Appendix E: Some approximate formulas for structural natural frequencies

A necessary pre-requisite for dynamic response estimation is knowledge of the natural frequencies in the lowest sway modes of the structure. It is also useful to know these values to determine whether or not dynamic response calculations to wind are, in fact, necessary.

Most modern frame-analysis or finite element computer programs will of course give this information. However if the structure is still in the early design stage, application of simple empirical formulas may be useful. Some of these are given here.

- for multi-storey office buildings (approximately uniform in plan) (Jeary and Ellis, 1983):

  $$n_1 \approx 46/h \tag{E1}$$

  where h is the height of the building in metres.
- for cantilevered masts or poles of uniform cross-section (in which bending action dominates):

  $$n_1 = (0.56/h^2)\sqrt{(EI/m)} \tag{E2}$$

  where EI is the bending stiffness of the section; and m is the mass/unit height. (This of course is an exact formula for uniform masts or towers; it can be used for those with a slight taper, with average values of EI and m).
- an approximate formula for cantilevered, *tapered*, circular poles (European Convention for Structural Steelwork, 1978)

  $$n_1 \approx [\lambda/(2\pi h^2)]\sqrt{(EI/m)} \tag{E3}$$

  where h is the height, and E, I, m are calculated for the cross-section *at the base*. λ depends on the wall thicknesses at the tip and base, e_t and e_b, and external diameter at the tip and base, d_t and d_b, according to the following formula:

  $$\lambda = \left[1.9\exp\left(\frac{-4d_t}{d_b}\right)\right] + \left[\frac{6.65}{0.9 + \left(\frac{e_t}{e_b}\right)^{0.666}}\right] \tag{E4}$$

  Note that for $(d_t/d_b) = (e_t/e_b) = 1.0$, i.e. a uniform cylindrical tube, $\lambda = 3.52$, and equation (E2) results.

- for free-standing lattice towers (without added ancillaries such as antennas, lighting frames etc.) (Standards Australia, 1994):

$$n_1 \approx 1500 w_a / h^2 \tag{E5}$$

where w_a is the average width of the structure in metres; h is tower height. An alternative formula for lattice towers (with added ancillaries) is (Wyatt, 1984):

$$n_1 \approx \left(\frac{L_N}{h}\right)^{2/3} \left(\frac{w_b}{h}\right)^{1/2} \tag{E6}$$

where w_b = tower base width; L_N = 270 metres for square base towers, or 230 m for triangular base towers.

- A formula which seems to fit data on bridges, with spans between 20 and 1000 m (Pretlove *et al.*, 1995; Jeary, 1997) is:

$$n_1 \approx 40(L_s)^{-3/4} \tag{E7}$$

where L_s is the span in metres (main span in the case of a multi-span structure).

References

European Convention for Structural Steelwork (E.C.C.S.) (1978) *Recommendations for the Calculation of Wind Effects on Buildings and Structures*. Technical Committee T12, E.C.C.S., Brussels.

Jeary, A. P. (1997) *Designer's Guide to the Dynamic Response of Structures*. London: E. F. and N. Spon.

Jeary, A. P. and Ellis, B. R. (1983) 'On predicting the response of tall buildings to wind excitation', *Journal of Wind Engineering and Industrial Aerodynamics* 13: 173–82.

Pretlove, A. J., Rainer, J. H. and Bachmann, H. (1995) 'Pedestrian bridges', in *Vibration Problems in Structures*, Basel: Birkhäuser Verlag.

Standards Australia (1994) Design of steel lattice towers and masts. Standards Australia, North Sydney, Australian Standard AS3995-1994.

Wyatt, T. A., (1984) 'Sensitivity of lattice towers to fatigue induced by wind gusts', *Engineering Structures* 6: 262–7.