ALTERNATIVE PRESSURE COEFFICIENTS FOR LOW-RISE BUILDINGS

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INTRODUCTION

In the recent No. 1 and No. 2 Amendments to the Australian Standard for Wind Loads, AS 1170.2 (SAA, 1989(a)), alternative values of external pressure coefficients for the roofs of low-rise buildings have been specified. These give an alternative roof pressure distribution intended to check the structure when the wind loads act in combination with gravity loads (dead, live or snow) on the roof. This paper discusses the possible situations for which these alternative coefficients might be required, and makes comparisons of the load effects for a building with a pinned base portal frame, derived from the code loads, with detailed studies of the load effects based on wind tunnel measurements.

THE SPECIFIED COEFFICIENTS

The values of external pressure coefficients specified for the roofs of buildings with a pitch less than ten degrees in Table 3.4.3.2(A) of AS 1170.2, are listed in the following Table I.

Table I

Distance from leading edge	C_{pe} (normal)	C_{pe} (alterative)
0 to h	–0.9	–0.4
h to 2h	–0.5	0
2h to 3h	–0.3	+0.2
> 3h	–0.2	+0.3

These coefficients, when used with a design peak gust wind speed, will give external pressures on the roof which approximate the range of pressure fluctuations expected on the roof during an extreme wind storm. However, the need for the alternative coefficients, which are generally of a lower magnitude, may not be immediately obvious.

LOADING SITUATIONS

To understand the need for these coefficients it is necessary to consider the following possible loading situations. Here we have denoted the wind loading derived from the larger magnitude 'normal' external roof pressure coefficients by W_{max}, and that derived from the lower (alternative) coefficients by W_{min}.

1. Gravity load acts alone (i.e. no wind - no wind pressures).

2. Extreme wind load acts in combination with gravity load, and the wind load effects act in the opposite direction to, and exceed the gravity load effects by a factor of 2 or more. This is usually the dominant wind load case for lightweight low-pitched roofs in Australia, with negative external pressures, and positive or zero internal pressures. In this case, the W_{max} wind loads must be used. When the gravity load is the dead load, G, a dead load factor of 0.8 should be applied according to AS 1170.1 (SAA, 1989(b)).

3. Extreme wind load acts in combination with a gravity load, and the wind load effects act in the opposite direction to, and exceed the gravity load effects by a factor of less than 2. In this situation, case 1 and case 2 will produce greater load effects.

4. Extreme winds act in combination with a gravity load, and the wind load effects act in the *same* direction as the gravity load effects. This is the main case for which the alternative wind loads W_{min} have been specified in AS 1170.2. In this case, the dead load factor of 1.25 in the load combinations in AS 1170.1 (SAA, 1989(b)) should be used.

In a recent detailed design study of steel low-rise building frames, carried out in collaboration with BHP Steel (Holmes, Syme and Kasperski, 1993), several examples of load effects were computed, for which Case 4 above produced the governing value, i.e. the largest magnitude of bending moment or reaction. These are tabulated in Table II. These examples were all for a building of low aspect ratio (h/d = 0.20), (shown in Figure 1), for which the alternative external coefficients were positive over a large part of the roof. The structural system was assumed to be a pinned base frame; the load effects considered are shown in Figure 2.

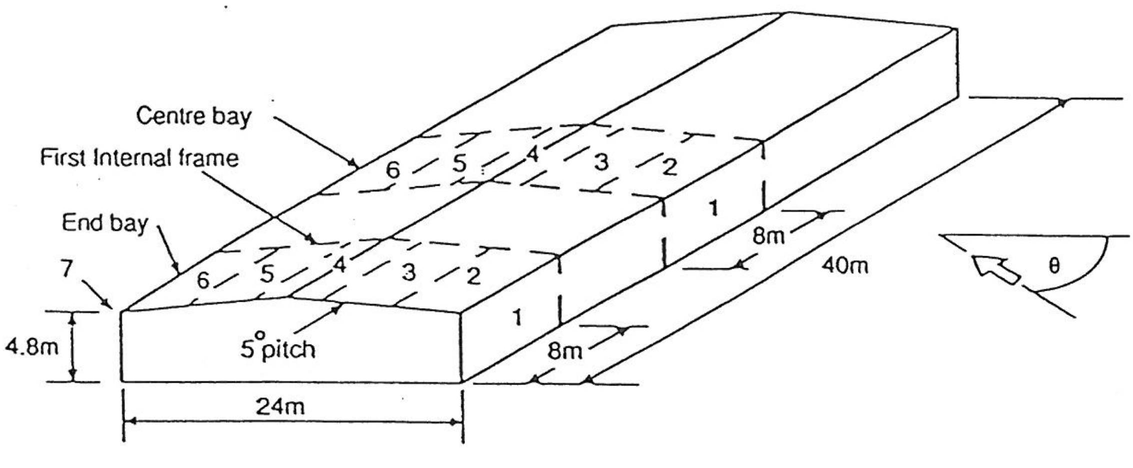

Figure 1. Building configuration.

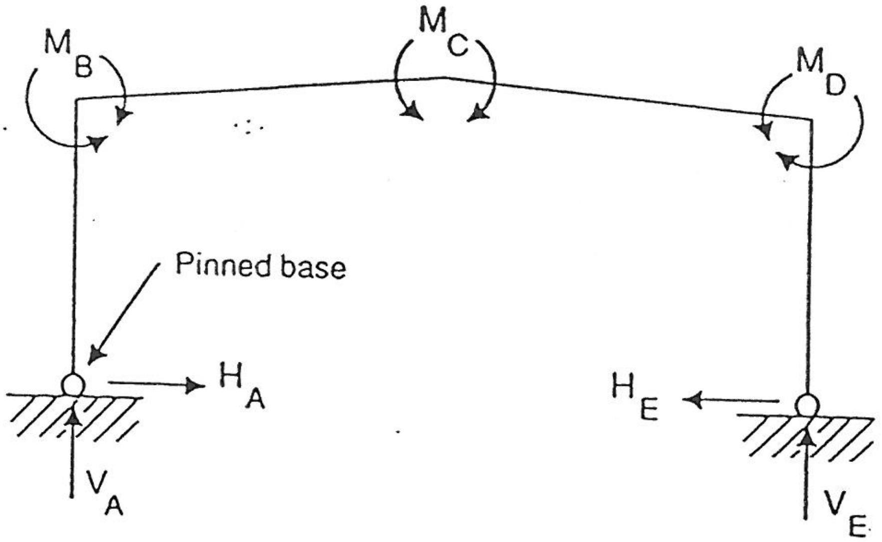

Figure 2. Structural load effects.

Table II.
Examples of extreme load effects for an industrial building for which the alternative external coefficients governed

Load effect	Value (kN or kN.m) from AS 1170 2	Values derived from CSIRO wind-tunnel	Bay	Wind direction	Internal pressure coefficient AS 1170.2
Corner b.m.	–172.9	–91.6 –114.0	centre end	0 degrees	0.0
Ridge b.m.	169.9	37.9 48.9	centre end	0 degrees	–0.5
Vertical reaction	51.0	38.4	centre	90 degrees	0.0
Ridge b.m.	100.4	73.3	centre	90 degrees	0.0

The sign convention for bending moments is that positive is compression in the outside of the frame. Thus in Table II, downwards roof loads produce positive moments at the centre or ridge of the roof, and negative moments at the corner of the frame. A positive vertical reaction acts upwards on the column.
The building considered for Table II was regarded as a fairly typical industrial building in Australia, with a lightweight roof (i.e. low dead load); no live or snow loads were considered. For buildings in countries with colder climates, with higher dead loads due to the weight of insulation, and with the possibility of snow loads in combination with wind, it is clearly even more important to consider the possibility of net downwards wind pressures on the roof. Kasperski (1993) discussed this problem from the European perspective, and has proposed alternative coefficients for the draft Eurocode (EEC, 1993).

COMPARISON WITH LOADING DERIVED FROM WIND-TUNNEL TESTS

A detailed and accurate study of the load effects for the industrial building shown in Figure 1 was also carried out using detailed information from a boundary-layer wind tunnel, including the correlation coefficients of the external fluctuating pressures over the tributary area of the frame (e.g. Holmes and Sankaran, 1993), and applying the methods of Kasperski (1992) and Holmes (1992) to determine effective peak load pressure distributions for the various load effects. The resulting design load effects, including the effect of dead load, are compared with the values from AS 1170.2 in Table II. It can be seen that the wind-tunnel values are 25–71% below the code values. This is mainly because the code is conservative by not allowing for the lack of correlation of the fluctuating pressures, although an area reduction factor of 0.8 was applied to the code roof external pressures. The code also assumes that the internal pressure is fully correlated with all the external pressures.

It is interesting also to compare the effective roof pressure coefficients which produce the load effects in Table II. This is done in Table III for the 0 degree wind direction and in Table IV for the 90 degree direction.

Table III
Comparison of pressure coefficients for peak corner bending moment 0 degree wind direction

Roof panel	$C_{pe}.K_a$ AS 1170.2 centre and end bays	Pressure coefficient from wind tunnel centre bay	Pressure coefficient from wind tunnel end bay
2	–0.32	–0.12	–0.01
3	0.0	+0.03	+0.08
4	+0.16	+0.01	+0.05
5	+0.24	+0.03	+0.07
6	+0.24	+0.06	+0.08

Table IV
Comparison of pressure coefficients for centre bay 90 degree wind direction

Roof panel	$C_{pe}.K_a$ AS 1170.2	Pressure coefficient from wind tunnel vertical reaction	Pressure coefficient from wind tunnel ridge bending moment
2	+0.24	+0.12	+0.11
3	+0.24	+0.12	+0.12
4	+0.24	+0.13	+0.14
5	+0.24	+0.12	+0.12
6	+0.24	+0.11	+0.11

In Tables III and IV, the wind tunnel pressure coefficients have been corrected to be compatible with the 2–3 second peak gust wind reference velocity used in AS 1170.2. The positive values obtained from the wind tunnel are instantaneous values associated with flow reattachment on the downwind roof. They are not necessarily the largest positive values that can occur on each panel, but they are the values which act simultaneously to produce the largest bending moment or reaction, and take into account the correlation between the fluctuating pressures on different parts of the roof.

Clearly, the differences between the wind tunnel and code pressure coefficients, when the wind loads from them are combined with the dead load and the wall pressures, are sufficient to produce significant differences in the design load effects.

CONCLUSIONS

The need for alternative roof pressure coefficients in AS 1170.2 for roofs has been justified to allow for the situations when the instantaneous wind load acts downwards and combines with gravity loads to produce critical load effects. The values currently specified in AS 1170.2 for low-pitched roofs are conservative, on the basis of comparison with detailed wind-tunnel studies.

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