Proc. CIBSE A: Building Serv. Eng. Res. Technol. 19(2) 107–110 (1998) Printed in Great Britain B455

Technical Note

Summary The aim of this research was to investigate the flow pattern around a test room which is used for natural ventilation studies. The test cell effectively represents an in-fill development of a low-rise building located adjacent to high-rise buildings. When considering natural ventilation in a building in such a location it is beneficial to understand the local wind flow patterns resulting from the impact of the surrounding buildings on the prevailing wind conditions. This paper describes wind tunnel trials undertaken to visualise the resultant local wind pattern around the test cell for all prevailing wind directions, discusses the findings and compares the local data with the prevailing wind measured at a nearby weather station.

Wind flow patterns around a test cell in a sheltered location: Wind tunnel visualisation

M M Eftekhari BSc DPhil MASHRAE, **D J Pinnock** BSc AIMechE and **I Lau** BEng
Department of Civil & Building Engineering, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK

Received 25 July 1997, in final form 29 December 1997

1 Introduction

With increasing consciousness in society of the need to address energy efficiency, natural ventilation is being widely investigated and implemented as an alternative approach to reduce the running costs of buildings. Natural ventilation is the movement of air through the building by means of natural driving forces. These develop pressure differences across the building openings, inducing air flow into or out of the building. Examples are the stack or buoyancy effect generated through the temperature difference between air inside and outside the building, and the wind effect. When considering the development of new or existing buildings with a view to harnessing the benefits of natural ventilation, the location and proximity of surrounding buildings and structures must be addressed to determine how they would modify the prevailing weather conditions at the given location. Particular parameters of interest are the resultant wind direction and velocity experienced by the development, and the consequent quality and quantity of wind-driven ventilation that could be expected. Wind tunnel measurements in the environmental wind tunnel of the Building Research Establishment demonstrated that a tall building near to a low building significantly changes the wind pressure distribution on the latter[1]. Research is in progress at Loughborough University to investigate and model the combined influence of the wind and stack effects upon the ventilation rates in a single-cell unit subject to single-sided natural ventilation through full scale trials[2]. The test cell is in a sheltered location and represents an in-fill low-rise building located adjacent to high-rise buildings. The local weather data are record and are compared to the data measured at a nearby weather station.

Although wind data have been recorded in close proximity to the test cell, it was considered that visualisation of the local wind air flow patterns resulting from the prevailing weather conditions would help understanding of the physical mechanisms involved in the interaction between wind- and temper-

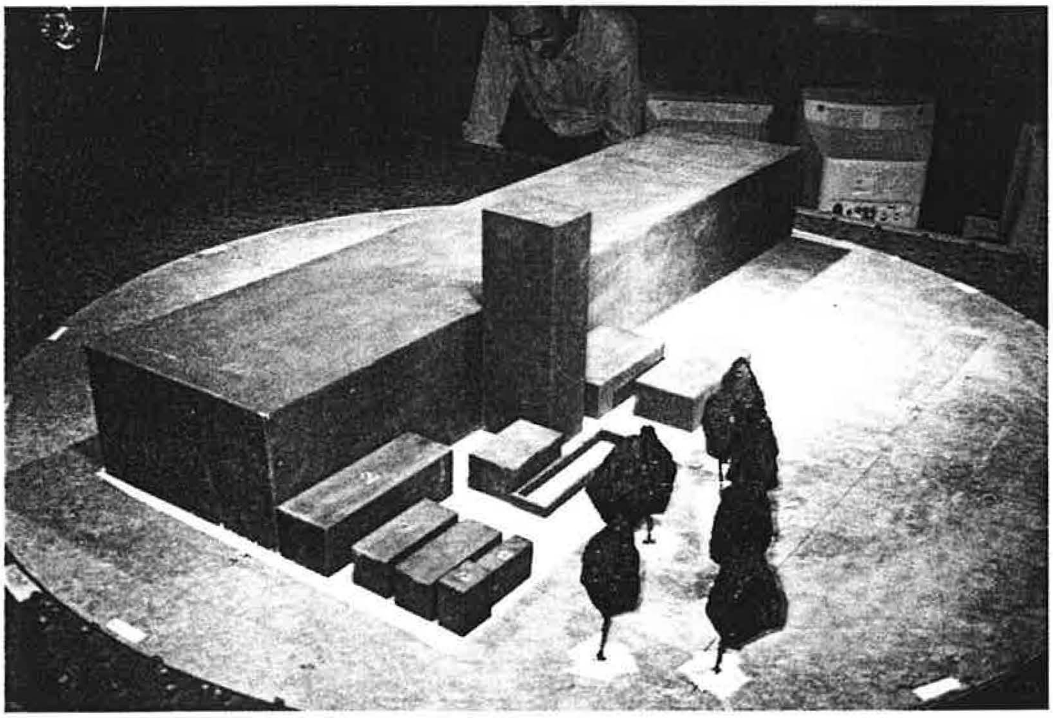

Figure 1 Scale model of test room and surrounding buildings

ature-driven ventilation, e.g. the effects of locally induced wind eddies and vortices. Computational fluid dynamics (CFD) was rejected for flow visualisation on the grounds of complexity and the difficulty of modelling the boundary conditions accurately. Flow visualisation was carried out on a scale model in wind tunnel at the Building Research Establishment.[1]

2 Model and trials

The test cell is a single room Portakabin® with a floor area of 3.6 × 2.95 m, 2.7 m high and is situated behind the Main Laboratory of the Civil and Building Services Department at Loughborough University. The latter stands 9.5 m high and adjacent to a water tower 17m high. Also in the immediate vicinity are other low-rise Portakabins® and sheds of the same height as the test cell (see Figure 1). The test cell is oriented so that the normal to the bulkhead in which the openings are situated points 330°N. A scale factor of 1:50 was used. The scaled dimensions of the test room and the surrounding buildings are given in Table 1. A scale model was built and painted black to facilitate visualisation and photographic records of flow paths of smoke injected into the wind tunnel. The model was placed on a computer-controlled turntable in the working section of the wind tunnel so that it could be orientated at any direction to the wind tunnel air stream. A series of 12 trials were undertaken with the model at different orientations to the air stream, representing wind directions of 0°N to 330°N in 30° intervals. Smoke was injected at each model orientation, and the smoke flow paths were observed and recorded with video photography. The wind air stream velocity was about 1 m s^{-1} and the flow patterns observed reflected those that would occur at full scale.

3 Results and discussion

The resultant air flow pattern is summarised in Table 2. The trials were performed with wind directions of 330°N to 0°N in 30°N intervals. It was evident from the start that the main laboratory block and the water tower dominated the system. The obstruction of the tower caused the wind direction to be diverted, and eddies were generated at the test cell area. The relatively large dimensions of the laboratory block funnelled the wind along the back façade of the block, depending on the prevailing wind direction, and consequently dictated the main air flow stream around the cell (see Figure 2). The direction of the resultant dominant air flow path at the test cell was either slightly south of west (around 260°N) or slightly north of east (around 70°N).

The westerly flow path at the test cell was far more dominant and stable than if it had come from the east, where swirl due to eddy generation was more evident. This can be accounted for by the fact that when the flow path is from the west the test cell is on the downstream side of the water tower and there are no buildings further downstream from the cell to create back eddies. When the flow path is easterly the water tower is upstream of the cell, causing an obstruction to the flow path and consequently generating eddies.

For the full-scale trials, wind conditions were measured immediately adjacent to the facade on the test cell in which the openings are located. On the campus not far from the test room there is a meteorological station where the prevailing wind direction, velocity and temperature are monitored at 10 m above the ground. The local and meteorological station outside wind velocity and air temperature were compared as shown in Figures 3 and 4. It can be seen that the outside temperatures are the same. The local wind velocity V_L measured at roof level is correlated with the prevailing wind velocity V_{10} at 10 m height by:

$$V_L = 0.416V_{10} \quad (1)$$

The local and meteorological station frequencies of wind velocity and direction are shown in Figure 5. It can be seen that the direction of the prevailing wind is well distributed; however the wind at the test cell generally comes from either a westerly or an easterly direction. This occurred for roughly 95% of the time the weather data have been measured. Therefore, the measurements from the full-scale trials and the observations from the wind tunnel scale model trials appear to be in total agreement. The measured data also suggest that when the test cell wind direction is generally easterly, the flow path is less stable and fluctuates more than if it is wester-

Table 1 Dimensions of the scaled test room and surrounding buildings

Number	Location	Length (mm)	Width (mm)	Height (mm)	Comments
1	Civil Engineering Laboratory 1	1500	330	190	
2	Civil Engineering Laboratory 2	236	78	70	
3	Water tower	88	120	340	
4	Shed	200	120	60	
5	Cabin next to test room	72	60	54	
6	Test room	72	58	54	
7	1st cabin next to car park	132	54	52	
8	2nd cabin next to car park	132	54	52	
9	Shed	200	100	60	
10	Concrete tank	214	42	18	Hollow (4 mm thick walls)
11	Water tank	24	17	12	
12	1st cabin (far end)	50	37	60	
13	2nd cabin (far end)	88	27	50	

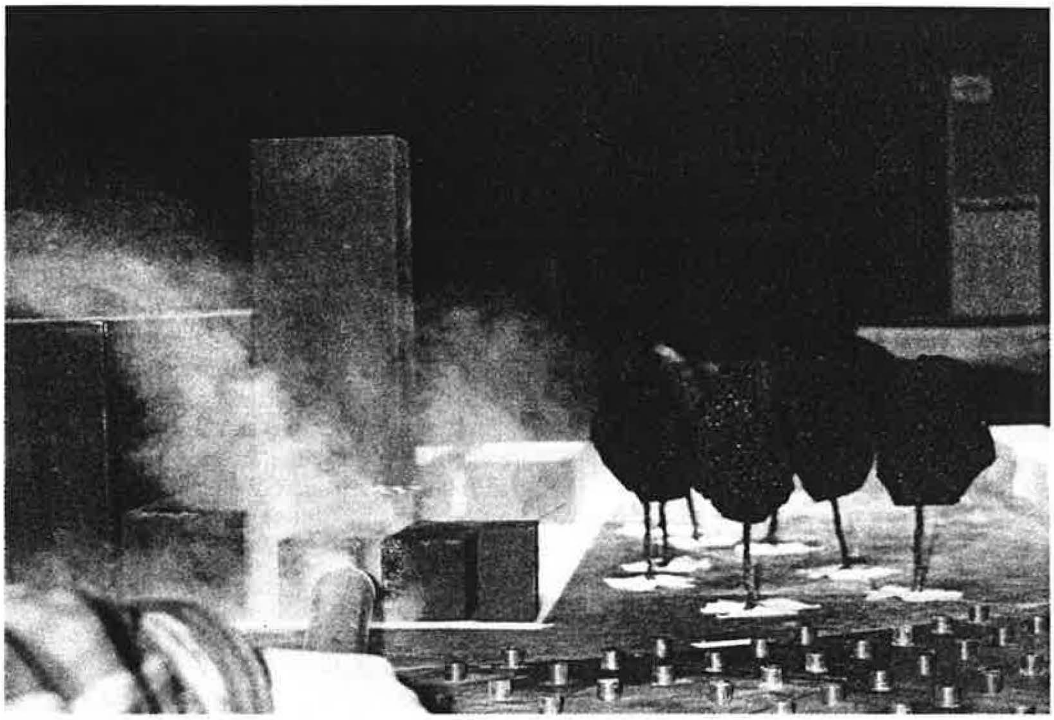

Figure 2 Smoke test for wind direction 30°N

Table 2 Summary of air flow pattern around the test cell

Wind direction (degrees to North)	Observations	Air flow direction at test cell (degrees to North)
0	Wind strikes low-rise buildings, spills over main laboratory block and splits around tower. Large eddies recirculate behind test cell.	60–80
30	As above with no eddies behind test cell	60–80
60	As above with slight eddies resulting from wind impinging on side façade of water tower	60–80
90	Wind passing over main laboratory block misses test cell, spills around side of laboratoryand runs along laboratory back façade. Eddies form behind test cell resulting from wind impinging on side façade of tower.	60–80
120	As above but with less dominant flows around side and back of main laboratory block	60–80
150	As above	60–80
180	Wind passes straight over main laboratory block, resulting in very weak flow patterns at test cell.	—
210–330	Wind splits around tower and passes over test cell as if genęrally coming from a westerly direction. Eddies develop behind test cell between main laboratory block and cell.	240–270

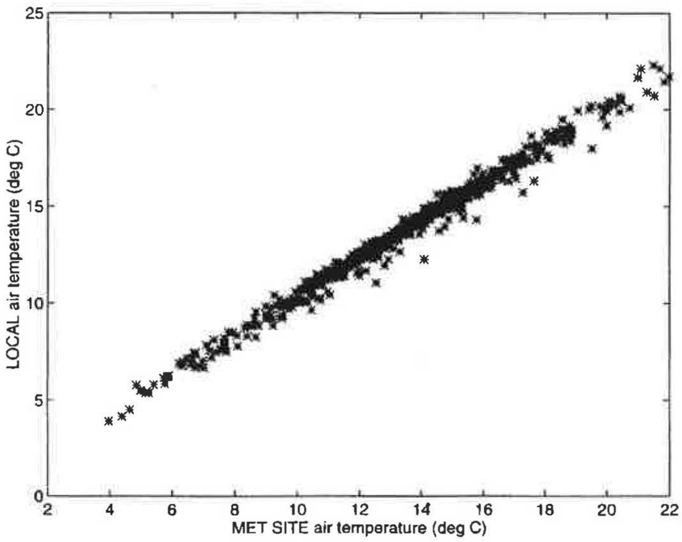

Figure 3 Comparison of local and prevailing outside air temperature

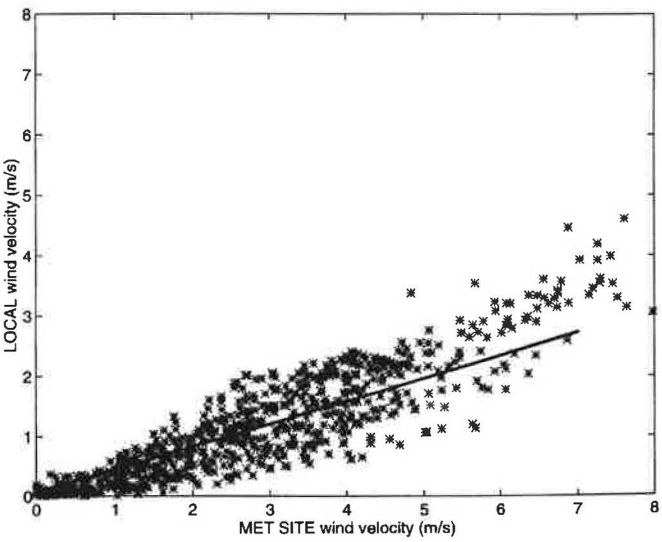

Figure 4 Comparison of local and prevailing wind velocity

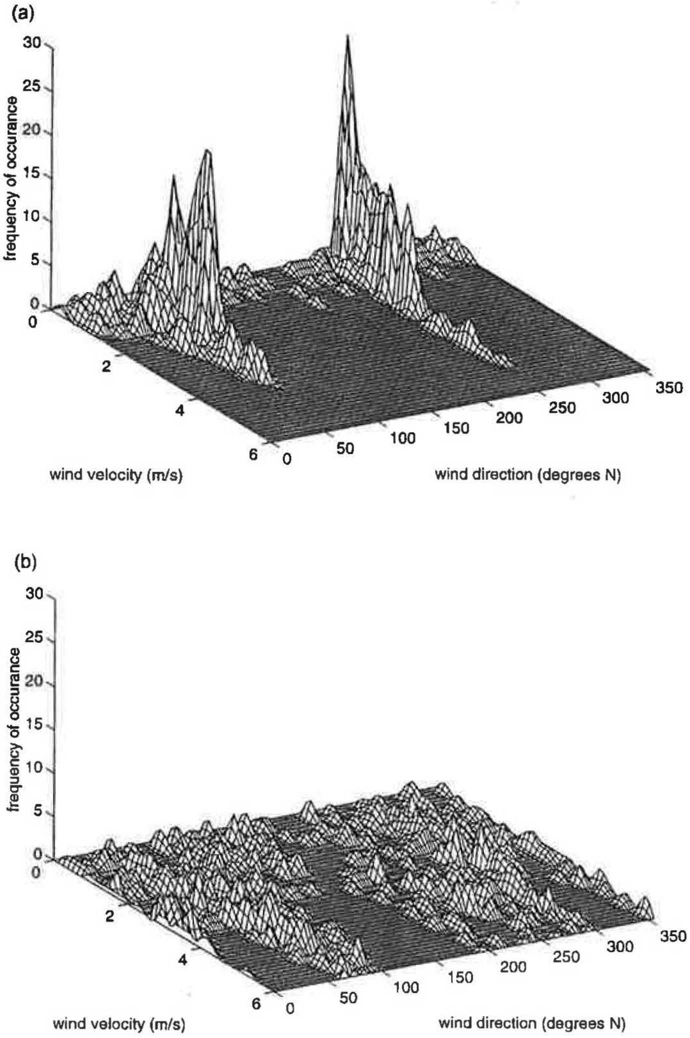

Figure 5 Comparison of (a) local and (b) prevailing frequency of occurrence of wind velocity and direction (Hourly averaged data for September 1996; velocity broken into 0.25 m s^{-1} samples for each direction)

flow path is less stable and fluctuates more than if it is westerly.

4 Conclusions

The wind tunnel measurements showed that the main laboratory block and the water tower are the dominant features in the system, and dictate the resulting air flow pattern at the test cell regardless of the prevailing wind conditions. The local wind velocity was measured to be about 0.41 times that of the prevailing wind, while the outside temperatures were measured as identical. Both the wind tunnel and full-scale measurements demonstrated that the wind at the test cell generally came from either a westerly or an easterly direction. The close agreement between observations from the wind tunnel trials and full-scale measured data showed how useful wind tunnel tests can be in helping to visualise and clarify the dynamics of the wind patterns recorded locally at the test cell in relation to the overall prevailing wind conditions. The results demonstrated the importance of the surroundings for local wind flow patterns. This should be taken into consideration when designing for natural ventilation.

Acknowledgement

The authors thank Dr M D A E S Perera for useful advice and for the use of the Building Research Establishment wind tunnel.

References

1 Perera M D A E S Proximity effects: Air infiltration and ventilation heat loss of a low-rise office block near a tall slab building *Proc. 14th AIVC Conf. Energy Impact of Ventilation and Air Infiltration* (September 1993)

2 Eftekhari M M and Pinnock D J Natural ventilation: Air flow measurements in a light weight test room *Proc. CIBSE A: Building Serv. Eng. Res. Technol.* **19**(1) 37–42 (1998)