Internal pressures in a high-rise building with window openings

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Abstract: A parametric wind tunnel study has been carried out in the boundary layer wind tunnel at Monash University to measure internal pressures in a high-rise building with cladding of various porosity resulting from window openings. This paper has shown that the mean internal pressure decreases with increase in façade porosity but increases as the level goes up in height of the building. With high porosity on only one face of the building, the internal pressure ranges from –0.65 to 0.53 at the lower levels and from –0.74 to 0.86 at the higher levels of the building.

1. INTRODUCTION

Wind induced internal pressures have been studied both experimentally and theoretically for quite some time. Holmes [1] was the first to predict the variation of internal pressure by applying Helmholtz resonator theory and verified with boundary layer wind tunnel measurements. Liu and Rhee [2] further refined the mathematical modelling with a more rigorous derivation of the internal pressure variation and supported with more experimental results. The dynamics of internal pressure propagated across the building envelope were later examined in detail by Harris [3] and Vickery [4]. More recently, Woods and Blackmore [5] investigated the effects of porosity and dominant openings on both steady and unsteady internal pressures. Although many of the results are believed to be applicable to all types of buildings, all these previous studies are referred to low-rise buildings only. A limited amount of data for wind induced internal pressures in a high-rise building was reported by Kato, Niihori, Kurita and Ohkuma [6]. They inferred, from some full-scale measurements, that the mean wind pressure coefficient obtained from wind tunnel testing would be sufficient for examining average internal pressures.

While most previous studies for wind induced internal pressures have been focused on low-rise buildings there is a shortage of experimental data to enable determination of internal pressures for high-rise buildings. Design data for tall buildings with or without dominant window openings have often been referred to the code values that were mainly derived for low-rise buildings. This paper describes an experimental study carried out in the 450kW boundary layer wind tunnel at Monash University to measure the effects of façade porosity as from window openings on the internal pressures at various levels of a high-rise building. Experiments were carried out to measure mean, standard deviation and minimum and maximum internal pressures in a single floor cell at various heights of the building. Preliminary results are highlighted for the measurements for the lower levels and the higher levels with different porosity in various faces of the building.

2. DESCRIPTION OF THE MODEL

The model of a tall building was made of Perspex, 140mm by 140mm wide and 700mm high (56m by 56m by 280m high tower full scale for a 1/400 scale model), with a single floor cell which could be installed at various heights of the tower. The floor cell was fully sealed with silicon gel with an internal volume of 130mm by 130mm by 9mm. The sides of the floor cell were drilled with small holes varying from 0.73mm to 4.8mm in diameter so that porosity ranging from 0.001 to 0.1 could be achieved. A pressure tapping was installed flush to the lower surface in the middle of the floor cell and connected to a pressure transducer with a restrictor to measure the internal pressure without resonance effects from the tubing. The response of the model pressure measuring system was flat, within +10%, up to a frequency of 100Hz. Great care was taken to ensure airtight of the floor cell apart from the prescribed porosity holes for every change in measurement configuration.

3. EXPERIMENTAL SET-UP

Wind tunnel tests were carried out in the 2m by 4m wind tunnel working section, using standard simulation techniques for flow over suburban terrain at a length scale of 1:400. The reference wind speed for the tests was approximately 13m/s at a height of the top of the tower. Mean, standard deviation, minimum and maximum internal pressures were measured with reference to the static pressure over a sampling period of 40 seconds for a porosity of 0.001, 0.01 and 0.1 at ground level up to roof level at four equal intervals in height. The measurements were made for wind direction azimuths from 0° (north, being normal to the building face) in 10° to 15° intervals. For each level of porosity, there were four configurations, being all four sides porous, north-east-west porous, north-west sides porous and north side porous. The internal pressures were normalized in pressure coefficient form with respect to the dynamic pressure at the top of the building.

4. TEST RESULTS

The mean, standard deviation, minimum and maximum internal pressure coefficients measured for a porosity of 0.1 on all façade sides at ground level are presented in Figure 1. This represents a relatively high porosity and gives the lowest internal pressure measured for buildings with uniform porosity. The mean internal pressure coefficient varies from –0.36 at 0° to a maximum of –0.2 at 45°. The full-scale measurement by Kato etc. [6] with a value of –0.26 at 23° agrees quite well within the range of the present measurements.

Figure 2 shows the variation of mean internal pressure coefficient at ground level with wind direction for configurations of 1, 2, 3 and 4 faces of the building being porous. The variation increases as the number of porous face decreases. As compared to the internal pressures given in AS1170, this compares well for the configuration of dominant openings on one wall only. For the configuration of openings of equal areas on all walls, the present results show a variation from –0.2 to –0.36 as compared to 0 to –0.3 given in the code. There is no provision for cases with dominant openings on two or three walls in AS1170.

Although a discrepancy is shown for the configuration with dominant openings as indicated above, there is a close agreement of values for the configuration with low porosity. The data for a porosity of 0.001 are shown in Figure 3 in the range of 0 to –0.2 which agree with those given in the code for an effectively sealed building having non-opening windows. Similarly the data measured for the case of one wall permeable are seen to be within the range provided in the code.

Whilst there is some general agreement of the results measured at low levels close to the ground with the values given in AS1170, an apparent difference is seen for data measured at higher level of the tall building. As shown in Figure 4, for dominant openings on one wall, the internal pressure ranges from –0.74 to 0.86 as compared to the range of –0.65 to 0.8 obtained from the code. Also, for a tall building effectively sealed with non-opening windows, an internal pressure range of –0.14 to 0.08 was measured at three-quarter height of the building.

5. CONCLUSIONS

Mean, standard deviation, minimum and maximum internal pressure coefficients have been measured at different height of a high-rise building with various sidewall openings of different porosity. The results measured at the lower level near ground have shown a close agreement with the values given in the wind code AS1170 and some full-scale data. At the upper levels of the tall building, values of internal pressure higher than those provided in the code have been measured.

6. REFERENCES

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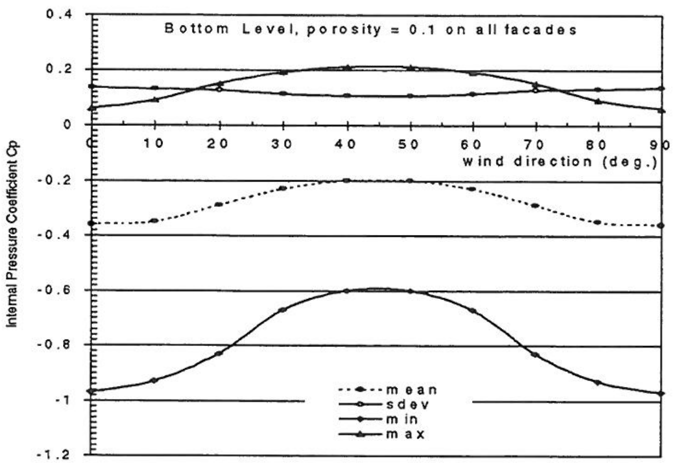

FIGURE 1

o Scale effects
o Size of opening

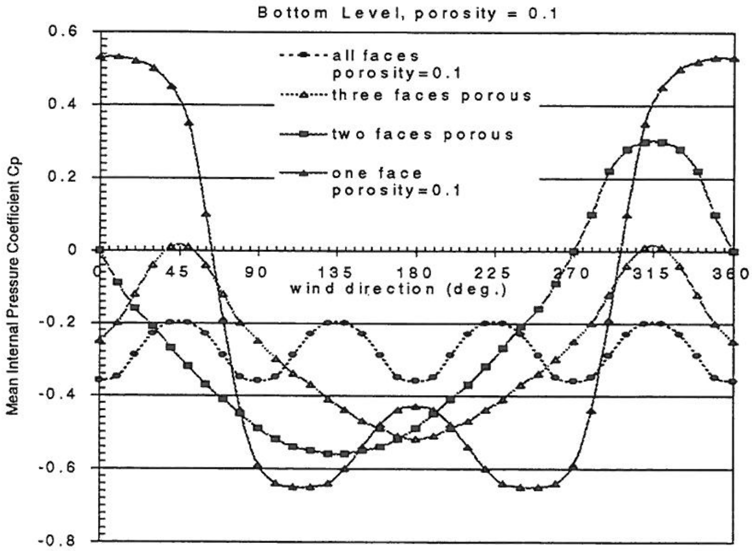

FIGURE 2

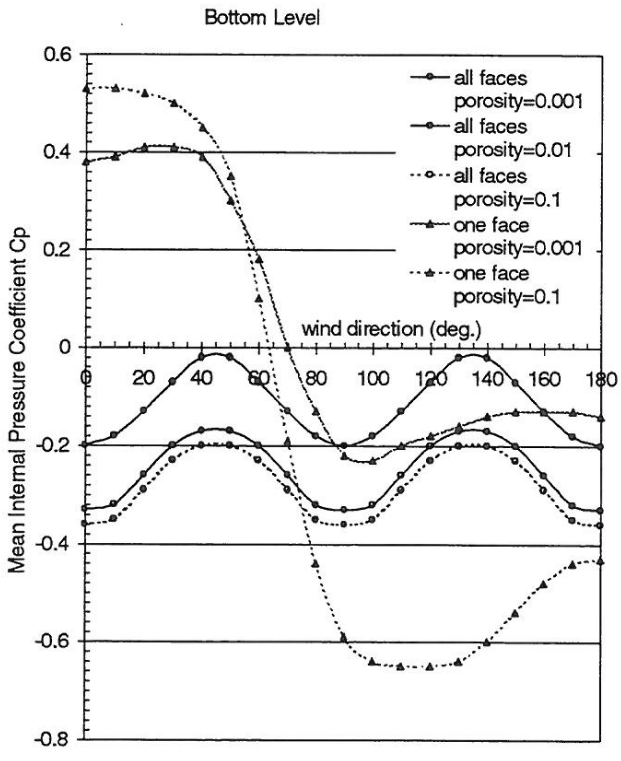

FIGURE 3

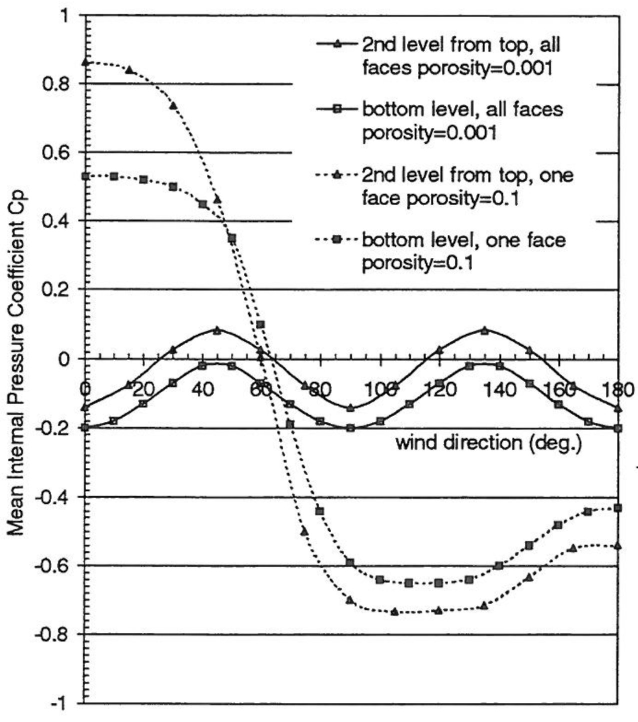

FIGURE 4