PERFORMANCE OF AN AUXILIARY NATURAL VENTILATION SYSTEM

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1.0 INTRODUCTION

A comprehensive wind tunnel study has been carried out by Windtech Consultants Pty Ltd to establish the differential wind pressures between the various openings in the corner, double-ended and double storey units within a development such that the corresponding amount of air flow between these openings can be determined. The results are compared against the airflows predicted for mid-wall units that are linked to an auxiliary form of ventilation using ventilation ducts that rise to the roof of the development. The results of this study are based on a building located within the Sydney metropolitan area, with directional wind speed data obtained from Sydney Airport.

2.0 SETUP

A 1:200 scale model of the development was prepared and fitted with 128 pressure sensors. For each tower of the development 5 roof taps were positioned to determine the optimum location of the auxiliary roof vent. From these a total of 164 differential pairs were derived. These consisted of 83 differential pairs for Tower A (northern) and 81 differential pairs for Tower B (southern). Photographs of the model are shown in Figure 1.

3.0 METHODOLOGY

The testing was performed in WINDTECH's Blockage Tolerant Boundary Layer Wind Tunnel. The good agreement between WINDTECH's wind tunnel cladding pressure results and full-scale data from the Texas Tech Experimental Building provides some indication of the accuracy of WINDTECH's wind tunnel results (Rofail, 1995). The maximum tunnel blockage generated by the model and the surrounding buildings was approximately 5 percent of the tunnel cross sectional area.

Measurements were made to assess the effectiveness of linking the balcony door opening for each the mid-wall unit with each of the 5 different roof vent locations. The differential pairs also allowed the measurement of the differential wind pressure between the various openings in the corner, double-ended and double-storey units within the development.

The mean differential pressure coefficient can be defined by the following equation:

$$\mathrm{D}\mathbf{C}_{\mathbf{p}_{\mathbf{mean}}} = \frac{\textbf{(mean pressure at inlet – mean pressure at outlet)}}{\textbf{reference pressure}}$$

The reference pressure is related to the reference mean wind speed by the following equation;

$$\textbf{Reference pressure, } \mathbf{P_R} = \tfrac{1}{2}\, r\, \mathbf{V^2} = \mathbf{0.6 \times V^2}$$

Where the air density, ρ, is assumed to be equal to 1.20 kg/m^3 and the value of the velocity, V, is the directional reference wind speed.

The airflow (m^3/s) through the smallest opening with a unit is computed as:

$$q = A_S * k_i * k_o * \sqrt{\frac{P_R * \Delta C_{p_{mean}}}{\frac{1}{2} r}}$$

Where A_S is the area (m^2) of the smallest opening and k_i and k_o are pressure loss coefficients for the inlet and outlet respectively. The pressure loss coefficients are taken as 0.6, which is typical.

4.0 CRITERIA FOR ACCEPTANCE

There is no definitive criterion in the BCA regarding the minimum flow required. Hence this exercise sets out to benchmark the performance of the corner-units and the double-ended units within this development as a minimum standard.

***Air-Flow Rates*:** Our interpretation of AS 1668-2:2002 is that a flow rate of 0.03 to 0.04m^3/s through a residential unit is generally suitable for natural ventilation. This is based on the guidelines presented in Clause 4.8 (General use enclosures, e.g, offices, residences, shops, stores, corridors, bars,..)

***Room Air Velocity*:** S.Selkowitz (2004) suggest that the assessment of the adequacy of natural ventilation should be based on air-speed within the unit rather than simply the amount of air-changes per hour. This is because the human body reacts more to the air-flow rather than just the quality of the air. It is considered by Selkowitz that a minimum average daily air speed in a room is of the order of 1m/s would provide an acceptable level of natural ventilation.

***Residential Flat Design Code (NSW)*:** Part 3 of this Code deals with Building Design. It states that corner-units, double-ended units and 2 storey units (where the upper floor is the top floor of the development, and is setback from the lower floor) can achieve good natural ventilation. The latter configuration is often misunderstood, as it is imperative that the second storey have the setback, and that it is at the top floor of the development, otherwise the difference in pressures between the 2 floors will be negligible, as was demonstrated in this case.

Wind tunnel tests undertaken by Windtech indicate that the flow rates in the double ended units and corner units for this development generally exceed the criteria calculated from AS1668:2-2002. However, 2 storey units, which do not fit the parameters of the Residential Flat Design Code, exhibit poor levels of natural ventilation, which reinforces the conditions for 2 level unit set out in the Residential Flat Design Code.

5.0 NATURAL VENTILATION DRIVING MECHANISMS

Natural ventilation is the intentional flow of outdoor air because of wind and thermal pressures through controllable openings. It can effectively control both temperature and contaminants, particularly in mild climates. Temperature control by natural ventilation is often the only means of providing cooling when mechanical air-conditioning is not available. The arrangement, location, and control of ventilation openings should combine the driving forces of wind and temperature to achieve desired ventilation rate and good distribution of fresh air through the building.

Natural ventilation is driven by pressure differences across the openings caused by ambient pressure and temperature differences between different openings within a unit. Alternatively, the differences can be between the internal pressure in a unit and the roof pressure in the case of a room having an auxiliary ventilation system using roof vents. For a mid-wall unit the internal pressure is dominated by the pressure at the dominant opening to the unit from balcony etc.

Our experience is that thermally driven components in natural ventilation are negligible when compared with the pressure driven components (See Rofail and Fernando, 1990)

6.0 RESULTS AND DISCUSSION

For each of the unit types tested (roof-vented, corner, double-ended, 2 storey), the flow rates through the units have been calculated. These flow rates have been calculated based on the daily average wind speed and a wind speed based on an 85% probability of being exceeded. These are presented in Figures 2 and 3 respectively. The daily average room velocity has also been calculated and is presented in Figure 4. Note that the number inside each bar represents the number of units tested in this configuration.

Results from the tests indicated that the units that use the auxiliary roof ventilation systems exceed the flow rate criterion stipulated in AS1668-2:2002, when based on the daily average wind speed.

The flow rates for these roof vented units, when calculated using a wind speed based on an 85% probability of being exceeded, generally satisfy the criteria. This was achieved by using vent areas in the auxiliary system as small as 1m x 0.5m compared with the window openings of 1m x 1m in the corner units. Increased flow rates can be achieved by increasing the size of the vent areas within the auxiliary system.

With respect to the daily average room air velocity criterion suggested by Selkowitz (2004), no unit within this development achieved a room air velocity of greater than 1m/s. In terms of the daily average room air velocity, our results do not show any significant difference between the various types of units investigated, with the exception of the 2 storey units.

Hence, it is considered that the best indicator for adequate natural ventilation within a unit is the criterion set out in AS1668-2:2002, which is dependant on the flow rate throughout the unit, rather than daily average room air velocity.

Figure 1: Photographs of the model in the wind tunnel

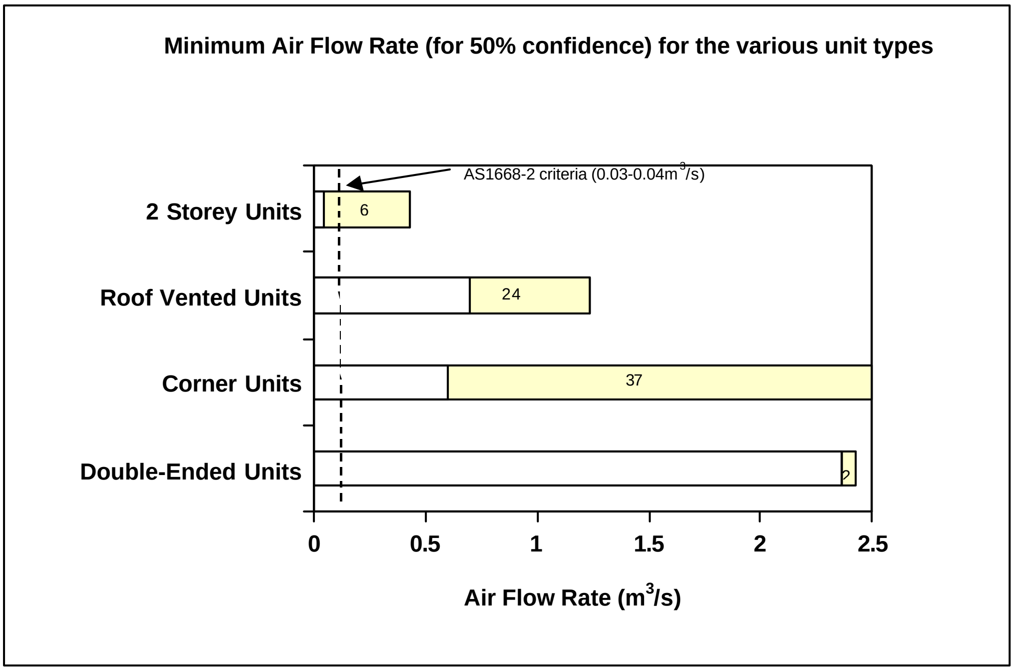

Figure 2: Minimum Air Flow Rate, based on 50% confidence, for the various unit types

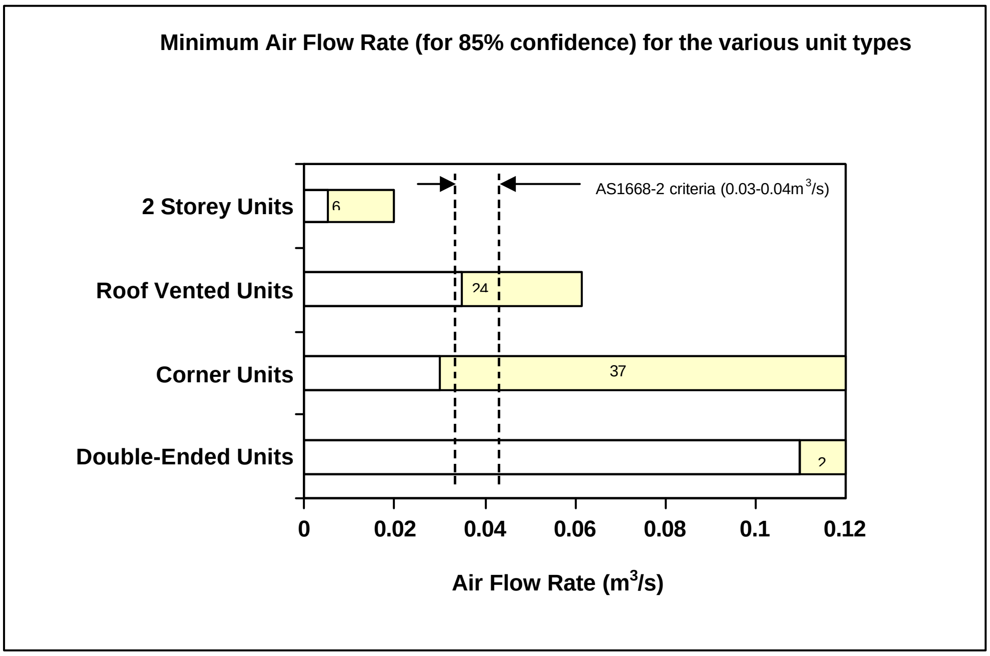

Figure 3: Minimum Air Flow Rate, based on 85% confidence, for the various unit types

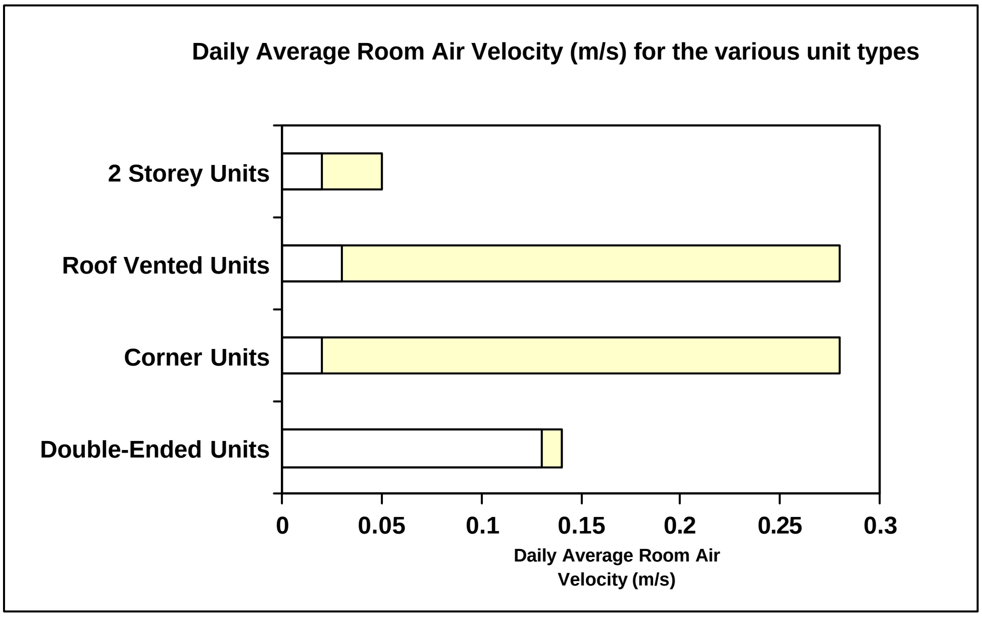

Figure 4: Daily Average Room Air Velocity

REFERENCES

Residential Flat Design Code (NSW), Part 3: Building Design

Selkowitz, S., 2004 (Head of Building Technologies, Lawrence Berkeley National Laboratories, California, USA) – private communication.

Standards Association of Australia, AS1688-2:2002, "The use of Ventilation and Air-conditioning in Buildings."

Rofail, A.W and Fernando, S, 2000, "Case Study: Assessment and Optimisation of Natural Ventilation for The University of NSW Main Service Tunnel"

Rofail, 1995, "Full-scale/ Model-scale comparisons of Wind Pressures on the TTU Building", Proceedings of the 9th International Conference on Wind Engineering, India, January 1995.