A Methodology for the determination of the Internal and Net Design Pressures for Tall Buildings with operable facades.

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Introduction

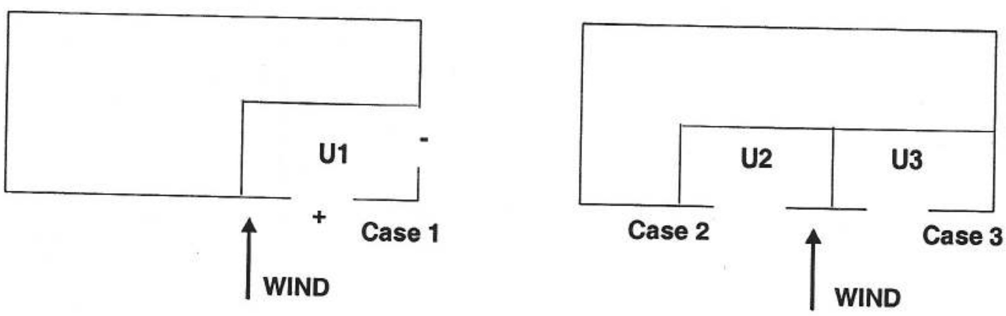
It is commonplace today for tall buildings, especially residential buildings, to have operable facades. With operable facades in place, the issues of internal partition failure and increased floor slab loads are highly relevant. It is also recognised that for such buildings an adoption of an estimate 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.

Methodology

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.



At specific locations within each unit that represent the location of operable portions of the façade, i.e. windows or doors, pressure sensors are placed, in addition to pressure sensors that are in place measuring the external pressure.

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 (external facade pressure 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.

Internal and Net Pressures for Type 1 Units.

Internal Pressures:

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.

Net 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.

Internal and Net Pressures for Type 2 Units.

Internal Pressures:

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.

Net 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.

Internal and Net Pressures for Type 3 Units.

Internal Pressures:

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

Net 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.

Internal Pressures:

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

Results

The methodology presented above has been used by Windtech Consultants for the determination of the internal and net design pressures on several tall residential buildings.

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	+0.8, -0.65	+0.29, -0.20	+0.8, -0.65
120 (Building 1)	±0.37	+0.8, -0.65	+0.37, -0.20	+0.8, -0.65
150 (Building 2)	±1.09	+0.8, -0.65	+0.52, -0.20	+0.8, -0.65
200 (Building 2)	±1.22	+0.8, -0.65	+0.46, -0.20	+0.8, -0.65
250 (Building 2)	±0.92	+0.8, -0.65	+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 underestimates the internal pressures coefficients for Type 1 units in very tall buildings whilst overestimating the internal pressure coefficients for the Type 2 units and for Type 1 Units in an average tall building.

With regards to the net pressure coefficients, the wind loading code generally overestimates the net pressure coefficients for both unit types.

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 for mid wall units (Type 2) with operable facades and the net pressure coefficients for unit types that feature mid wall openings (Type 2) and openings on both the windward wall and side wall (Type 1). The results also indicate the predicted values of the internal pressure coefficient of Type 1 units presented in the Australian Wind Loading Code are below experimental values determined for very tall buildings, as measured by Windtech Consultants.

References

Standards Australia, SAA Loading Code, Part 2, Wind Loads. Australian Standard AS1170.2-2002.

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