The response of slender, line-like, structures to a gusty wind

by

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Dr T. A. Wyatt (Imperial College of Science and Technology) considered that the Paper marked a great step forward in understanding wind effects on this type of structure, and was of particular interest in conjunction with developments reported at the recent Conference on Wind Effects on Structures held at the National Physical Laboratory. Professor Davenport had then suggested¹³ that the lateral scale of longitudinal gusts be taken as only 1/30 of the wavelength. This reduced the predicted effects, but before considering this further Dr Wyatt wished to raise two points concerning Table 1 of the Paper.

77. First, the third column of Table 1, headed K , would appear to represent K/W , where W was the weight (mg) per unit length of the cable, a stiffness parameter defined by the last equation in § 20.

78. Secondly, the fact that the cable was 200 ft above ground had apparently been neglected. Assuming the specified mean velocity of 100 ft/sec to apply at the actual height, the mean velocity at the standard height by which the gustiness was determined would have been only 66 ft/sec. The column marked (1) in Table 1 was thus slightly amended, but the values in column (5), etc, were considerably reduced since P in the denominator remained the value for 100 ft/sec. As an example, the first horizontal mode would become $\sigma(Y)=7.8$ feet.

79. With the horizontal scale of turbulence reduced to 1/30 of the wavelength, the value for the first horizontal mode became $\sigma(Y)=3.8$ ft, giving a predicted maximum deflexion in this mode of 14 ft.

80. The horizontal force applied to the supporting tower was of particular interest to the engineer. This could be deduced from Table 1, since this force was approximately equal to the product of the mean cable tension with the horizontal deflexion angle θ , say. The variance of θ could be evaluated, since for each mode:

$$\theta_r = \frac{r\pi}{l} Y_r, \text{ and}$$

peak horizontal load $= D \cdot \frac{Wl}{2} + g\sigma\left(\frac{\theta l}{\pi}\right) \frac{\pi}{4f} \frac{Wl}{2}$ where D =drag force per unit weight and f =dip.

81. For the example given in the Paper, with turbulence scale 1/30, the peak horizontal force on the tower thus calculated was only 15% greater than the mean value.

82. This was a very small increase, but observations on long span cables were roughly in agreement. Professor Davenport's warnings concerning high wind-loading effects on structures that are more susceptible to gusts were thus based on methods that could also show low values of loading in appropriate circumstances.

The Author replied that Dr Wyatt's comments were much appreciated and raised interesting points of discussion. The Author was in complete agreement with the

amendments suggested by Dr Wyatt to the worked example. With these taken into account the peak deflexions were as follows:

	Mode	Peak deflexion, ft
Horizontal	1st	15
	2nd	4
Vertical	1st	2
	2nd	1

84. With the mean deflexion of 85 ft the ratio of the overall maximum deflexion to the mean was 1.15, as noted by Dr Wyatt. This corresponded to a conventional velocity gust factor of 1.08 on the hourly mean velocity, which was appreciably less than those conventionally employed. As Dr Wyatt had commented, this gust factor would also apply to the supporting tower structure (setting aside any possibility of resonance at higher modes of vibration between the line vibrations and the tower).

85. It was of some interest to generalize these results to apply to other cable spans. On the strength of the formulas given in the Paper it was found that, for the practical range of cables and spans, the normalized standard deviation of the response could be written:

$$\frac{\sigma(Y)}{\bar{Y}} \approx F \cdot \frac{D^{\frac{1}{2}}}{l^{\frac{1}{2}}} \cdot \frac{K^{\frac{1}{2}}}{C_D^{\frac{1}{2}}} \cdot \rho_{\text{cable}}^{\frac{1}{2}} \left(\frac{33}{h} \right)^{\frac{1}{2}} \frac{\bar{V}^{\frac{1}{2}}}{n^{\frac{1}{2}}},$$

where

D/l = ratio cable diameter to cable span;

K = ground surface drag coefficient;

C_D = cable drag coefficient;

ρ = cable density;

h = height of cable above ground;

$\bar{V}$ = mean wind velocity at 33 ft;

n = natural fundamental frequency of cable; and

F = a numerical factor which, for units of ft, lb, and sec, has the value of about 0.35.

86. The conventional velocity gust factor (the ratio of the effective velocity to the mean hourly velocity) could be approximated to $1 + [g(vC)/2][\sigma(Y)/\bar{Y}]$ in which $g(v^T)$ may be taken as about 4.

87. From this it may be seen that the gust factor increases with cable diameter, cable density surface roughness and mean wind velocity and decreases with increase in span, cable drag coefficient, height, and natural frequency. This expression should be of value in collating the considerable amount of empirical information amassed on the behaviour of power lines in the wind.

REFERENCE

13. A. G. DAVENPORT. The buffeting of structures by gusts. *Conf. Wind Effects on Structures*. National Physical Laboratory, Teddington, 1963.

CORRIGENDA

In the original Paper:

Equation 39 should read $\dots = \frac{\bar{P}_1}{n_r \bar{V}_1} \int \dots$ instead of $\dots = \frac{\bar{P}_1}{n_r} \int \dots$

§ 66, last line, should read $\frac{2l}{c} \frac{1}{N_r^2} \int \dots$ instead of $\frac{2}{c} \frac{1}{N_r^2} \int \dots$

Table 1, fourth column heading, should read

$$\frac{n_r S_v(n_r)}{\kappa V_1^2} \quad \text{instead of} \quad \frac{n_r S_v(n_r)}{n_B V_1^2}$$

§ 73, last line, should read $\dots$ 85 ft (at the mid point).

A slightly more accurate expression for equation (43) would be

$$g(v^T) = \sqrt{(2 \log_e v^T + [0.5772/\sqrt{2 \log_e v^T}])}$$