WIND LOADS ON ATTACHED CANOPIES

E.D. Jancauskas[1] and J.D. Holmes[2]

Introduction

Despite the fact that the vast majority of canopy-type structures are installed in an attached configuration (that is, abutting an enclosed parent building) there has to date been no detailed study reported on the wind loads that such structures attract. This absence of information in the open literature is reflected in the Australian Wind Loading Code, AS1170 Part 2 - 1983, which provides no guidance on wind loads for attached canopies.

As a consequence of this absence of information, the Department of Civil & Systems Engineering at James Cook University and the CSIRO Division of Building Research embarked on a collaborative research project aimed at measuring the wind loads on this class of structure. This paper, which presents selected results from this project, describes the uplift forces on attached canopies as a function of the relative geometry of the canopy and the adjacent building. This data forms the basis of a codified description of attached canopy loads prepared by the authors for the upcoming revision of the Australian wind loading code.

Experimental Technique

The measurements reported in this paper were made in the boundary layer wind tunnels at James Cook University (Townsville) and CSIRO Division of Building Research (Melbourne). In both cases, a simulated boundary layer equivalent to flow over rural (Category 2) terrain was established using a combination of a plain barrier and carpet roughness. At a nominal scale of 1/75, the mean velocity and turbulence intensity profiles were a good fit to those of Deaves & Harris [1] with a roughness length (Zo) of 0.03 m.

The basic canopy dimensions, the canopy thickness and the dimensions of the parent building were identical for both laboratories. Figure 1 shows a schematic representation of the attached canopy configuration, together with the adopted nomenclature.

Although both laboratories measured the integrated peak loads exerted on the attached canopies, the experimental techniques employed were entirely different. At James Cook University the forces were measured directly using lightweight canopy models of various sizes mounted on a sensitive three-component force balance [2]. The clearance gap between the canopy and the parent building was sealed with a latex membrane. At the nominal scale of 1/75, the canopies had a frequency response equivalent to approximately 3.5 Hz in full scale.

The measurements performed at CSIRO were obtained using a pressure-based technique. Eight pressure transducers were used to simultaneously monitor pneumatically-averaged pressures from 48 pressure tappings on both sides of the canopy model. Manifolding was done internally within the canopy model, and the system had a frequency response equivalent to approximately 10 Hz in full scale (assuming a scale of 1/75).

Results

The canopy loads are given in terms of mean and peak nett vertical force coeffic-

---

1. James Cook University of North Queensland
2. CSIRO Division of Building Research.

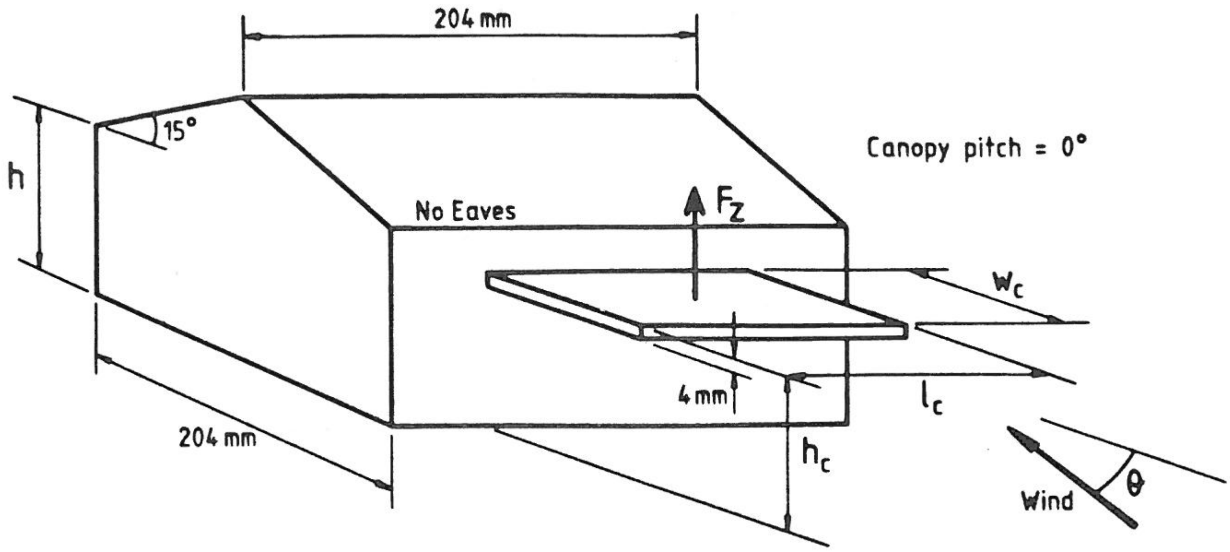

Figure 1 The attached canopy configuration.

ients, $C\bar{F}_z$ and $C\hat{F}_z$, defined as follows:

Mean coefficient $$C_{\bar{F}_z} = \frac{\bar{F}_z}{\frac{1}{2}\rho \bar{u}_c^2 A}$$

Peak coefficient $$C_{\hat{F}_z} = \frac{\hat{F}_z}{\frac{1}{2}\rho \bar{u}_c^2 A}$$

where $\bar{F}_z$ = mean nett vertical force on the canopy

$\hat{F}_z$ = peak nett vertical force on the canopy occurring within a time equivalent to 10 minutes full scale

$\bar{u}_c$ = mean wind velocity at canopy height

A = area of the canopy.

For the purpose of codification, the peak coefficients have been converted to quasi-steady (code-type) coefficients defined as

Quasi-steady Coefficient $$(C_{F_z})_o = \frac{\hat{F}_z}{\frac{1}{2}\rho \hat{u}_c^2 A}$$

where $\hat{u}_c$ = peak 2-3 second gust velocity at canopy height.

This conversion was based on pressure gust factors $\left(\frac{\hat{u}_c}{\bar{u}_c}\right)^2$ of 2.6, 2.7 and 2.85 at the three canopy heights of 84 mm, 63 mm and 42 mm respectively.

The canopy loads have been tabulated in Table 1 and plotted as a function of canopy height-to-width ratio in Figure 2.

Discussion

The first point that should be noted is that there was very good agreement between the measurements made using the two different experimental techniques. This was so not only with regard to the mean forces but also the peaks.

TABLE 1 MEASURED UPLIFT FORCES ON ATTACHED CANOPIES

Run	Wind Direction θ	h (mm)	hc (mm)	wc (mm)	lc (mm)	$\frac{hc}{h}$	$\frac{hc}{wc}$	UPLIFT		
								C_{F_z}	$\hat{C}_{F_z}$	$(C_{F_z})_o$
JCU										
1	0°	84	84	64	96	1.0	1.31	+0.85	+2.28	+0.88
2	45°	84	84	64	96	1.0	1.31	+0.64	+2.11	+0.81
3	90°	84	84	64	96	1.0	1.31	-0.02	+1.06	+0.41
4	0°	84	84	36	96	1.0	2.33	+1.34	+3.58	+1.38
5	0°	84	84	36	192	1.0	2.33	+1.21	+3.16	+1.22
6	0°	84	84	52	96	1.0	1.62	+1.03	+2.71	+1.04
7	0°	84	84	96	96	1.0	0.88	+0.65	+1.69	+0.65
8	0°	63	63	64	96	1.0	0.98	+0.64	+1.88	+0.70
9	0°	42	42	64	96	1.0	0.66	+0.50	+1.43	+0.50
10	0°	84	63	64	96	0.75	0.98	+0.26	+1.06	+0.39
11	0°	84	42	64	96	0.50	0.66	-0.01	+0.51	+0.18
CSIRO										
12	0°	84	84	64	96	1.0	1.31	+0.87	+2.37	+0.91
13	0°	84	84	32	96	1.0	2.63	+1.35	+3.64	+1.40
14	0°	84	63	64	96	0.75	0.98	+0.38	+1.31	+0.49
15	0°	84	63	32	96	0.75	1.97	+0.37	+1.70	+0.63
16	0°	84	42	64	96	0.50	0.66	-0.01	+0.65	+0.23
17	0°	84	42	32	96	0.50	1.31	-0.21	+0.56	+0.20

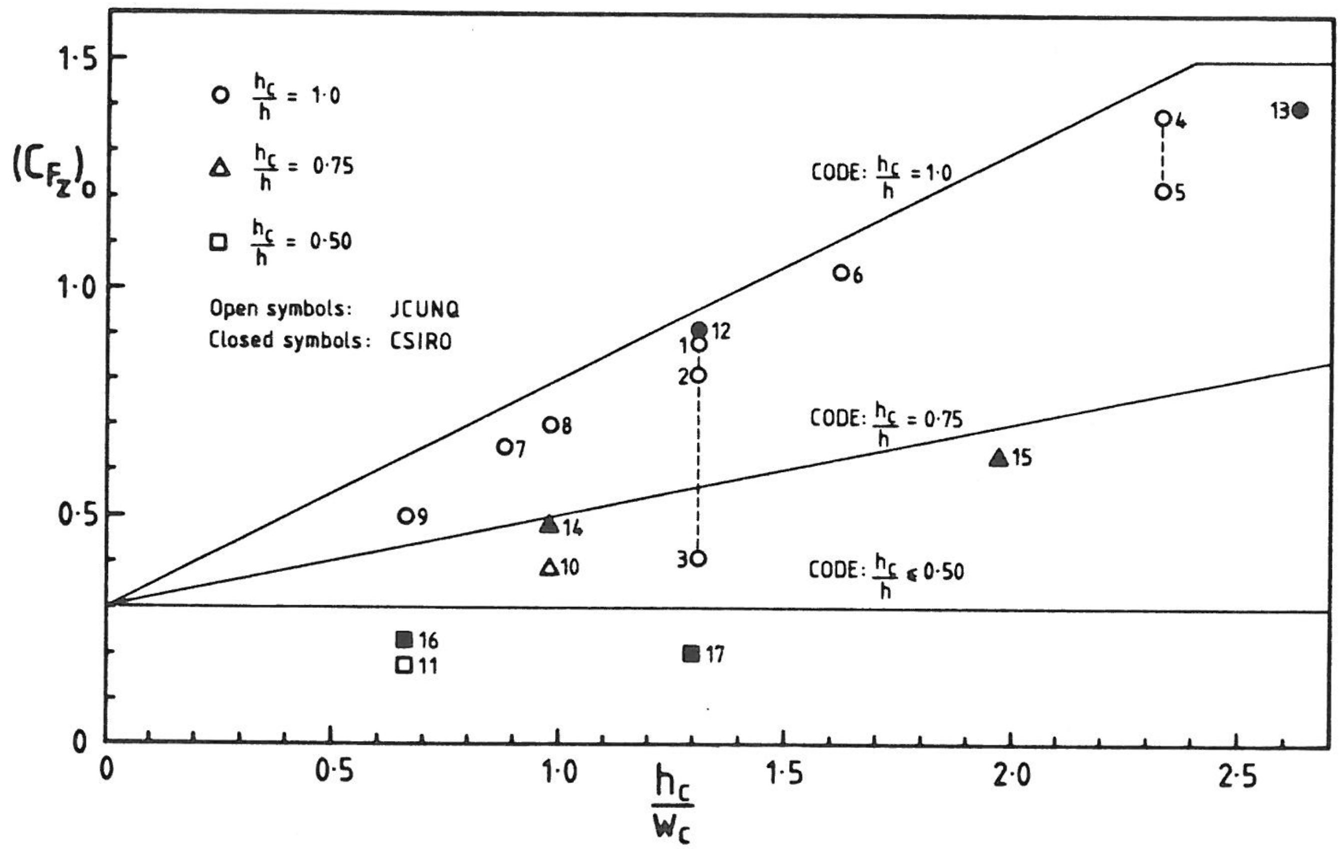

Figure 2 Measured uplift force as a function of canopy height-to-width ratio.

As a comparison between runs 1, 2 and 3 demonstrates, the uplift force on the attached canopy was greatest for a wind direction of θ = 0°. This of course corresponds to the development of maximum stagnation pressure under the canopy.

Runs 4 and 5 indicate the effect of the canopy length, ℓ_c. As the length of the canopy is increased (keeping the canopy height and width constant), the uplift per unit area is decreased. This is due primarily to the decrease in the correlation of the forces over the increased span of the canopy.

The remainder of the runs investigate the dependence of the uplift forces on the two ratios, $\frac{h_c}{h}$ and $\frac{h_c}{w_c}$. Decreasing either of these ratios decreases the uplift on the canopy. In the case of $\frac{h_c}{h}$, a decrease in the ratio corresponds to an increase in the amount of parent wall above the canopy. This produces increased stagnation of the flow above the canopy and a decrease in the nett uplift.

In the case of $\frac{h_c}{w_c}$, a decreased value corresponds to an increase in canopy width for a given canopy height. This results in a decrease in the proportion of the total upper surface of the canopy under the reattaching shear layer shed from the leading edge of the canopy. Consequently, the uplift per unit area is decreased.

Code Recommendation

On the basis of the above data, the authors offer the following codified description of the uplift forces on attached canopies:

For $\frac{h_c}{h} = 1.0$: $(C_{F_z})_o = 0.3 + 0.5\ (\frac{h_c}{w_c})$ or 1.5, whichever is the lesser

For $\frac{h_c}{h} = 0.75$: $(C_{F_z})_o = 0.3 + 0.2\ (\frac{h_c}{w_c})$ or 1.5, whichever is the lesser

For $\frac{h_c}{h} \leq 0.5$: $(C_{F_z})_o = 0.3$

Linear interpolation may be used to obtain values for $\frac{h_c}{h}$ ratios other than those shown.

These recommendations have been plotted in Figure 2. It can be seen that in all cases the code recommendations conservatively estimate the uplift forces on attached canopies.

Conclusions

- There was very good agreement between the measurements of peak uplift made at James Cook University and CSIRO using entirely different experimental techniques.
- The maximum uplifts on attached canopies occur for a wind direction of $\theta = 0°$.
- The wind loads on attached canopies are primarily dependent on the two ratios $\frac{h_c}{h}$ and $\frac{h_c}{w_c}$.
- The code recommendation offered by the authors conservatively estimates the uplift forces on attached canopies.

Acknowledgements

This research was funded by a grant from the CSIRO/James Cook University Collaborative Research Fund. The technical assistance of Mr. G. McNealy is gratefully acknowledged.

References

1. Deaves, D. and Harris, R.I. "The Structure of Strong Winds", Cranfield Institute of Technology Report, 1981.

2. Roy, R.J. "Total Force and Moment Measurement on Wind Tunnel Models of Low Rise Buildings", M.Eng.Sc. Thesis, James Cook University, 1982.