AIR FLOW DISTRIBUTION IN A NATURALLY VENTILATED LIGHT WEIGHT ROOM

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ABSTRACT

The objective of this research is to investigate air flow distribution inside a light weight test room which is single sided naturally ventilated. The ventilation rate into the room is controlled by adjusting four sets of louvres. The local outside air temperature, humidity, pressure, wind velocity and direction were measured. Inside the room the velocity and direction of the inflow air across the high and low level openings, temperature and velocity distribution at four locations and six levels across the room were recorded. The results demonstrated that a displacement mode of ventilation was maintained in the space when the wind came from behind the test room. When the wind impinged on the louvre bulkhead the displacement flow into the room was reduced. A simulation package was used to calculate the Predicted Mean Vote (PMV) values for different measured indoor velocities. The predicted thermal comfort indicated that PMV values were significantly improved with a higher internal air velocity.

Keywords: -Natural ventilation, air flow distribution, thermal comfort

INTRODUCTION

The commitment to reduce the use of ozone-depleting refrigerants and energy consumption of HVAC systems has focused attention on alternative methods of conditioning occupied spaces in buildings. A new philosophy of building design is emerging with an interest in the use of structure and form to provide low-energy building with high-quality indoor climates . Much attention has been focused on taking advantage of natural ventilation; however, as it is driven by forces which are primarily of a stochastic nature, there is need to evaluate and control the resulting air flow in order to maintain comfortable conditions.

The link between natural ventilation and comfort levels has been studied in some recently reported work. Matthews [1,2] used a flow network model which took account of both wind and buoyancy forces. It was found that the changes in air temperature along the flow path were not easy to predict and that empirical room air temperature profiles were necessary for the evaluation of thermal comfort. Also recent experimental studies at Loughborough University [3] demonstrated that thermal comfort can be achieved for most days during summer in a single-sided naturally ventilated office.

The objective of this research was to investigate air flow and temperature distribution for a single-sided naturally ventilated test room. The room is a portable cabin [4] with a volume of 22.2 m^3 located in a sheltered area. The ventilation rate into the room was controlled by adjusting four sets of metal louvres. The local outside air temperature, humidity, pressure and wind velocity and direction were measured. Inside the room the velocity and direction of the inflow air across the high and low level openings and temperature and velocity distribution at four locations and six levels across the room were recorded. The experimental results for wind velocities to the face of the louvres and from the behind of the test room are presented. A simulations package developed by Ove Arup, Room programme [5] was used to predict the PMV values [6] for different measured indoor velocities.

EXPERIMENTAL TECHNIQUES

Test Room

A portable cabin of light mass was used as a test room which was fitted with four sets of louvres inside the room Each unit had the overall dimensions of 125 cm wide, 80 cm high and 20 cm deep and contained 5 of 12 cm wide adjustable louvre blades. Relative to the internal dimensions the louvres covered just over 60% of the bulkhead area with a capability, when fully open, to provide an aperture equivalent to approximately 28% of the bulkhead area. The adjustable louvres were fitted to ensure that significant ventilation entered the test room.

In order to accurately regulate the degree of opening of the louvre blades while controlling each louvre unit or bank individually to any configuration a motor actuator was required for each unit. The motors were driven by a 24 V d.c. supply with a positioning signal ranging from 0 to 10 volts. The motors provided a return signal ranging from 2 to 10 volts to indicate their position. In the set up used 2 volts represented fully open and 10 volts fully closed. It also incorporated a 0 to 10 volt voltmeter that could be switched between the motors to measure the return signal and, hence, allowed the motor to position accurately and consistently.

Instrumentation and data acquisition

Due to the sheltered nature of the test room, the external environmental weather conditions local to the test room were measured. Weather station sensors were mounted locally which measured the wind velocity, direction, outside temperature, humidity and pressure. Inside the room, the air flow through the louvre opening, air flow and temperature across the room were measured. The direction and air flow at the openings were measured using two ultrasonic air flowmeters. During the experimental tests the flowmeters designated ultra1 and ultra2 were located in the cell adjacent to the top and to the bottom opening respectively. A type 54N10 multichannel flow analyser was used for the measurements of the inside air temperature and velocity at four locations and six levels above the floor. The positioning of indoor sensors is shown in Figure 1.

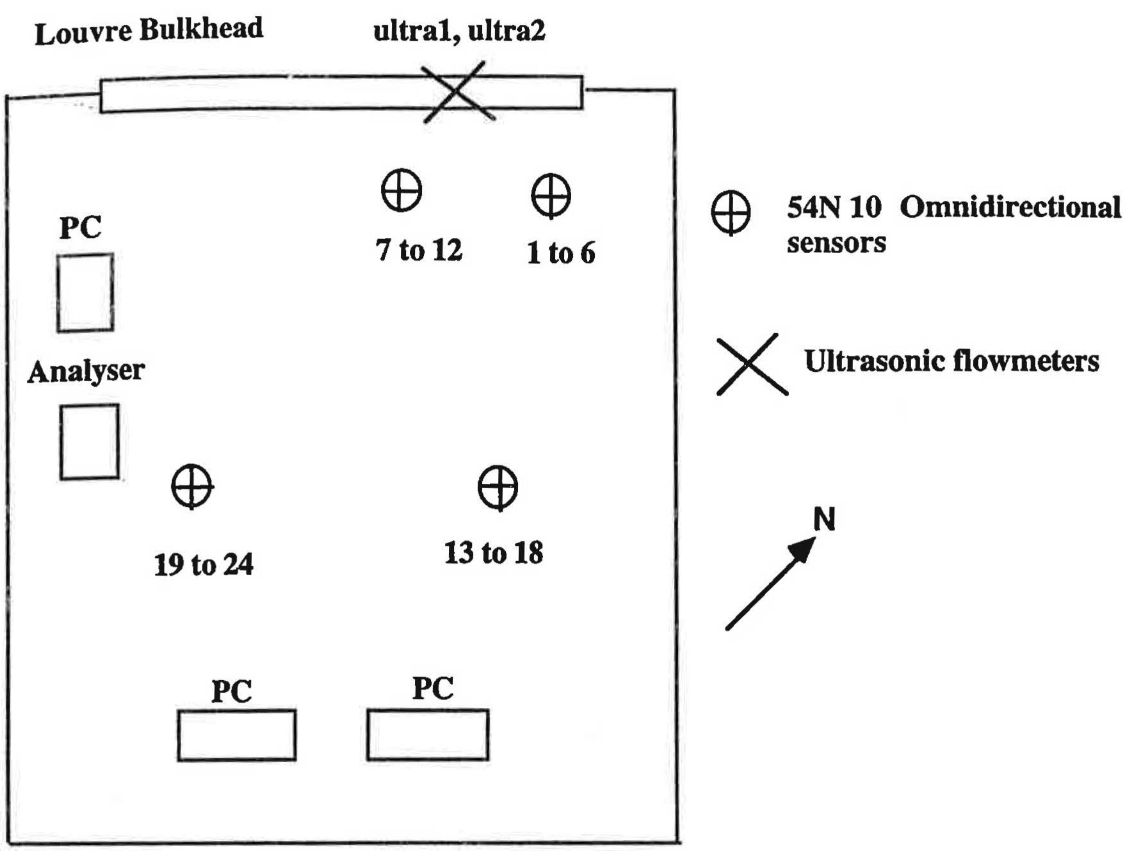
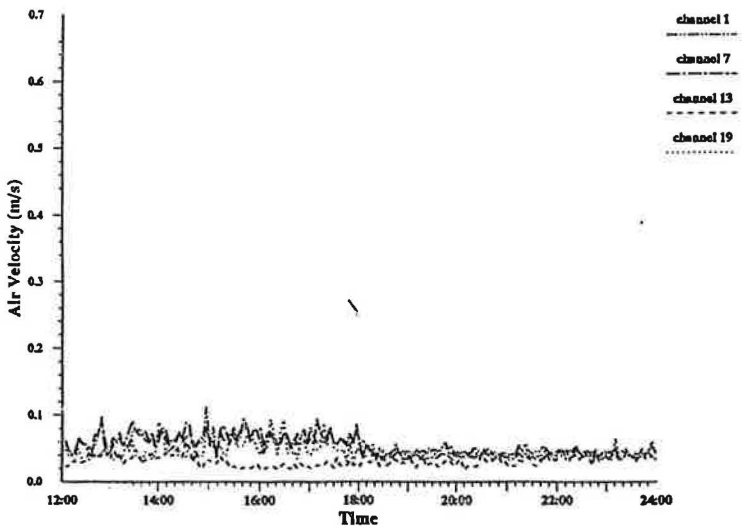


Figure 1 The location of the sensors inside the test room

EXPERIMENTAL RESULTS

The results for two different outside wind direction and velocity of 64 N, 2.17 m/s and 257 N, 2.22 m/s are presented here. The velocity distributions across the room at the height of upper and lower opening for all eight locations are shown in Figures 2.



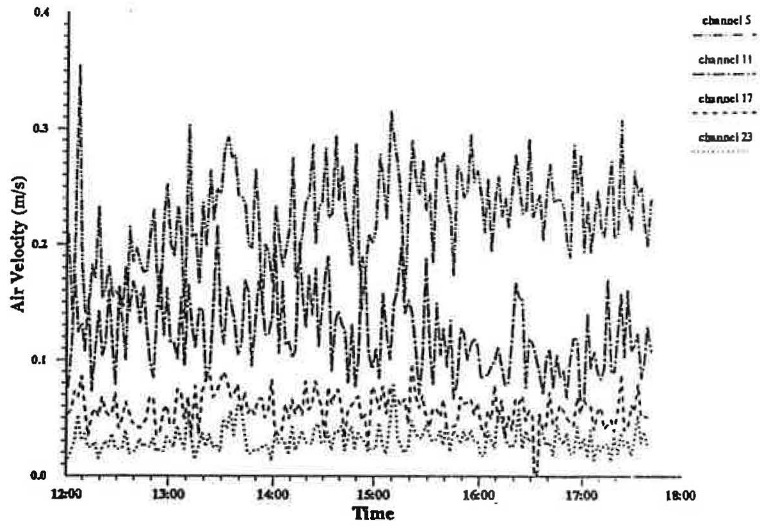


Figure 3 The velocity variation at the height of upper and lower opening across the room for wind direction of 257 N

The results indicate that the flow into the room is restricted and air velocities are much lower than the first case mainly due to the direction of the wind.

The ROOM programme developed by Ove Arup was used to calculate thermal comfort parameters for different indoor air velocities. Figure 4 shows the PMV values for air velocities of 0.05 m/s and 0.4 m/s. Due to air infiltration overnight initially the PMV values are negative and as the outside and internal temperatures increase the PMV values are improved. The average PMV values after mid-day for 0.05 m/s and 0.4 m/s velocities are 0.4 and 0.84 respectively. The results indicate that thermal comfort for September is improved significantly with a higher internal air velocity.

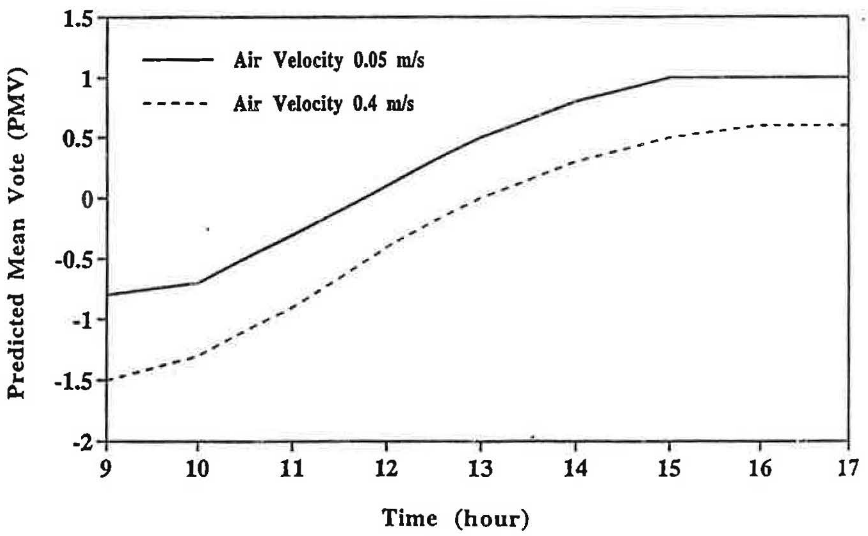


Figure 4 The PMV values for indoor air velocities of 0.05 m/s and 0.4 m/s

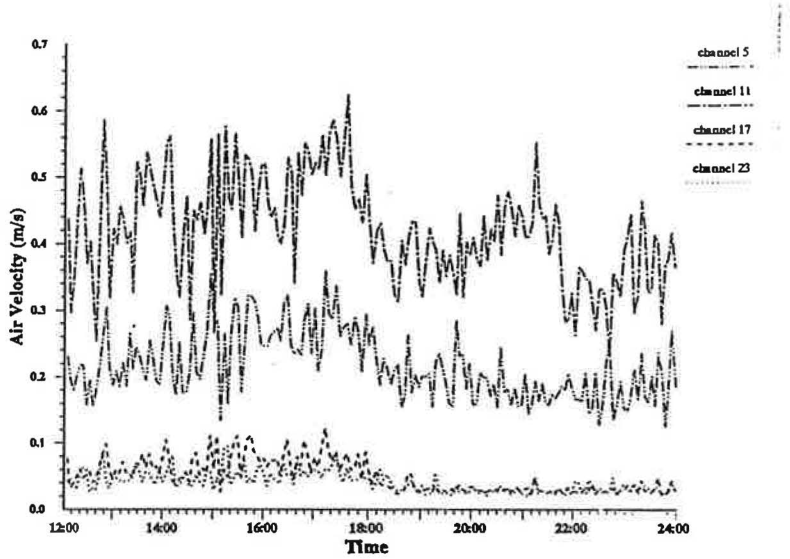
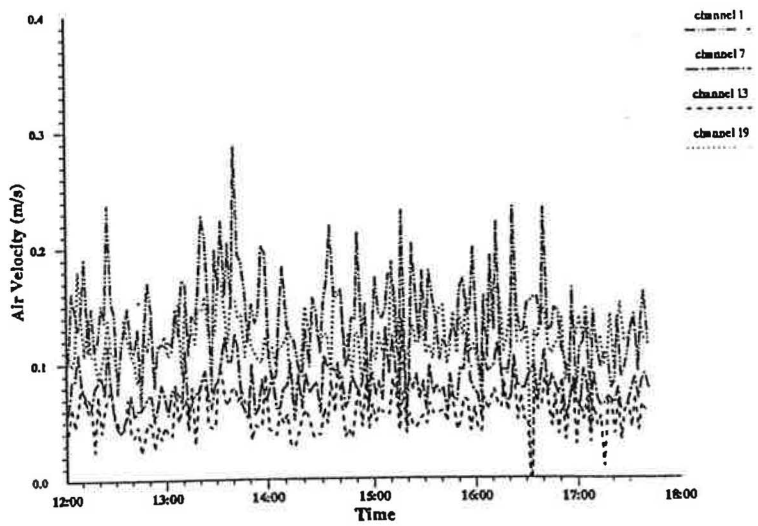


Figure 2 The velocity variation at the height of upper opening and lower opening across the room for wind direction of 64 N

The air velocities at the height of upper opening are very close with an average value of 0.05 m/s. The velocity at the height of lower opening and at the two locations close to the louvres follows the outside wind direction and are about 0.4 m/s and 0.2 m/s. The velocity distribution at the other two locations are very low with an average value of 0.04 m/s. The ultrasonic flowmeters indicated that flow through the higher opening tended to be outward, whereas through the lower opening the trend was inward flow. The air velocity for both heights and a mean wind direction of 257 N are shown in Figure 3. The air velocities at high levels are very close together and follow the outside wind velocity. The air velocity at the height of lower opening and at the two locations near to the louvres are about four times higher than the other locations and are about 0.2 m/s and 0.15 m/s.



CONCLUSIONS

In general the measurements demonstrated air movement inside the room. Sensors furthe into the room away from the louvres showed less air flow movement and temperatur variations, whereas sensors closer to the openings recorded more air movemen particularly at low levels. The velocity at low levels was significantly affected by th direction of the wind. For a wind direction to the face of the louvres the air velocity wa 0.2 m/s and for a wind direction from the back of the test room the velocity was measure to be 0.4 m/s. However the air velocity at low level followed the outside wind velocity and was greater than the velocity at the higher opening. Flow through the higher opening tended to be outward, whereas through the lower opening the trend was inward flow. The internal temperature in all cases was higher than outside, which would suggest warmer ai leaving the room at the higher opening. The experimental results demonstrated that a displacement mode of ventilation is maintained in the space when the wind either comes from behind the test room or impinges directly on the louvre bulkhead. Thermal comfort simulations demonstrated that for this month, the higher internal air velocity of 0.4 m/s improved the averaged PMV values by 40%.

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