CODIFICATION OF WIND LOADS ON HIGHWAY NOISE BARRIERS

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Introduction

In 1999 extensive wind tunnel-testing was carried out at Monash University for wind loads on noise barriers for the Roads & Traffic Authority NSW, Australia. This work is summarized in [1].

The results have been re-examined in detail with a view to codifying them for use by designers. Wherever possible the Australian/New Zealand Standard for Wind Actions, AS/NZS1170.2:2002, has been used as a basis for the codification, but some modifications were required to better match the wind-tunnel data. This paper describes the final codification for design, and the statistical indicator used for comparison of the computed loads with the measured values. This method of comparison may have general application for codifying of wind-tunnel data for a large number of geometrical situations.

Wind-tunnel test data

The basic test configurations used in the 1999 tests at Monash University are summarized in Figure 1. Mean fluctuating and peak pressure coefficients were measured on both windward and leeward walls of parallel pairs. Pressures were averaged over wall lengths of 1*h*, 2*h* and 4*h* (refer Figure 1 for notation). The sample time in the tests was equivalent to 15 minutes in full scale, and values were averaged over three samples. Two-dimensional walls spanning the wind tunnel were used, and a wind direction normal to the axes of the walls only was studied in the tests, as this is clearly the worst loaded wind direction when there is no free end. The geometric ratios w/h, h/H and s/h were varied for Cases (b), (c) and (d) in Figure 1.

Application of AS/NZS1170.2:2002

The Australian/New Zealand Standard for Wind Actions, AS/NZS 1170.2:2002 [2] contains net pressure coefficients $C_{p,n}$ for freestanding walls and hoardings in Section D2. These basic coefficients can be applied to unshielded noise walls. In the application here it was assumed that noise barriers were walls on ground ($c/h = 1.0$ in Figure D1 of [2]), except for the barriers on bridges, which were treated as elevated hoardings.

For application to noise barriers, Equation (2.2) of the Standard was modified as follows :

$$V_{sit,\beta} = V_R \, M_{z,cat} \, M_s \, M_t \, M_b \qquad (1)$$

The peak pressure is then obtained from:

$$p_n = 0.5\rho_{air} \, C_{p,n} \, K_a \, V_{sit,\beta}^{\;2} \qquad (2)$$

$M_{z,cat}$ is obtained directly from the Standard [2]. Since noise barriers are normally erected in urban situations, the applicable Terrain Category will usually be T.C.3. The variable z for evaluating $M_{z,cat}$ is the height from top of barrier to local ground level. Hence $z = h$ in Cases (a), (b) and (c) of Figure 1, $z = h+H+s$ in Case (d); z = 7.2 m (nominal) in Cases (e) and (f) and z = 11 m(nominal) in Case (g).

The Shielding Multiplier M_s in Section 4.3 of the Standard is primarily intended for groups of buildings and may not be directly applicable to shielded noise walls. Thus M_s has been redefined as follows for the noise barriers:

$$M_s = 1 - 5(h/w)^2 \quad \text{but not less than } 0.75 \qquad (3)$$

where h is the wall height, and w is the spacing between parallel walls. Shielding was considered only for barriers which are fully shielded by stream lines parallel to the ground. Hence shielding was only taken into account for Cases (b) and (c) in Figure 1 and was ignored for Cases (e), (f) and (g). Shielding is also ignored ($M_s = 1$) for walls on slopes for which $w/H < 4$ as flow separation occurs. In many cases the downwind wall is in the recirculating flow behind the upwind wall, leading to negative pressure coefficients; however this situation is not critical for design as walls on both sides would generally be designed for the upwind pressure coefficients, which are always greater.

Similarly the Topographic Multiplier, M_t, given in Section 4.4 of the Standard is intended for small three-dimensional structures. There are clearly topographic effects involved in the wind loads experienced by the noise barriers in several of the situations shown in Figure 1; however the barriers themselves are comparable in size to the topographic features, and some modification to the multipliers obtained from the Standard was required. In the codification for noise barriers, the Topographic Multiplier, M_t, is obtained from the hill-shape multiplier, M_h, [2], as follows.

$$M_t = k\, M_h \qquad \text{for } \tan\psi < 0.67 \;\; (\psi < 33.7^\circ) \qquad (4a)$$

$$M_t = 0.8\, M_h \qquad \text{for } \tan\psi \geq 0.67 \qquad (4b)$$

where

$$k = 1 + 0.7\tan\psi - 1.5\,(\tan\psi)^2 \qquad (4c)$$

ψ = average slope angle over top half of the topographic feature ($\tfrac{1}{2}H/L_u$)

Thus k is an adjustment factor for the hill-shape multiplier within the local topographic zone. Outside this zone $k = 1$. Thus k increases from 1.0 for $\psi = 0$ to a maximum of 1.08 for $\psi = 13^\circ$ and reduces to its minimum permissible value of 0.80 for $\psi = 33.7^\circ$. However, at present Equation 4 has been tested for only the slopes shown in Figure 1 (33.7° for Case (b) and 11.3° for Cases (e), (f) and (g)).

Barriers on bridges are treated as hoardings, with $c = h+H$ for determining $C_{p,n}$. Where barriers are provided on both sides of the bridge the upwind direction will obviously be critical for each side and shielding can be ignored. For the case of a barrier on one side only, in the downwind direction, a special factor (M_b) in Equation (1) is introduced, given by

$$M_b = 1 - \frac{x}{15(s+H)} \qquad (5)$$

where x is the downwind distance from the leading edge of the bridge ($x = w$ in Figure 1(d)). Note that $M_s = 1$ in all cases for bridges.

In Equation (2), $C_{p,n}$ for walls on ground from the Standard (i.e. a value of 1.20) was used for all cases except the bridges. In the case of the walls on bridges, values of $C_{p,n}$ for elevated hoardings were applied – this resulted in values of 1.45 to 1.53 for the test cases considered.

A new Span Reduction Factor, K_a, which allows a reduction in peak pressure for support spans greater than one wall height, was also proposed. The factor took the following form.

$$K_a = 0.5 + 1.35\exp\left[-\left(a/h\right)^{0.15}\right] \qquad (6)$$

where a is the span between wall supports.

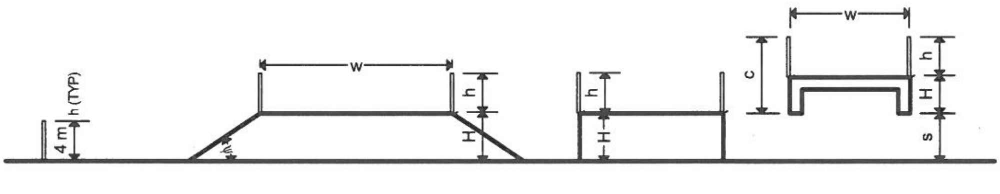
A factor of this form was previously derived from the 1999 wind tunnel test results, and proposed in [1]. The peak pressures tend to reduce with increasing span, a, because the fluctuating component of the peak wall force is less correlated over the larger area. Thus for $a/h = 2$, $K_a = 0.95$, and for $a/h = 4$, $K_a = 0.89$.

Comparison of calculated and experimental wind loads

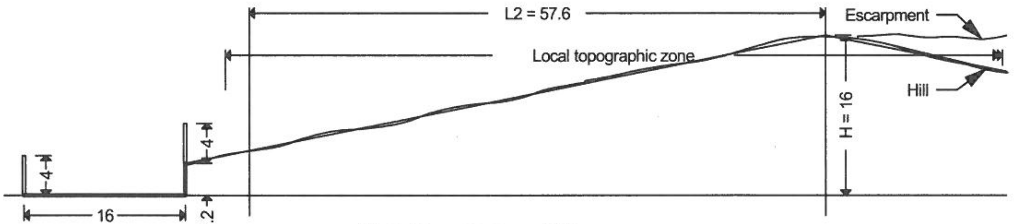
A parameter, ρ, was defined as a statistical indicator of agreement between the computed and measured values. The following definition was adopted:

$$\rho = \mu_r - \sigma_r \qquad (7)$$

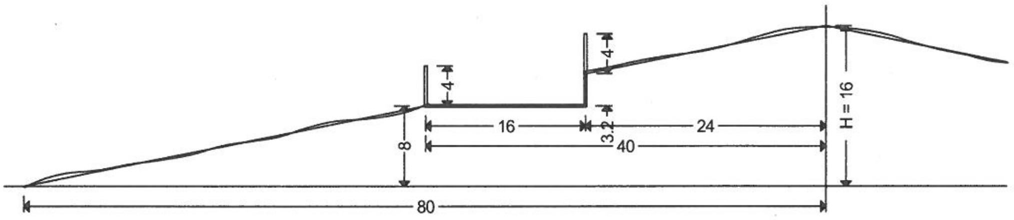
where $r = p_c/p_m$ is the ratio of computed pressure (p_c) to measured pressure (p_m), and μ_r and σ_r are respectively the mean and standard deviation of r averaged over a group of similar situations. Using one standard deviation in Equation (7) is somewhat arbitrary, but allows for a certain amount of variability within the configurations, without being overly conservative.



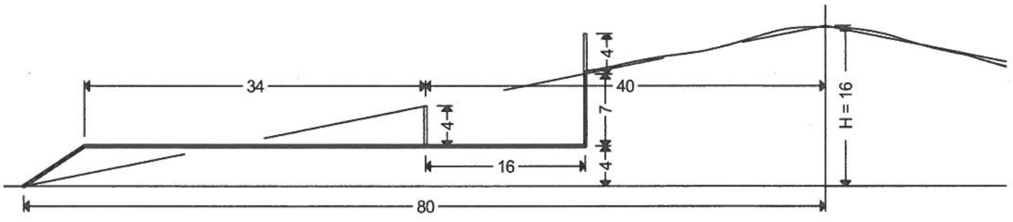
(a) On level ground (b) Embankment (c) Cliff (d) Bridge



(e) Cutting at bottom of hill



(f) Cutting half way up a hill



(g) Cut and fill near bottom of hill

NOTE: All dimensions are in metres

Figure 1 – Wind Tunnel Test Configurations (with nominal full-scale dimensions)

The final comparisons of computed pressures, using the above multipliers and factors, and the pressures measured in the wind-tunnel studies are summarized, for 138 different cases, in Table 1. Ideally a value of ρ of around 1.0, and a coefficient of variation (σ_r/μ_r) of 0.1 or less, is desirable. Although these targets could not be achieved in all cases, the values obtained in Table 1 are regarded as reasonable ones, considering that not all geometric situations were covered in the wind-tunnel tests. The values of ρ for the downwind (shielded) barriers on level ground are significantly less than one – however, this case is not of practical significance as the design will be dominated by winds from the opposite direction as an upwind barrier.

Table 1 - Comparison of computed and measured peak pressures

Situation	**Case in Figure 1**	**Number of cases tested**	**Mean(r)** μ_r	**Coefficient of variation** σ_r/μ_r	**Indicator** $\rho = \mu_r - \sigma_r$
Level ground - upwind	(a)	12	1.08	0.056	1.02
Level ground - downwind	(a)	6	1.11	0.153	0.94
Bridges	(d)	18	1.06	0.076	0.98
Bottom of ridge/escarpment	(e)	18	1.20	0.169	0.99
Cliff upwind	(c)	21	1.04	0.063	0.98
Embankment upwind	(b)	21	1.08	0.056	1.02
Cliff downwind	(c)	12	1.21	0.136	1.05
Embankment downwind	(b)	12	1.19	0.113	1.06
Halfway up ridge; cut-and-fill	(f), (g)	18	1.16	0.084	1.06

Conclusions

For the design of noise barriers for wind forces, it was found necessary to modify the Australian/New Zealand Standard [2] by modifying the Shielding and Topographic Multipliers to obtain reasonable agreement with the peak pressures measured in wind-tunnel tests. A 'Bridge Multiplier', and a 'Span Reduction Factor' were also introduced. With the modified and additional factors, good agreement between computed and measured peak pressures was achieved, as indicated by low coefficients of variation. Moreover the recommendations yield a moderately conservative design, indicated by $\rho \approx 1$.

References

1. Holmes J. D. (2001). Wind loading of parallel free-standing walls on bridges, cliffs, embankments and ridges . *Journal of Wind Engineering and Industrial Aerodynamics,* 89, 1397-1407.

2. Standards Australia (2002). Structural design actions. Part 2: Wind actions. Australian/New Zealand Standard AS/NZS1170.2:2002.

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Disclaimer

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