WIND LOADS ON A LARGE STORAGE SHED

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INTRODUCTION

Large, low-rise buildings with spans greater than 30m and lengths exceeding 100m are often used for bulk storage of materials. The structural systems of such large buildings generally consist of portal frames or trusses, usually spaced evenly at the mid section and closer together at the gable-ends. Cladding is attached to roof purlins and wall girts, which are fixed to these frames. Design wind loads on the cladding and primary structure of such buildings may be determined using data in wind load standard AS/NZS 1170.2 (2002) or from a wind tunnel model study. This paper summarises results from a wind tunnel study carried out on a large storage shed.

WIND TUNNEL TESTS

The wind tunnel model study was carried out at a length scale of 1/500, in the 2.0m × 2.5m × 22m long Boundary Layer Wind Tunnel at the School of Engineering at James Cook University, on a 348m × 109m × 28.1m high storage shed, shown in Figure 1, (in a simulated terrain category 2 approach flow, in Townsville, designated a Tropical Cyclone Region C with a design wind speed of 70 m/s as per AS/NZS 1170.2(2002)).

External pressures on the wall and roof panels were obtained for approach wind directions (θ) at intervals of 15°. Pressure taps were connected to Honeywell pressure transducers via Scanivalves and a calibrated tube and restrictor system. The pressure signals were low-pass filtered at a frequency of 250Hz, and sampled at 500Hz. The pressures were analysed to give mean, standard deviation, maximum and minimum pressure coefficients as;

$$C_{\overline{p}} = \overline{p}/(\tfrac{1}{2}\rho\overline{U}_h^{\,2}), \quad C_{\sigma_p} = \sigma_p/(\tfrac{1}{2}\rho\overline{U}_h^{\,2}), \quad C_{\hat{p}} = \hat{p}/(\tfrac{1}{2}\rho\overline{U}_h^{\,2}) \text{ and } \quad C_{\breve{p}} = \breve{p}/(\tfrac{1}{2}\rho\overline{U}_h^{\,2})$$

where, $\frac{1}{2}\rho\overline{U}_h^{\,2}$ is the mean dynamic pressure at height h, the average roof level of 20.3m.

PRESSURE DISTRIBUTIONS

Peak pressures for $\theta = 0°$, 45° and 90° on Panels 1..14 on the tributaries of Frames B/C (near the gable-end of the shed) and Frames J/M (near the central part of the shed) are given in Tables 1a and 1b respectively.

The load effect $x(t)$ resulting from wind pressure p_i acting on a tributary area divided into N panels is given by Equation 1, where and β_i and P_i are the influence coefficient and load at panel i of area A_i.

$$x(t) = \sum_{i=1}^{N} \beta_i p_i(t) A_i = \sum_{i=1}^{N} \beta_i P_i(t) \tag{1}$$

The LRC method developed by Kasperski (1992) in Equation 2 gives the load at j, P_j which generates the peak value of load effect $\hat{x}$. Here r_{Pjx} is the correlation coefficient between the fluctuating load effect x and the pressure P_j.

$$(P_j)_{\hat{x}} = \overline{P_j} + g_x r_{P_j x} \sigma_{P_j} \tag{2}$$

The ridge bending moments (M_R) and horizontal reactions (H_X and H_Y) at the base of frames B/C and M/J shown in Figure 2 are analysed in this section. Based on the structural system used for this shed, the influence coefficients for M_R, H_X and H_Y are given in Table 2.

Table 3 shows peak (i.e. design) wind load effects for $\theta = 0°$, $45°$ and $90°$, derived from the "covariance integration" method of Holmes and Best (1981) and compared with those derived from data in AS/NZS 1170.2 (2002). The largest negative ridge bending moment is experienced near the windward end for $\theta = 90°$. In the central part of the shed, the largest bending moment is experienced for $\theta = 45°$. The largest horizontal reaction H_X is around +40 kN/m-width with the maximum negative value about -4 kN/m-width, for $\theta = 90°$ in the central part of the shed. The largest horizontal reaction H_Y is around -40 kN/m-width, with the maximum positive value about +5 kN/m-width for $\theta = 45°$ near the gable-end of the shed. The effective design pressure distributions on the frames (trusses), for the corresponding peak load effects are given in Tables 4 and 5.

CONCLUSIONS

Wind tunnel model studies were carried out to determine pressure distributions and wind load effects on a storage shed in Townsville. Selected design load effects were derived for Frames B/C (near the gable-end of the shed) and Frames J/M (near the central part of the shed) by applying the external pressures measured in the wind tunnel and compared with data prescribed in AS/NZS 1170.2. The effective pressure distributions generating the peak load effects of interest were also determined.

AS/NZS 1170.2 generally provides conservative estimates for the ridge bending moments and horizontal reactions at the base of the frames. However, support reactions can be underestimated by AS/NZS 1170.2 on some parts of such large buildings.

REFERENCES

AS/NZS 1170.2 Structural design actions – Part 2: Wind actions (2002)

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Table 1a. Peak pressures in kPa on Truss B/C

Wind Dir.	Panel 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	1.86 -0.35	1.23 -0.60	0.83 -0.63	0.29 -1.10	0.22, -2.97	-0.05 -1.01	-0.13 -1.09	-0.19 -1.35	-0.02 -0.97	-0.08 -1.30	-0.07 -1.23	0.05 -1.17	-0.06 -1.02	0.00 -0.84
45	1.41 -0.20	1.04 -0.44	0.83 -0.41	0.46 -0.69	-0.04 -1.92	0.20 -4.05	-0.17 -4.21	-0.43 -4.23	-0.45 -2.98	-0.17 -2.46	-0.20 -1.89	-0.22 -1.90	-0.30 -1.73	-0.23 -1.76
90	0.29 -1.14	0.18 -1.64	0.12 -2.43	0.14 -2.37	-0.17 -2.57	-0.22 -3.71	-0.24 -2.79	-0.18 -2.85	-0.25 -2.91	-0.20 -3.01	-0.02 -2.72	0.12 -2.81	0.23 -2.17	0.30 -1.66

Table 1b. Peak pressures in kPa on Truss J/M

Wind Dir.	Panel 1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	2.18 -0.20	0.97 -0.67	0.68 -0.68	-0.06 -1.39	-0.39 -3.17	-0.16 -1.10	-0.31 -1.51	-0.30 -1.50	-0.05 -0.86	-0.01 -0.64	0.06 -0.76	0.08 -1.04	-0.08 -0.92	0.08 -0.69
45	1.31 -0.19	0.89 -0.49	0.59 -0.43	0.12 -1.01	-0.19 -2.43	-0.08 -0.92	-0.19 -1.19	-0.25 -1.19	-0.12 -1.09	0.00 -1.60	-0.01 -2.49	0.16 -2.05	0.42 -1.73	0.32 -1.87
90	0.36 -0.50	0.27 -0.52	0.20 -0.73	0.32 -0.82	0.34 -0.82	0.33 -1.05	0.54 -0.76	0.47 -0.92	0.48 -0.93	0.49 -0.88	0.37 -1.07	0.41 -0.91	0.32 -0.75	0.42 -0.52

Table 2 Influence Coefficients for M_R, H_X and H_Y

Panel	1	2	3	4	5	6	7	8	9	10	11	12	13	14
M_R	1.05	1.69	2.92	4.17	4.95	6.38	3.43	3.43	6.38	4.95	4.17	2.92	1.69	1.05
H_X	0.82	0.23	-0.04	-0.19	-0.44	-0.27	-0.03	-0.01	-0.10	-0.25	-0.42	-0.35	-0.19	-0.11
H_Y	0.11	0.19	0.35	0.42	0.25	0.10	0.01	0.03	0.27	0.44	0.19	0.04	-0.23	-0.82

Table 3. Peak wind load effects on storage shed Frames B/C and J/M

Load Effect	Using Wind Tunnel data		AS/NZS 1170.2 (2002)
	Maximum	Minimum	
M_R (B/C)	kNm/m-width	kNm/m-width	kNm/m-width
$\theta = 0°$	-490.05	-8.80	-781.9
$\theta = 45°$	-904.22	32.95	
$\theta = 90°$	-956.45	-35.43	-1256.5
M_R (J/M)			
$\theta = 0°$	-534.87	-35.19	-781.9
$\theta = 45°$	-562.11	-29.80	
$\theta = 90°$	-245.56	105.11	-308.5, 292.7
H_X (B/C)	kN/m-width	kN/m-width	kN/m-width
$\theta = 0°$	30.13	0.37	48.53
$\theta = 45°$	36.86	0.54	
$\theta = 90°$	38.77	0.14	42.26
H_X (J/M)			
$\theta = 0°$	31.59	2.14	48.53
$\theta = 45°$	32.37	2.47	
$\theta = 90°$	9.13	-3.98	9.67, -15.00
H_Y (B/C)	kN/m-width	kN/m-width	kN/m-width
$\theta = 0°$	-15.94	1.84	-14.97
$\theta = 45°$	-21.59	4.83	
$\theta = 90°$	-36.60	1.09	-42.26
H_Y (J/M)			
$\theta = 0°$	-17.23	0.07	-14.97
$\theta = 45°$	-18.51	1.61	
$\theta = 90°$	-8.70	4.27	-9.67, 15.00

Table 4 Effective design pressures in kPa on Frames B/C

Load Effe.	Panel 1	2	3	4	5	6	7	8	9	10	11	12	13	14	See Tab 3
M_R	-0.45	-0.64	-1.32	-1.46	-1.77	-2.33	-1.95	-1.92	-2.15	-1.92	-1.78	-1.42	-0.92	-0.73	-956.5 kNm/m
H_X	-0.31	-0.47	-1.11	-1.35	-1.81	-2.19	-1.73	-1.65	-1.88	-1.99	-2.03	-1.74	-1.11	-0.84	38.77 kN/m
H_Y	-0.47	-0.73	-1.51	-1.69	-1.89	-1.94	-1.65	-1.60	-2.06	-1.95	-1.64	-0.96	-0.47	-0.32	-36.60 kN/m

Table 5 Effective design pressures in kPa on Frames J/M

Load Effe.	Panel 1	2	3	4	5	6	7	8	9	10	11	12	13	14	See Tab 3
M_R	0.22	-0.02	-0.21	-0.70	-1.62	-0.82	-1.16	-1.17	-1.09	-1.51	-2.02	-1.48	-1.06	-0.89	-562.1 kNm/m
H_X	0.51	0.19	-0.06	-0.62	-1.74	-0.75	-1.09	-1.07	-0.98	-1.43	-1.99	-1.56	-1.04	-0.86	32.37 kN/m
H_Y	0.16	-0.09	-0.25	-0.69	-1.56	-0.77	-1.04	-1.01	-0.98	-1.37	-1.88	-1.15	-0.59	-0.32	-18.51 kN/m

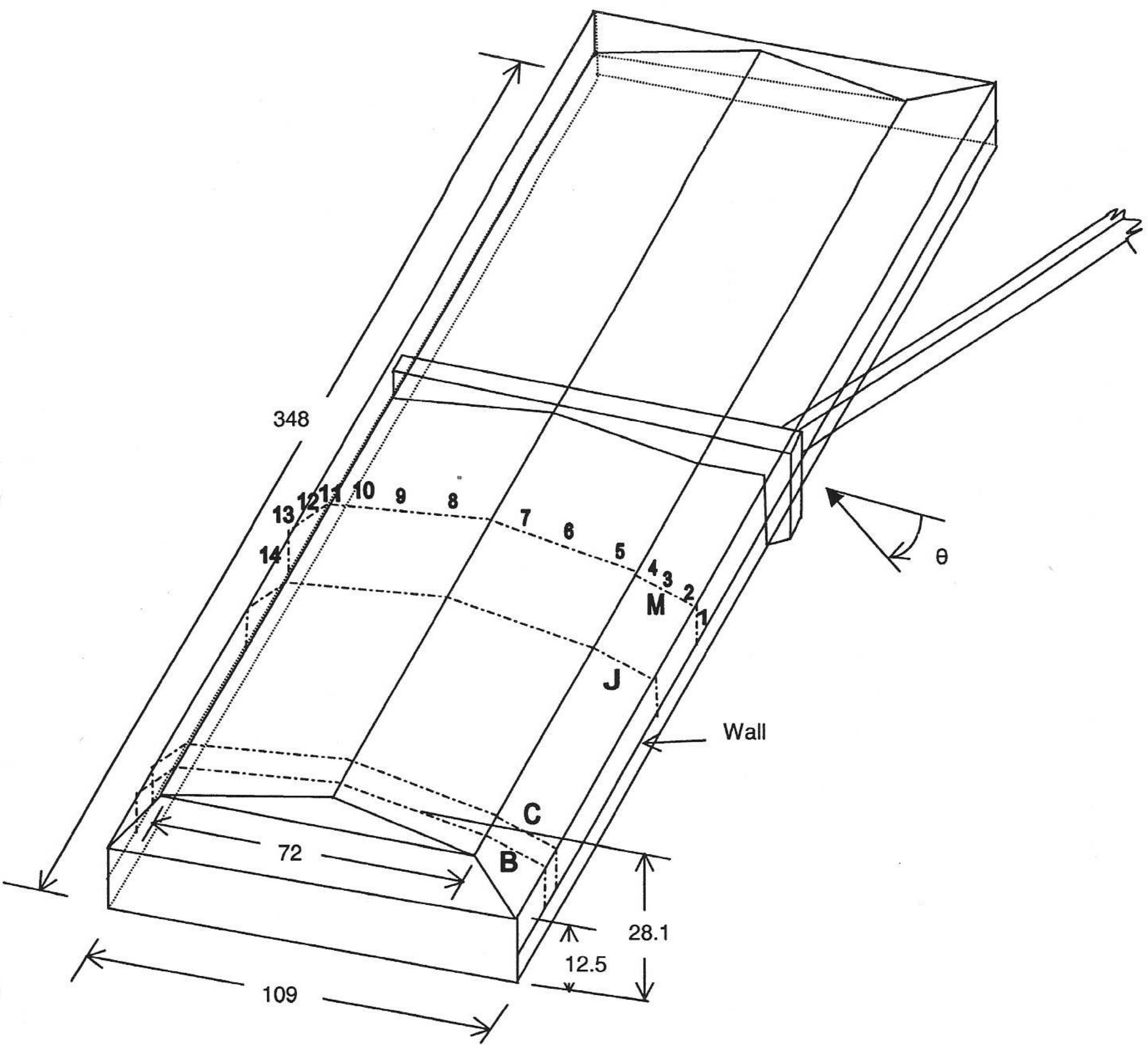

Figure 1. 109m × 348m × 28.1m Storage Shed – Not to scale

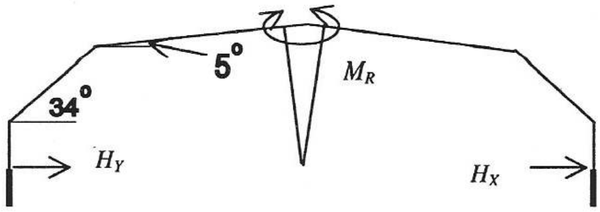

Figure 2. Wind load effects analyzed