TOTAL LOAD MEASUREMENTS ON LOW RISE BUILDINGS

TERRAIN CATEGORY 3

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Introduction

This paper is a follow-on from the paper by Roy and Walker [1] on total load measurements on low rise buildings in Terrain Category 2. It presents the results of wind tunnel studies on four models of differing roof pitches in a simulated urban environment (Category 3 in Code terms) and some preliminary comparisons with the Category 2 results.

Boundary Layer Simulation

Simulation of the boundary layer was carried out by using a plain barrier at the inlet to the tunnel followed by an array of polystyrene roughness elements over a distance of 12 m to the turntable. The boundary layer developed at the turntable was a reasonable fit to the log-law with a roughness length of 160 mm and a displacement height of 3.8 m in full scale from a height of 5 m to 25 m in full scale.

To simulate local conditions more precisely the test models were placed at the centre of an array of similar 10° pitch dummy models located within a circle of 90 m diameter and at 20 m spacing either way in full scale.

Models and Instrumentation

The same four test models and associated instrumentation were used as in the Category 2 studies [1].

Total Load Coefficients

The same terminology was used for defining the total load coefficients except that the reference velocity was taken to be the mean velocity at a height of 10 m above ground in full scale.

Results

The set of results for the four models for wind directions of 15° increments from 0° - 90° is shown in Table 1.

For the same basic wind velocity the Code [2] predicts a value of 0.52 for the ratio of the peak wind loads on a 3 m high house in Category 3 to those on an identical house in Category 2. Figure 1 shows the results of determining this ratio from the experimentally measured peak loads on the houses in Categories 2 and 3 respectively.

The results presented in Figure 1 are based on referencing the peak total load coefficients from both terrain categories to the gradient mean wind velocity. For the Category 2 results a log-law relationship with a roughness length of 20 mm in full scale was assumed between the experimental reference height of 3 m in full scale and 30 m in full scale, and a power law relationship assumed between 30 m and a gradient height of 300 m with an exponent of 0.15. For the

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category 3 results the measured log-law relationship - i.e. roughness length of 160 mm and displacement height of 3.8 m in full scale was assumed between 10 m and 30 m in full scale, and a power-law relationship assumed between 30 m and a gradient height of 400 m with an exponent of 0.25.

Figure 2 compares the effect of wind direction on the peak total loads for the 15° roof pitch model in Categories 2 and 3. The results are presented in terms of F_{ϕ}/F_{O} where F_O is the peak load corresponding to side-on winds for F_x and My, and end-on winds for Fy and M_x, and $F\phi$ is the corresponding peak load for wind directions at an angle ϕ to those giving F_O.

Discussion of Results

The results show that the current code approach of determining Category 3 wind loads by scaling Category 2 loads by a value dependent only on the terrain category velocity multipliers may lead to serious errors.

For the particular geometries studied the code approach appears to seriously underestimate peak total uplift loads for roof pitches above 15°, to significantly underestimate peak total horizontal loads across the width of house for all roof pitches and the peak total overturning moments about the long axis at roof pitches of the order of 30° and greater, and to significantly overestimate the peak total overturning moments about the length axis for roof pitches up to 20°, and the peak total overturning moments about the width axis for all roof pitches. In the case of uplift the results indicate that for a roof pitch of 30° the peak total uplift load is 25 percent greater in Category 3 than in Category 2 for the same basic wind velocity!

The results shown in Figure 2 also raise questions in regard to common assumptions made in regard to wind directional effects on peak total loads with strong cross wind effects being particularly evident in Category 3 conditions for end-on horizontal loads and the overturning moments in both directions, and for side-on horizontal loads in Category 2 conditions. For the latter the peak load is indicated as being 20 percent greater with the wind blowing at 45° then with the wind blowing side-on. For these loads and this geometry a directional reduction factor does not seem justified!

These are only preliminary results but they indicate that loads on buildings within the roughness layer may be markedly different in character than those on buildings above the roughness layer such as isolated buildings in Category 2. This raises serious questions about the applicability of current code rules to Category 3 housing, which is the majority of housing. Studies of point pressures, torsional loads and other building geometries in Category 3 conditions appear to be urgently needed.

Acknowledgements

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References

1. Roy, R.J. and Walker, G.R. 'Total Load Measurements on Low Rise Buildings: Terrain Category 2'. Wind Engineering Workshop, CSIRO Melbourne, July 1984.

2. 'SAA Loading Code, Part 2 - Wind Forces' AS1170, Part 2 - 1983.

TABLE 1

TOTAL LOAD COEFFICIENTS, 20 METRE x 20 METRE HOUSE SPACING: URBAN TERRAIN (10 METRE REFERENCE HEIGHT)

Pitch	Degree Azimuth	$\hat{C}_{F_x}$	$\check{C}_{F_x}$	$\bar{C}_{F_x}$	$\bar{\bar{C}}_{F_x}$	$\hat{C}_{F_z}$	$\check{C}_{F_z}$	$\bar{C}_{F_z}$	$\bar{\bar{C}}_{F_z}$	$\hat{C}_{M_y}$	$\check{C}_{M_y}$	$\bar{C}_{M_y}$	$\bar{\bar{C}}_{M_y}$	$\hat{C}_{F_y}$	$\check{C}_{F_y}$	$\bar{C}_{F_y}$	$\bar{\bar{C}}_{F_y}$	$\hat{C}_{M_x}$	$\check{C}_{M_x}$	$\bar{C}_{M_x}$	$\bar{\bar{C}}_{M_x}$
10 PITCH	0	2.26	-0.74	0.40	0.32	1.15	-0.15	0.28	0.16	3.88	-1.51	0.57	0.62	1.61	-1.68	-0.01	0.33	1.91	-2.18	-0.04	0.37
	15	2.00	-0.74	0.35	0.29	1.07	-0.13	0.27	0.15	3.58	-1.60	0.50	0.57	1.59	-1.20	0.12	0.28	2.05	-1.49	0.10	0.34
	30	2.10	-0.70	0.34	0.29	1.16	-0.15	0.28	0.16	4.18	-1.33	0.66	0.60	2.00	-1.21	0.26	0.32	2.25	-1.37	0.21	0.36
	45	1.85	-0.78	0.30	0.27	1.13	-0.20	0.25	0.16	4.05	-1.60	0.47	0.63	2.03	-1.00	0.34	0.31	2.09	-1.03	0.28	0.33
	60	1.67	-0.92	0.21	0.26	1.18	-0.22	0.19	0.15	3.91	-1.68	0.33	0.60	2.07	-0.95	0.38	0.31	2.13	-1.03	0.30	0.34
	75	1.33	-0.97	0.12	0.23	0.93	-0.27	0.13	0.13	2.98	-1.96	0.21	0.56	2.12	-0.86	0.36	0.31	2.10	-0.86	0.30	0.32
	90	1.04	-0.99	0.01	0.20	0.76	-0.28	0.08	0.11	1.44	-2.31	0.02	0.50	2.62	-0.84	0.38	0.34	2.09	-0.98	0.23	0.34
15 PITCH	0	2.43	-0.70	0.41	0.33	1.15	-0.14	0.28	0.16	3.44	-1.84	0.35	0.59	1.49	-1.45	0.01	0.30	2.16	-1.89	0.00	0.36
	15	2.31	-0.76	0.40	0.32	1.12	-0.12	0.27	0.15	3.30	-1.70	0.40	0.58	1.67	-1.22	0.14	0.29	2.19	-1.51	0.14	0.36
	30	2.21	-0.73	0.35	0.30	1.17	-0.16	0.27	0.16	3.60	-1.94	0.39	0.65	1.89	-1.08	0.26	0.29	2.28	-1.31	0.27	0.36
	45	1.82	-0.83	0.29	0.27	1.12	-0.18	0.24	0.16	3.34	-1.61	0.25	0.53	1.93	-0.92	0.32	0.29	2.36	-1.08	0.57	0.35
	60	1.77	-0.95	0.23	0.27	1.08	-0.20	0.18	0.15	3.45	-1.59	0.35	0.54	1.94	-0.88	0.36	0.29	2.48	-0.75	0.43	0.34
	75	1.49	-1.10	0.12	0.25	0.89	-0.23	0.12	0.12	2.76	-2.00	0.15	0.51	2.01	-0.83	0.34	0.30	2.19	-0.79	0.35	0.34
	90	1.30	-1.31	0.01	0.24	0.83	-0.24	0.09	0.11	2.34	-2.75	-0.08	0.52	2.07	-0.82	0.33	0.30	2.21	-0.80	0.31	0.31
20 PITCH	0	3.18	-0.65	0.57	0.43	1.12	-0.19	0.24	0.15	2.38	-1.90	0.10	0.50	1.45	-1.63	-0.01	0.32	2.13	-2.16	0.01	0.43
	15	3.21	-0.65	0.58	0.43	1.25	-0.16	0.27	0.16	2.74	-1.76	0.25	0.51	1.65	-1.37	0.13	0.30	2.52	-1.70	0.24	0.41
	30	2.64	-0.70	0.49	0.38	1.19	-0.14	0.29	0.17	3.02	-1.86	0.25	0.59	1.76	-1.11	0.23	0.28	2.60	-1.23	0.36	0.39
	45	2.47	-0.79	0.38	0.35	1.17	-0.15	0.27	0.16	2.87	-1.61	0.25	0.52	2.03	-0.93	0.31	0.29	2.48	-0.97	0.40	0.39
	60	2.21	-1.02	0.31	0.33	1.10	-0.19	0.21	0.18	2.76	-1.70	0.17	0.49	1.77	-0.85	0.33	0.28	2.24	-0.82	0.40	0.35
	75	1.85	-1.18	0.15	0.29	1.01	-0.23	0.14	0.13	2.66	-1.77	0.14	0.47	2.14	-0.97	0.36	0.31	2.34	-0.87	0.41	0.37
	90	1.44	-1.51	0.00	0.27	0.91	-0.23	0.11	0.11	1.94	-2.16	-0.08	0.46	2.25	-0.83	0.35	0.32	2.49	-0.70	0.39	0.33
30 PITCH	0	5.05	-0.51	1.10	0.69	0.87	-0.40	0.10	0.13	3.12	-1.71	0.37	0.60	1.65	-1.75	-0.01	0.36	1.98	-2.17	-0.02	0.42
	15	4.86	-0.57	1.07	0.66	0.97	-0.36	0.13	0.14	3.06	-1.22	0.49	0.48	1.91	-1.41	0.18	0.34	2.41	-1.72	0.18	0.41
	30	4.60	-0.70	0.97	0.63	1.12	-0.30	0.22	0.16	3.15	-1.22	0.57	0.52	2.15	-1.12	0.31	0.32	2.76	-1.19	0.41	0.41
	45	3.77	-0.71	0.72	0.52	1.09	-0.16	0.26	0.26	2.50	-1.11	0.37	0.41	2.30	-0.76	0.42	0.33	3.00	-0.86	0.57	0.43
	60	3.62	-0.99	0.53	0.49	1.15	-0.17	0.23	0.16	2.88	-1.37	0.41	0.48	2.26	-0.68	0.43	0.32	3.04	-0.77	0.57	0.44
	75	2.78	-1.28	0.26	0.40	0.98	-0.19	0.15	0.14	2.25	-1.49	0.16	0.42	2.28	-0.69	0.44	0.32	2.91	-0.53	0.58	0.42
	90	2.01	-2.03	0.01	0.35	0.84	-0.20	0.11	0.11	1.76	-2.08	-0.09	0.41	2.27	-0.72	0.44	0.34	3.12	-0.73	0.60	0.47

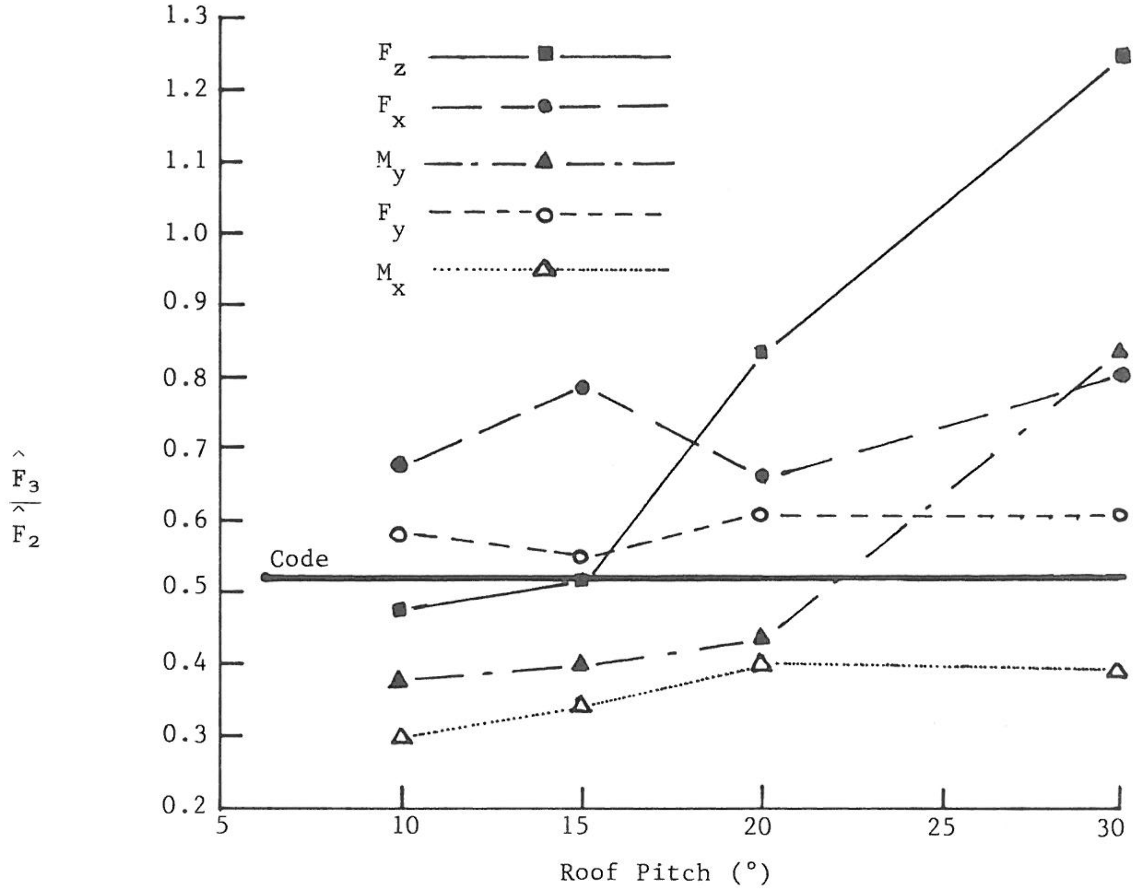

Figure 1 Ratio of Category 3 Loads to Category 2 Loads

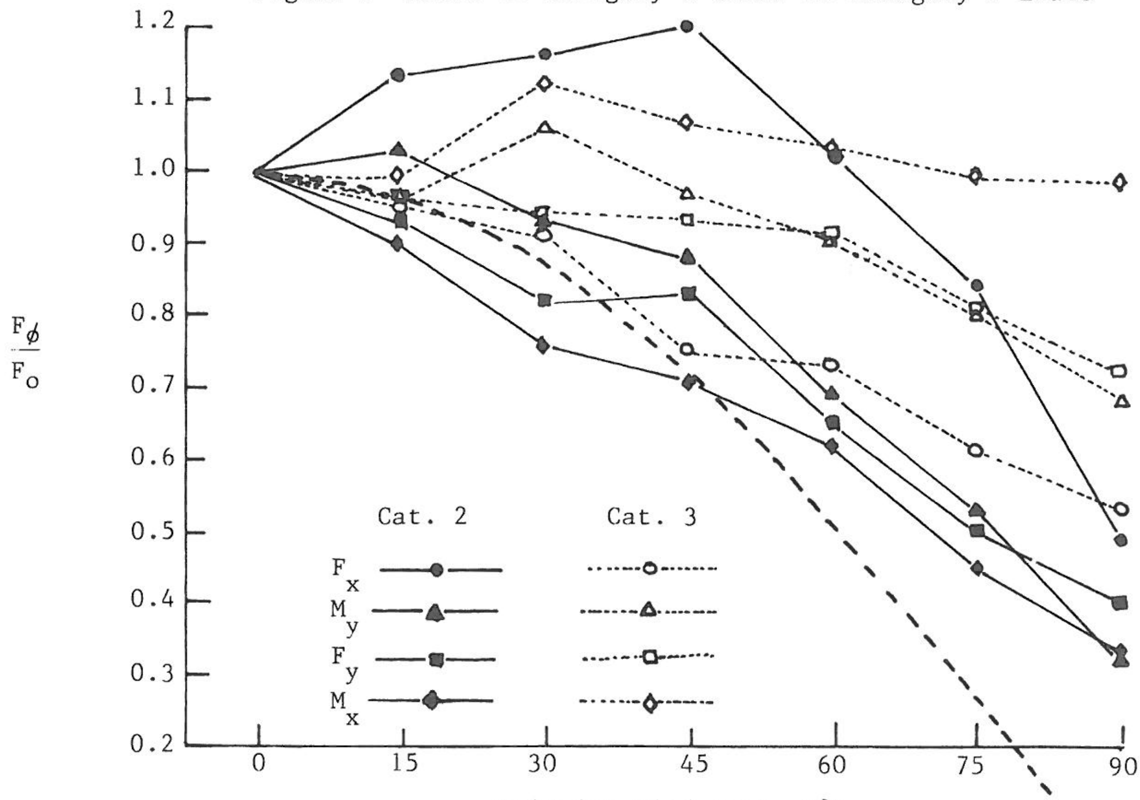

Figure 2 Effect of Wind Direction on Peak Total Loads