REVIEW OF RESPONSE TO GUSTING WIND

The peak value of a random process is:

$$\hat{y} = \bar{y} + g\sigma_y$$

where $\hat{y}$ = the peak value
$\bar{y}$ = the mean value
g = the peak factor
σ_y = the RMS or standard deviation

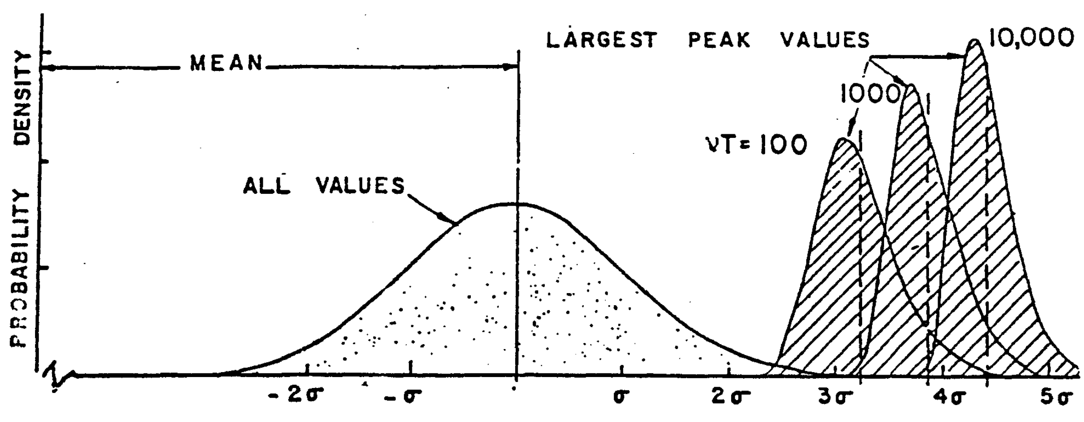

Fig. 8.15 Probability distributions of all values and peak values

The peak factor is:

$$g = \sqrt{2\log_e \nu T} + \frac{0.5772}{\sqrt{2\log_e \nu T}} \qquad (8.36)$$

The cycling rate, or apparent frequency of the process is:

$$\nu = \sqrt{\frac{\int_0^\infty f^2 S(f)df}{\int_0^\infty S(f)df}} \quad \text{(Hz)} \qquad (8.34)$$

$\nu \approx f_o$ for a narrow-band process (Hz)

Point Structures

A point structure is one where the size of the structure is much less than the wavelength of the turbulence, i.e. $\sqrt{A} << \lambda(f)$.

The drag force as a function of time is:

$$F_D(t) = \frac{1}{2}\rho C_D A V^2(t) = \frac{1}{2}\rho C_D A\left[\overline{V} + v(t)\right]^2 \tag{9.1}$$

and $\overline{V} >> v(t)$ so,

$$F_D(t) = \frac{1}{2}\rho C_D A\overline{V}^2 + \rho C_D A\overline{V}v(t) \qquad (9.2,\ 9.3)$$

The drag force as a function of time is equal to the mean drag force plus a fluctuating component. This is a linearization of the general non-linear equation describing the load due to turbulent wind.

The spectrum of force is equal to:

$$S_F = \frac{4\overline{F}_D^2}{\overline{V}^2} S_v(f) \tag{9.5}$$

Large Structures

Real structures have characteristic lengths of the same order of that of the turbulence, so this approximation will be overly conservative. The instantaneous wind induced pressures are not fully correlated over the frontal area of the body, so and “Aerodynamic Admittance” is introduced which takes this lack of spatial correlation into account.

$$S_F = \frac{4\overline{F}_D^2}{\overline{V}} \left|\chi\left(\frac{fL}{\overline{V}}\right)\right|^2 S_v(f) \tag{9.7}$$

The argument: $fL/\overline{V}$ a measure of the size of the structure ($L = \sqrt{A}$) to the wavelength of the gust ($\overline{V}/f = \lambda_f$)

$$\left|\chi\left(\frac{\sqrt{A}}{\lambda_f}\right)\right|^2 \to 1 \text{ as } \frac{\sqrt{A}}{\lambda_f} \to 0 \quad \text{and} \quad \left|\chi\left(\frac{\sqrt{A}}{\lambda_f}\right)\right|^2 \to 0 \text{ as } \frac{\sqrt{A}}{\lambda_f} \to \infty$$

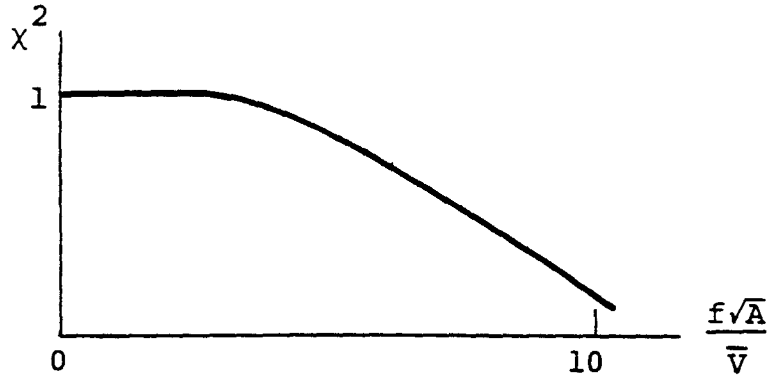

Fig.9.1 The Aerodynamic Admittance Function

National Building Code of Canada

Gust Factor Approach:

The peak response is related to the mean response via the gust effect factor:

$$\hat{y} = C_g \bar{y}$$

We have previously defined the peak response through a peak factor:

$$\hat{y} = \bar{y} + g\sigma_y = \bar{y}\left(1 + g\,\sigma_y / \bar{y}\right)$$

$$\text{so, } C_g = 1 + g\,\sigma_y / \bar{y}$$

The NBCC has a procedure for evaluating C_g with the following assumptions:

i) Simple shapes of buildings
ii) 1st sway mode of the building, linear with height
iii) Mass distribution is constant with height
iv) Only drag is considered

The NBCC Approach:

A pressure is applied to the exterior surface of the structure which is of the form:

$$P = qC_g\left[(C_eC_p)_{front} - (C_eC_p)_{back}\right]$$

where: P = the pressure

$q = \frac{1}{2}\rho\overline{V}^2_{ref}$ = the mean reference velocity pressure

C_g the gust effect coefficient

C_e the exposure factor

C_p the Aerodynamic Pressure Coefficient

$$C_g = 1 + g_p\left(\sigma/uU\right)$$

and

$$\left(\sigma/u\right) = \sqrt{\frac{K}{C_e}\left(B + \frac{SF}{\beta}\right)} \qquad (6)$$

The wind-induced displacements are:

$$\sigma_y = \overline{U}\sqrt{\frac{K}{C_e}\left(B + \frac{SF}{\beta}\right)}$$

so, the wind-induced accelerations are:

$$|\ddot{y}| = (2\pi f)^2|y|$$

and since $\sigma_y^2 = \sigma_{yB}^2 + \sigma_{yR}^2$, then, by analogy, $\sigma_{\ddot{y}}^2 = \sigma_{\ddot{y}B}^2 + \sigma_{\ddot{y}R}^2$

and the background and resonant components were:

$$\sigma_{\ddot{y}B}^2 = \frac{1}{K^2}\int_0^\infty (2\pi f)^4 S_F(f)df$$

$$\sigma_{\ddot{y}R}^2 = \frac{1}{K^2}(2\pi f_o)^4\frac{\pi}{4D}f_oS_F(f) \quad \text{and } \sigma_{\ddot{y}B}^2 << \sigma_{\ddot{y}R}^2$$

Now, back to the NBCC:

$$\sigma_{\ddot{y}} \cong (2\pi f_o)^2 \sigma_{yR}$$
$$\cong (2\pi f_o)^2 \bar{y} \sqrt{\frac{K}{C_e} \frac{sF}{\beta}}$$

the peak acceleration is:

$$\hat{a} \cong g_p \sigma_{\ddot{y}}$$
$$\cong (2\pi f_o)^2 g_p \bar{y} \sqrt{\frac{K}{C_e} \frac{sF}{\beta}}$$

and $\bar{y} = \hat{y} / C_g$

so:

$$\hat{\ddot{y}} = \hat{a} = (2\pi f_o)^2 g_p \frac{\hat{y}}{C_g} \sqrt{\frac{K}{C_e} \frac{sF}{\beta}} \qquad (8)$$