A Wind Tunnel Modelling Methodology for the determination of the Internal and Net Design Pressures for Tall Buildings having operable facades.

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1 Introduction

It is commonplace today for tall buildings, especially residential buildings, to have operable facades. With operable facades in place, the issue of what constitutes a design internal pressure for net façade loading, the recent incidences of failure of inter-tenancy walls and increased floor slab loads are highly relevant. It is also recognised that for such buildings an adoption of an estimate of the design loads from the Wind Loading Code would be too simplistic.

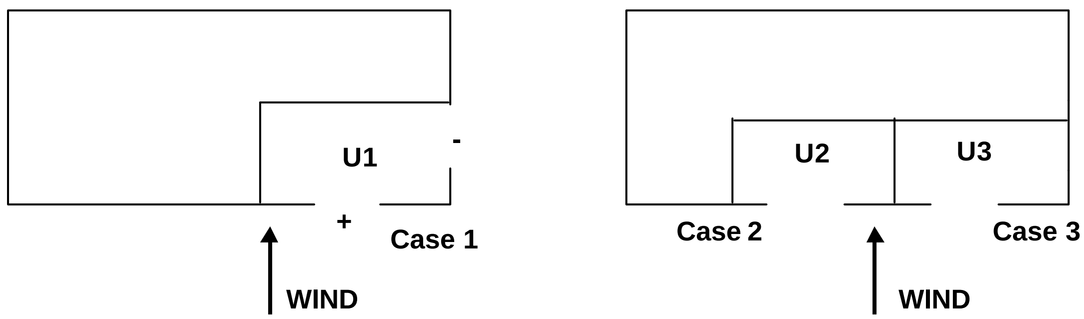
Windtech Consultants have developed a new methodology for the measurement of the internal and net design pressures. By measuring the internal pressures and applying a risk analysis approach the internal and net pressures can be predicted with greater accuracy.

2 Methodology

2.1 Net Façade and Slab Loads

The method proposed for the determination of the internal and net design pressures is simpler than that proposed by Irwin and Sifton (1998) in that the rate of change of wind direction over time and also a combined probability approach is not required.

With regards to the internal and net pressure effects within a tall building with an operable façade there are 3 possible unit configurations, as shown below.



Sensors are placed at specific locations within each unit that represent the location of operable portions of the façade, i.e. windows or doors. Pressure sensors are also positioned to measure the external pressures on the façade.

Firstly, let us define the maximum magnitude in peak design pressure between the effectively sealed case and the open façade case as the “worst case”.

Next, it is assumed that an external opening for an apartment will be open (worst case) for 50% of the time and will be closed (internal pressure is based on the effectively sealed case) for 50% of the time.

Hence we adopt the average between the effectively sealed case and the worst case as the value representing a 50% probability of a façade being open. This is consistent with the permissible stress design approach.

2.1.1 Net Façade Pressures and Slab Loads for Type 1 Units.

Net Façade Pressures:

The net facade pressures for these units are the average of the worst case net pressure and the net facade pressure based on an effectively sealed case.

The net façade pressure based on an effectively sealed building is the difference of the external pressure based on an effectively sealed case and the internal pressure based on an effectively sealed case.

The worst case net pressure is the maximum of either the net facade pressure based on an effectively sealed case or the maximum differential pressure between any two taps within this unit.

Slab Loads:

The internal pressures for these units are the average of the worst case internal pressure and the internal pressure based on an effectively sealed case.
The internal pressure coefficient based on an effectively sealed building is either 0.0 for positive external pressures, or –0.2 for negative external pressures.

The worst case internal pressure is the maximum of either the internal pressure based on an effectively sealed case or the maximum differential pressure between any two taps within this unit.

2.1.2 Net Façade Pressures for Type 2 Units.

Net Facade Pressures:

The net façade pressure for these units is the average of the worst case net pressures and the net facade pressure based on an effectively sealed case.

The worst case net pressure is the net facade pressure based on an effectively sealed case. Hence the net pressure for these units is the net facade pressure based on an effectively sealed case.

Slab Loads:

The internal pressure for these units is the average of the internal pressure based on an effectively sealed case and the worst case internal pressure.

The worst case internal pressure is the maximum of either the external facade pressure based on an effectively sealed case or the internal pressure based on an effectively sealed case.

2.1.3 Net Façade Pressures and Slab Loads for Type 3 Units.

Net Façade Pressures:

The net façade pressure for these units is the average of the worst case net pressure and the net facade pressure based on an effectively sealed case.

The worst case net pressure, or open window pressure, is different for the side-wall or main wall pressure taps. For the side-wall pressures the worst case net pressure is the differential pressure measured between two taps. The main wall worst case net pressure is the net facade pressure based on an effectively sealed case.

Slab Loads:

The internal pressures for these units are calculated in the same manner as the Unit 1 internal pressures.

2.2 Inter Tenancy Partitions

The methodology for the determination of the pressures on the inter-tenancy partitions is similar to the methodology described above for the determination of the pressures on the internal partitions or slabs. However, the pressure differential used to compute the internal pressure is taken from different combinations of façade openings from the two adjoining units. This is shown in Figure 2.

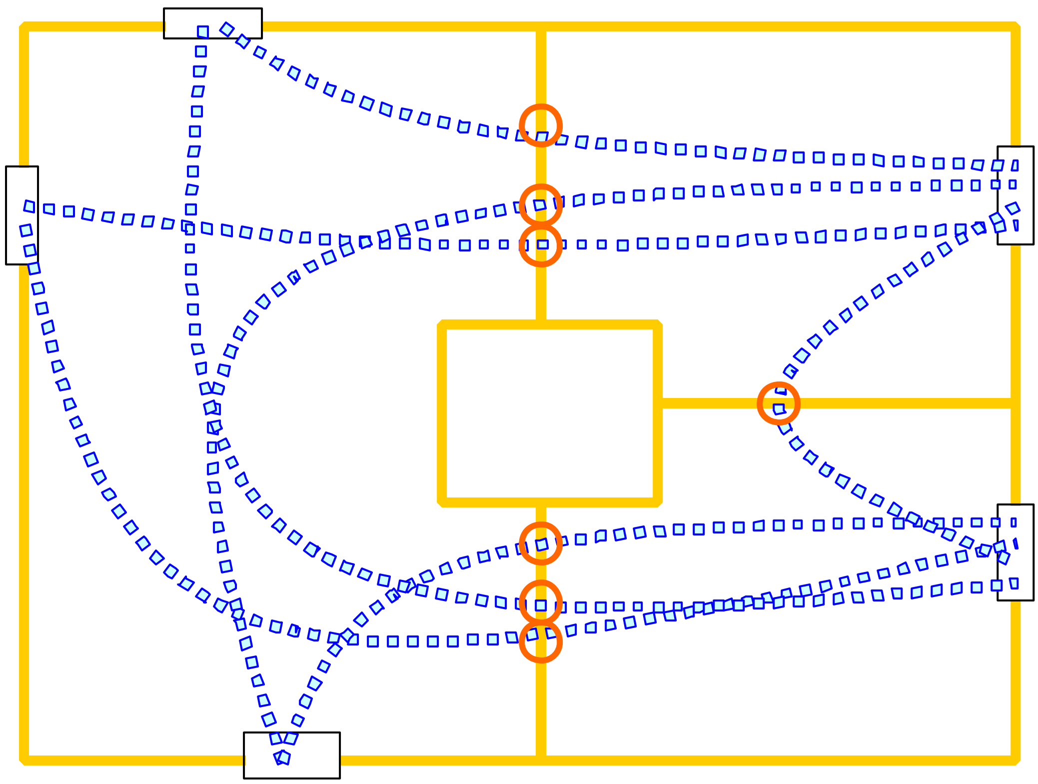


Figure 2: Load Combinations for Cross Unit Pressure

Again we assume that the windows or façade openings will be open 50% of the time, and that the "worst case" is the maximum magnitude in peak design pressure of either the open façade case or the effectively sealed case.

Another assumption is that the internal pressure within an effectively sealed building will be uniform. Hence the maximum internal pressure coefficient, based on an effectively sealed building, will be 0.0, whilst the minimum internal pressure coefficient will be -0.2.

Based on these assumptions we have adopted the average between the worst case and the effectively sealed case as the value representing a 50% probability of a façade being open.

Hence the maximum and minimum internal pressures are:

$$\hat{C}_{pi} = \frac{\hat{C}_{pi,worstcase}}{2}$$

$$\breve{C}_{pi} = \frac{\breve{C}_{pi,worstcase} - 0.2}{2}$$

Results

The methodology presented above for the loading of inter-unit partitions and slab loads has been used by Windtech Consultants for the determination of the internal and net design pressures on several tall residential buildings. No comparison has been made for the inter-tenancy loads as the relevant wind loading standards do not address this issue of wind loading.

The experimental results presented in Tables 1 and 2 were recorded for two separate tall building models tested by Windtech Consultants. The results presented are based on the pressures for the unit with the largest recorded pressure for a particular height above ground. Table 1 presents the internal pressure results, whilst Table 2 presents the net pressure results. For these tests only unit types 1 and 2 were applicable. The internal and net pressure coefficients at several heights above ground were calculated for these buildings and have been compared to those calculated by the wind loading code.

Table 1: Comparison of Experimental Results and Code Estimates for Internal Pressure Coefficients

Height (m)	Unit Type 1 Experimental	Unit Type 1 Code	Unit Type 2 Experimental	Unit Type 2 Code
70 (Building 1)	±0.37	±1.45	+0.29, -0.20	+0.8, -0.65
120 (Building 1)	±0.37	±1.45	+0.37, -0.20	+0.8, -0.65
150 (Building 2)	±1.09	±1.45	+0.52, -0.20	+0.8, -0.65
200 (Building 2)	±1.22	±1.45	+0.46, -0.20	+0.8, -0.65
250 (Building 2)	±0.92	±1.45	+0.87, -0.20	+0.8, -0.65

Table 2: Comparison of Experimental Results and Code Estimates for Net Pressure Coefficients

Height (m)	**Unit Type 1 Experimental**	**Unit Type 1 Code ***	**Unit Type 2 Experimental**	**Unit Type 2 Code ***
70 (Building 1)	±0.84	+1.65, -2.75	+0.57, -0.64	+1.2, -0.98
120 (Building 1)	±0.97	+1.65, -2.75	+0.95, -0.64	+1.2, -0.98
150 (Building 2)	±1.36	+1.65, -2.75	+0.92, -1.01	+1.2, -0.98
200 (Building 2)	±1.06	+1.65, -2.75	+0.92, -1.01	+1.2, -0.98
250 (Building 2)	±0.92	+1.65, -2.75	+0.92, -1.01	+1.2, -0.98

* These code estimates include a local area factor of 1.25 for the maximum external pressures.

From Tables 1 and 2 it can be seen that the wind loading code generally overestimates the internal pressures coefficients for both the Type 1 and Type 2 units, particularly in tall buildings less than 150m in height. The code also tended to overestimate the net façade pressure coefficients for the Type 1 and Type 2 Units for the lower heights (buildings less than 150m in height) but showed reasonably good agreement for the taller buildings.

Conclusions

The methodology used by Windtech Consultants to determine the internal and net pressures of units within tall buildings that feature operable facades has been used to determine the internal and net pressure coefficients for two tall building models. The results indicate that the Australian Wind Loading Code (AS1170.2:2002) generally overestimates the internal pressure coefficients and the net façade pressure coefficients for both types of units having with operable facades but show reasonably good agreement in the other cases.

References

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