet(Pa)	Delt Ceiling
1.5	0.031	1.4	28.5	11	0.57
2	0.042	1.9	54.5	21	1
3	0.063	2.9	127	48	1.8
3.5	0.074	3.4	179	66	2
5.1	.107	4.9	385	142	3.5

Table 1: Flow rate and pressure drop across the ceiling

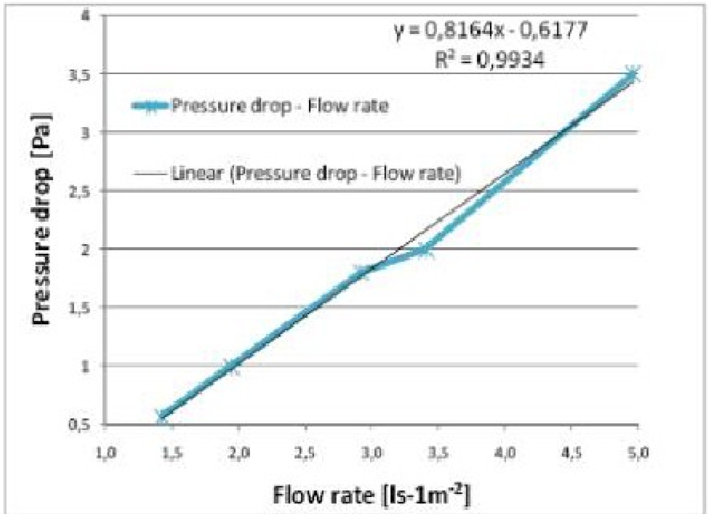

Figure 5: Correlation between the pressure drop and flow

The pressure increases lineally with the increase of ventilation flow rate. However it is observed that for the same flow rate, pressure drop is higher in Hviid's case. The possible reason is that diffuse ceiling plates in Hviid's study have a membrane above the acoustic plates. The membrane introduces a large resistance for the air inlet. Therefore a relative large pressure drop is measured in Hviid's system. However in the investigated diffuse ceiling type, air diffuse mostly from the strips and other cracks between the acoustic plates, which results in a smaller resistance than that of the membrane. It is also found that even with a flow rate of 107 l/s, the pressure drop across the ceiling is only 3.5 Pa. If he ATD in the test chamber is replaced with a normal perforated ceiling inlet diffuser with a typical branch pipe connection (Ø125). According to Figure 6, the pressure drop of diffuse ceiling is only 7% of perforated ceiling diffuse at the same flow rate.

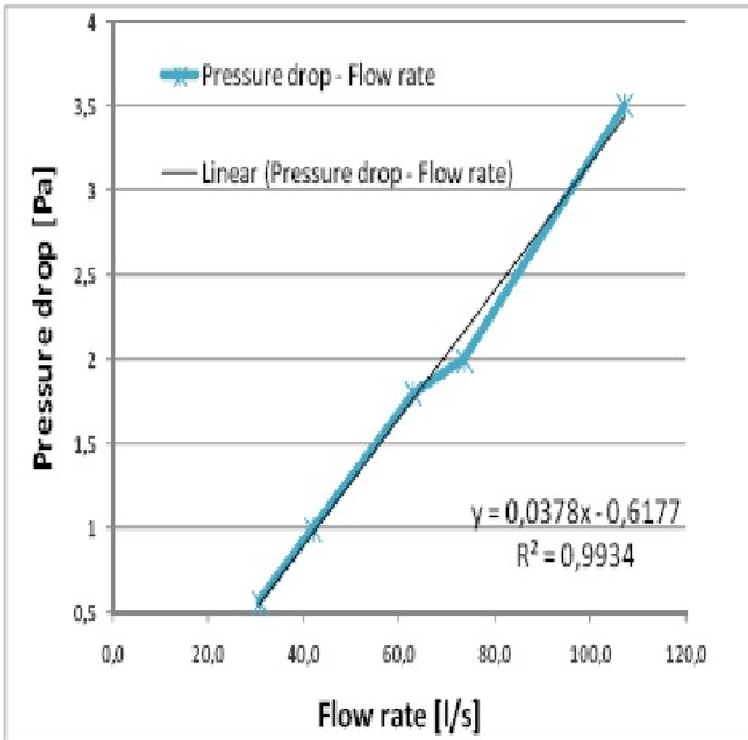

Figure 6: Correlation between the pressure drop and flow for DCV

Conclusions

He experiments show that diffuse ceiling as an air terminal device works well in the case of cooling even at a high heat load and high ventilation flow rate. Test conditions consists of scenario one with a ACH of 3.5 h-1 and scenario two with a ACH of 5.1 h-1. No draught problem is found in both test conditions. The draught rating results in an indoor environment of Class A in a normal ventilation rate. Even at the high heat load and flow rate, the draught rating is still within the Class B. If the inlet temperature in second scenario would be the design value as calculated from the analytical pproach, Class A is achievable in second scenario. Both DR results and velocity measurements show that highest DR and velocity is found at ankle level in five investigated spots. Possible reason could be that the convective flow from heat source interacts with air inlet in the upper occupied zone, which generates a high reverse flow at the ankle levels. Similar results are also reflected in Nielsen's experiment. Two tested scenarios also show an overall comfortable thermal environment, which 5% and 8% of people are expected to be unsatisfied. Since both cases show a good mixing in the occupied zone, there is no need to evaluate the radiant thermal asymmetric. The result of ventilation effectiveness indicates a fully mixing air movement in the occupied zone in both scenarios. This gives good evidence that DCV is able to efficiently remove the indoor contaminant.

Thermal images elucidate the expected air movement across the ceiling. The cold air mostly falls down through the strips in the middle, while small part of cold air penetrates through the acoustic plates and the end strips. Thermal image of acoustic ceiling shows that acoustic ceiling has the potential to work as a radiant cooling ceiling. It is known that radiant ceiling cooling is superior to provide large cooling capacity at a low energy use. However radiant cooling ceiling also causes draught problem especially at high flow rate. The experiments again prove DCV's advantage of providing draught free environment in he occupied zone. In future it is interesting to investigate a new air distribution system with a combination of diffuse ceiling ventilation and radiant ceiling panel. Measurement of the pressure across the acoustic ceiling shows using acoustic ceiling as an air terminal evice results in a much lower pressure drop than raditional ceiling diffusers. The investigated DCV system is favourable in the design of air distribution system in respect of energy saving

Reference

1. DTU lecture slice. Economical benefits from improving indoor environmental quality. March 2, 2011
2. Christian Anker Hviid, Building integrated passive ventilation systems, Ph.D Thesis, Department of Civil Engineering, Technical University of Denmark, 2010.
3. Nielsen V. P. Termisk Komfort ved brug af et ventilationsloft – Widex domicil. Måling og simulering. 2009
4. P.V. Nielsen, E. Jakubowska, The performance of diffuse ceiling inlet and other room air distribution systems, in: Proceedings of Cold Climate HVAC, Sisimiut, 2009.
5. P.V. Nielsen, E. Jakubowska, The performance of diffuse ceiling inlet and other room airdistribution systems, in: Proceedings of Cold Climate HVAC, Sisimiut, 2009.