WIND INDUCED DEFLECTION IN LOW-RISE STEEL BUILDINGS

INTRODUCTION

The codification of wind forces for low-rise structures has universally been a compromise between the simplicity that the professional community will accept, and the complexity that the flow conditions require. Although many codes of practice follow the same loading format for low-rise structures, the individual magnitudes of the loadings vary considerably. The Canadian code of practice, the National Building Code of Canada, has taken the unusual step of separating the low-rise provisions in terms of its calculation format, and basing the low-rise provisions on an 'envelope' of experimental values unique to low-rise wind tunnel experiments.

This paper explains the Phase IV study of low-rise buildings at the University of Western Ontario, and its implications in terms of calculating structural deflections. The problem of deflection is central to the serviceability limit state, and the difficulty for code writers is the compromise between simplicity (on the one hand) and the multiplicity of limit states (on the other).

EXPERIMENTAL PROGRAM

Phase IV of the Western Ontario study was based on a repeat of 'open' and 'suburban' terrain results for the 1:250 model shown in Fig. 1. The ten (pneumatically averaged) pressure taps were used to create typical 'end bay' and 'middle bay' pressure envelopes shown in Fig. 2. In contrast to the original study, the pressure envelope was computed for a cubic polynomial distribution on each of the windward and leeward roof surfaces. In addition, various frames were chosen to determine structural influence coefficients (Fig. 3). The extended study was intended to act as an independent check on the validity of the Phase II results (1977).

In the U.W.O. experiments, influence coefficients for frame reactions could be introduced to provide an on-line basis for structural force calculations. Influence coefficients for deflection could be added to the existing computer programs without altering the run times of the experiments.

Results of the Phase IV experiments were obtained for the two terrain conditions. The results were consistent in the middle bays, but inconsistent in the end bays.

	End Bay	Middle Bay	
Open Terrain	0.60	0.76	(code/experiment)
Suburban Terrain	1.03	0.77	

The middle bay values (less than 1.0) indicated a deficiency in the prescribed code pressures, which appeared to be caused by higher middle-bay wall pressures measured in the latest experiments. The end bay results (being variable) were attributed to the sensitivity of the deflection to pressure peaks at the centre of the windward roof span.

DEFLECTIONS (IN GENERAL)

Deflections of low-rise buildings are a function of both wall pressures and roof pressures. If the buildings (and models) are symmetric, the load can be conveniently divided into symmetric and anti-symmetric components. Only the latter produce side sway deflections (while both contribute to stress). It is interesting to note that codes vary considerably in their unsymmetric components of roof loading (Fig. 4), and it is not surprising, therefore, that different codes produce widely different deflection estimates. The difference (presumably) reflects an emphasis on stress calculations in the choice of pressure distributions.

A further complication in low-rise deflection predictions can be traced to the influence of roofing (stressed skin) in the serviceability limit state. Roofing can be shown to be highly effective in limiting deflection in low-rise structures, even when stressed skin design procedures have not been used. Calculations of isolated frame deflections are grossly conservative for most frames, due to the rigidity of braced end-bays in most buildings.

A computer model of a (typical) steel building is shown in Fig. 5. The model can be coupled to a 'covariant integration' procedure to estimate peak deflections due to wind along a complete structure. Results of wind correlation calculations are shown in Figs. 6-10, based on correlation coefficients in References 3 and 4.

RESULTS

The ANSI code can be used as a 'convenient' reference point, since the deflections are dependent upon wall pressures alone (see Fig. 4). In Fig. 6, the ANSI code pressures are compared with and without stressed skin action. The reductions are economically significant below 10 bays. Fig. 7 extends the comparison to end-sheeted (unbraced) buildings. The reductions are generally small.

The NBC code (Canada) combines roof and wall pressures in the calculation of deflection. Fig. 8 shows the effect of roof pressures in reversing the direction of deflection in the Canadian code. The effect of stressed skin action is still significant for end-braced buildings.

Figs. 9 and 10 show the results of experimental (covariant integration) calculations for stressed skin buildings. The results generally corroborate the NBC results (i.e. a change in the direction of building deflection with increasing aspect ratio). Results in Figs. 9 and 10 are based upon published correlation coefficients for two different low-rise structures. The results show good agreement in both form and magnitude.

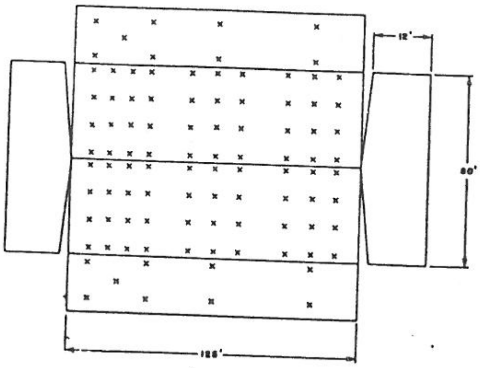
The results of the U.W.O. Phase IV study were largely inconclusive, due to the particular choice of breadth-to-span ratio. The results indicate the importance of 'weighting' experiments over a range of significant parameters.

REFERENCES

1. Wind Loads on Low-Rise Buildings: Phase IV, K.T. Kavanagh, D. Surry, T. Stathopoulos, A.G. Davenport BLWT-SS14-1983

2. Theodore Stathopoulos, Wind Pressure Loads on Flat Roofs, BLWT-3-1975, University of Western Ontario, 1975.

3. Holmes, J.E. and Rains, G.J., Wind Loads on Flat and Curved Roof Low Rise Buildings - Wind Engineering Report JCU, February 1981.



MODEL
FIG 1

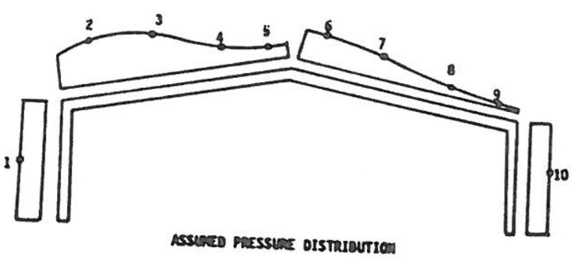
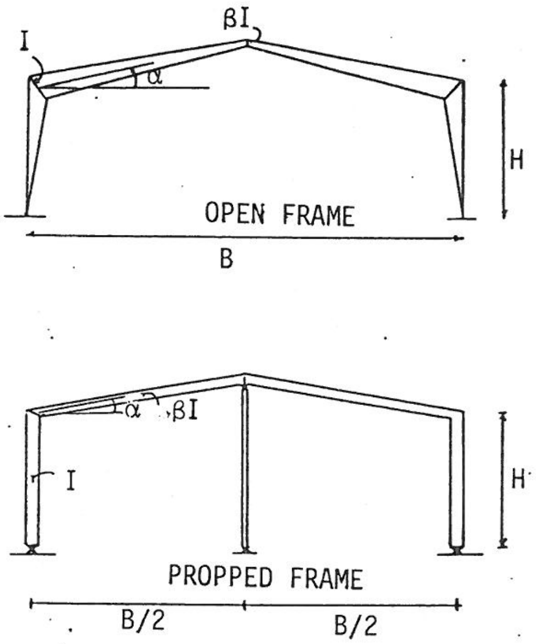


FIG 2



FRAME TYPES
FIG 3

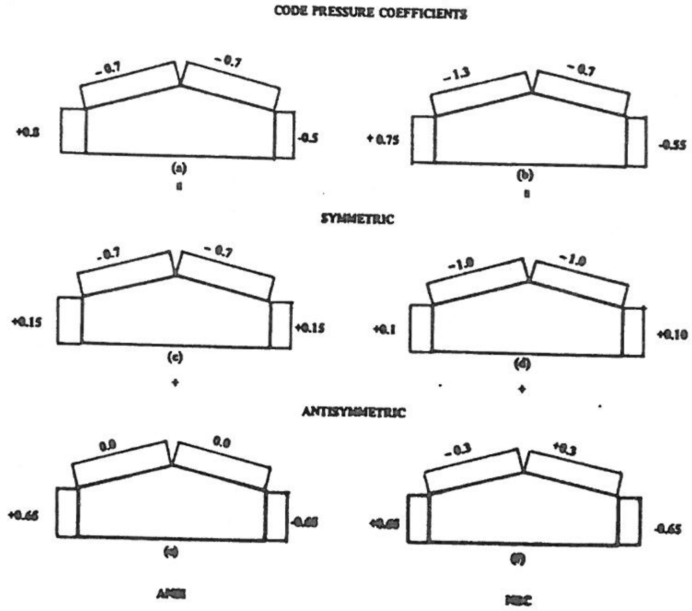


FIG 4

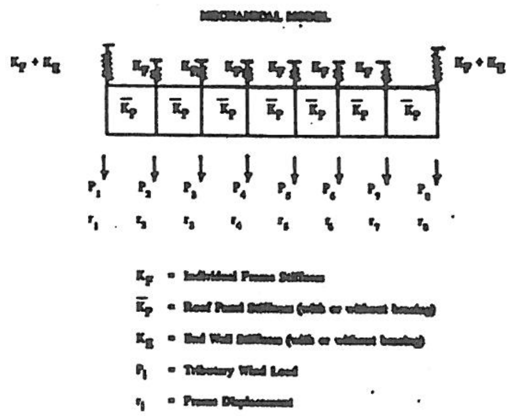
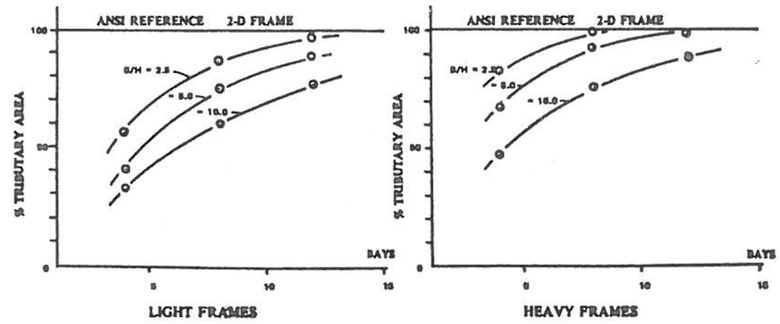


FIG 5

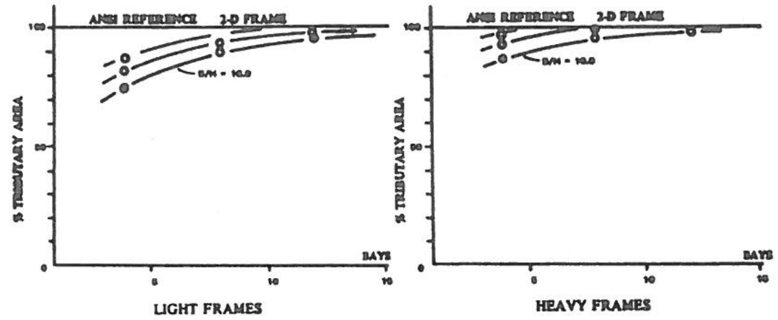
FIG 6



WIDE BAY SPACING

ANSI CALCULATION UTILISING DIAPHRAGM ACTION
END BRACED BUILDINGS

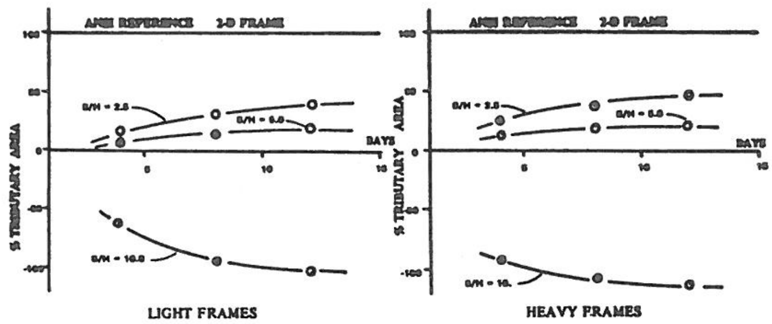
FIG 7



WIDE BAY SPACING

ANSI CALCULATION UTILISING DIAPHRAGM ACTION
END SHEETED BUILDINGS

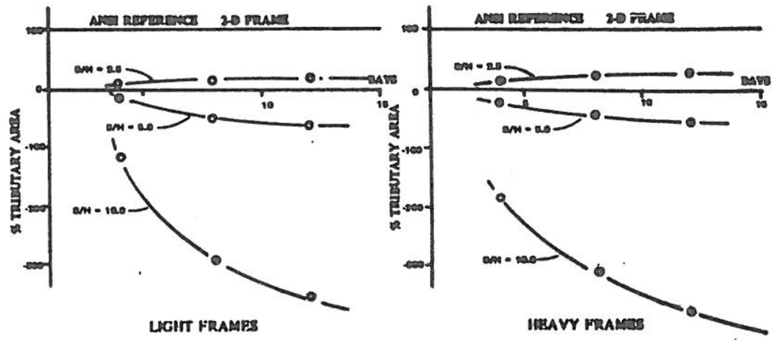
FIG 8



WIDE BAY SPACING

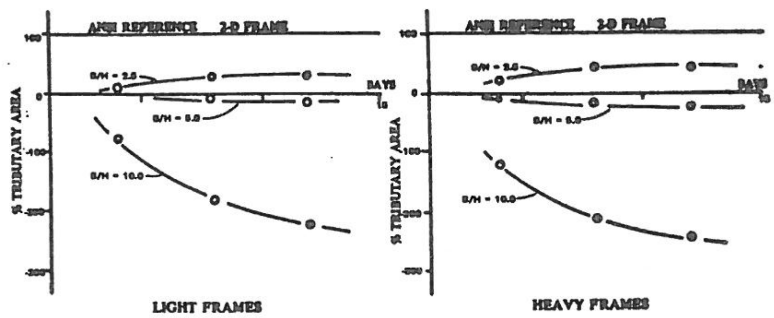
NBC CALCULATION UTILISING DIAPHRAGM ACTION
END BRACED BUILDINGS

FIG 9



REFERENCE 5

FIG 10



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