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'Lift-curve slope' for structural response calculations

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THE PREPARATION OF THIS DATA ITEM

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'LIFT-CURVE SLOPE' FOR STRUCTURAL RESPONSE CALCULATIONS

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1. NOTATION AND UNITS

		SI Unit
A	reference area; bL for buildings and angle sections, aL for bridge decks	m^2
a	depth of section shape in along-wind direction or deck width at zero incidence	m
b	width of section shape normal to wind direction at zero incidence	m
C_D	drag coefficient; value of C_F parallel to wind direction	—
C_F	force coefficient; $F/(\frac{1}{2}\rho V_H^2 A)$	—
C_L	lift coefficient; value of C_F normal to wind direction	—
C_{FP}	value of C_F in OP principal-axis direction	—
C_{FQ}	value of C_F in OQ principal-axis direction	—
C_{FX}	value of C_F in OX body-axis direction	—
C_{FY}	value of C_F in OY body-axis direction	—
C'_X	basic force coefficient in OX direction for sharp-edged prism at zero incidence in low turbulence, uniform flow	—
C'_Y	basic force coefficient in OY direction for sharp-edged prism at 90° incidence in low turbulence, uniform flow	—
F	component of resultant mean force in plane of section in particular direction	N
H	height above ground of top of structure	m
H_B	barrier height	m
I_u	intensity of u -component of turbulence	—
I_w	intensity of w -component of turbulence	—
k_i, k_l	correction factors for effect of turbulence intensity and scale on C'_X	—
k_r	correction factor for effect of rounded edges on C'_X	—
k_s	correction factor for effect of non-uniform velocity profile on C'_X	—

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$k_{\phi x}$	correction factor for effect of incidence on C'_X	–
$k_{\phi y}$	correction factor for effect of incidence on C'_Y	–
L	length of structure; $L = H$ for buildings	m
P, Q, R	system of rectangular Cartesian co-ordinates defined along principal axes	–
r	edge radius of rectangular section	m
V	mean wind speed	m/s
X, Y, Z	system of rectangular Cartesian co-ordinates defined along body axes with OX aligned to wind direction at zero incidence	–
z	height above ground	m
α	power law index giving variation of wind speed with height; $V_z/V_H = (z/H)^\alpha$	–
ρ	air density	kg/m ³
ϕ	flow incidence to reference axis	degree

Subscripts

H	denotes value at height H
z	denotes value at height z
ϕ	denotes value at incidence ϕ
0	denotes value for $\phi = 0^\circ$
90°	denotes value for $\phi = 90^\circ$

2. BACKGROUND

ESDU 84049^{1*} and ESDU 91010² describe methods for calculating the response of structures to buffeting by across-wind turbulence components and to galloping, respectively. Both calculations require as an input the rate of change of an appropriate force coefficient with wind direction, $dC_F/d\phi$.

Although buffeting and galloping can be potential problems at any wind incidence, they most often require consideration for situations in which the wind direction is along one of the principal axes of the structure. For most regular cross-sectional shapes this wind direction will usually coincide with a body axis and often with a condition for which C_L is zero, commonly considered as the zero incidence condition. The more important response is usually that approximately normal to the mean wind direction and the relevant force coefficient is C_{FQ} .

This Item provides information on the rate of change with incidence of force coefficients in the principal axis directions for a range of building shapes of rectangular cross-section, bridge deck sections and structural member sections. Cross references are also given for structures of circular section and lattice towers.

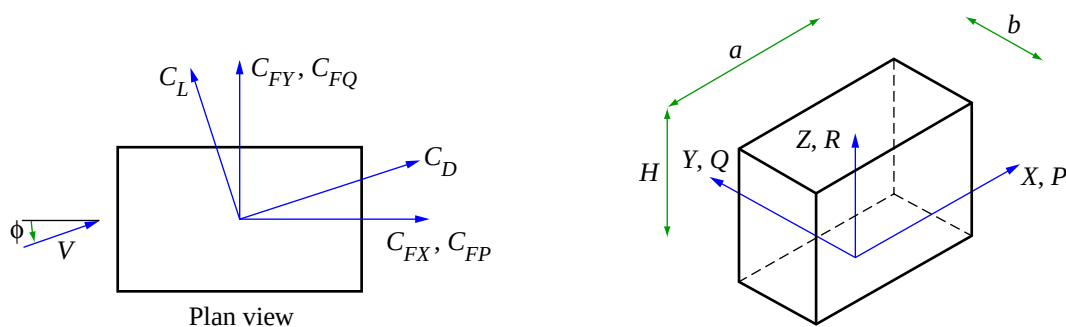
2.1 Axis Systems

The sign convention for this Item uses a right-handed coordinate system for the principal and body axes. The plan view in Sketch 3.1 shows a view along the negative $0R$ principal axis or negative $0Z$ body axis (here assumed coincident) of a building shape. For a bridge section it is assumed that the side force coefficient is C_L and for structural section shapes wind incidence and sign conventions are shown in Section 5. The side force coefficient C_{FY} or C_{FQ} is sometimes taken as positive in the opposite direction to that shown. Since the sign of $dC_F/d\phi$ is important, care should be taken to ensure that the data from this Item are compatible with the sign convention used in the calculation procedure adopted.

3. BUILDING SHAPES OF RECTANGULAR SECTION

It is assumed that the principal axes $0P$ and $0Q$ are aligned to the body axes $0X$ and $0Y$.

ESDU 80003¹¹ gives the variation of mean force coefficient with wind incidence for various building shapes of rectangular cross section. The variation of force coefficient with incidence is dependent on the side length ratio (a/b), aspect ratio (H/b), turbulence properties of the incident wind, corner radius and wind shear. The derivation of values of $dC_{FX}/d\phi$ and $dC_{FY}/d\phi$ from these data is explained in Appendix A, but for convenience values for typical configurations are summarised in Tables 3.2 and 3.3 for $\phi = 0^\circ$ and 90° and for values of $I_{uH} = 0.05, 0.1$ and 0.15 .



Sketch 3.1 Rectangular prism dimensions and force directions

* The procedure in ESDU 89049 is available as a computer program in ESDUpac B9236.

3.1 Tabulated Values of $dC_{FX}/d\phi$ and $dC_{FY}/d\phi$ for Building Shapes

The values presented in Tables 3.2 and 3.3 are evaluated for full-scale body shapes for which the corner radius is small ($r/b \approx 0$, $k_r = 1$) and for which the length scale of turbulence is large compared to the building width ($k_l \approx 1$). In uniform flow $k_s = 1$, but in practice wind speeds in the atmospheric boundary layer vary with height and for these cases k_s is less than unity and can be approximated by

$$k_s = \frac{1}{2\bar{a} + 1}. \quad (3.1)$$

Typical values of $\bar{a}$ and k_s are given in Table 3.1.

TABLE 3.1 Typical values of $\bar{a}$

Terrain	$\bar{a}$	k_s
Open sea, desert	0.13	0.79
Open country	0.16	0.76
Suburbs	0.22	0.69
Town and city centres	0.3	0.63

TABLE 3.2 Values of $\frac{1}{k_s} \frac{dC_{FX}}{d\phi}$ for building shapes*

H/b	a/b	$\phi = 0$			$\phi = 90^\circ$		
		$I_{uH} = 5\%$	$I_{uH} = 10\%$	$I_{uH} = 15\%$	$I_{uH} = 5\%$	$I_{uH} = 10\%$	$I_{uH} = 15\%$
1	0.25	-0.08	-0.09	-0.09	-3.48	-4.17	-4.14
1	0.5	-0.08	-0.10	-0.09	-3.54	-4.36	-4.20
1	1	0.25	0.28	0.26	1.51	1.75	1.62
2	0.25	-0.07	-0.08	-0.08	-3.38	-3.85	-3.68
2	0.5	-0.08	-0.09	-0.08	-3.46	-4.00	-3.61
2	1	0.27	0.30	0.27	2.52	2.80	2.53
2	2	0.74	0.91	0.88	-0.18	-0.22	-0.22
4	0.25	-0.08	-0.08	-0.07	-3.60	-3.72	-3.30
4	0.5	-0.08	-0.08	-0.07	-3.62	-3.74	-3.22
4	1	0.17	0.18	0.16	1.81	1.87	1.66
4	2	0.76	0.87	0.79	1.53	1.76	1.59
4	4	0.72	0.86	0.85	1.45	1.73	1.72
8	0.25	-0.09	-0.08	-0.07	-3.92	-3.72	-3.28
8	0.5	-0.09	-0.09	-0.08	-4.27	-4.04	-3.56
8	1	0.20	0.19	0.16	2.05	1.94	1.71
8	2	0.81	0.84	0.72	1.64	1.70	1.46
8	4	0.72	0.82	0.79	1.46	1.66	1.59

TABLE 3.3 Values of $\frac{1}{k_s} \frac{dC_{FY}}{d\phi}$ for building shapes*

H/b	a/b	$\phi = 0$			$\phi = 90^\circ$		
		$I_{uH} = 5\%$	$I_{uH} = 10\%$	$I_{uH} = 15\%$	$I_{uH} = 5\%$	$I_{uH} = 10\%$	$I_{uH} = 15\%$
1	0.25	-1.45	-1.73	-1.72	-0.72	-0.86	-0.85
1	0.5	0.18	0.22	0.22	-0.74	-0.91	-0.88
1	1	-1.51	-1.75	-1.62	-0.25	-0.28	-0.26
2	0.25	-1.46	-1.66	-1.59	-0.72	-0.82	-0.79
2	0.5	-1.53	-1.76	-1.59	-0.76	-0.87	-0.79
2	1	-2.52	-2.80	-2.53	-0.27	-0.30	-0.27
2	2	3.54	4.36	4.20	0.08	0.10	0.09
4	0.25	-1.49	-1.54	-1.37	-0.74	-0.76	-0.68
4	0.5	-1.64	-1.70	-1.46	-0.81	-0.84	-0.72
4	1	-1.81	-1.87	-1.66	-0.17	-0.18	-0.16
4	2	3.46	4.00	3.61	0.08	0.09	0.08
4	4	3.48	4.17	4.14	0.08	0.09	0.09
8	0.25	-1.47	-1.39	-1.23	-0.73	-0.69	-0.61
8	0.5	-1.81	-1.72	-1.51	-0.90	-0.85	-0.75
8	1	-2.05	-1.94	-1.71	-0.20	-0.19	-0.16
8	2	3.62	3.74	3.22	0.08	0.08	0.07
8	4	3.38	3.85	3.68	0.07	0.08	0.08

* Note that values in the Table must be multiplied by the factor k_s (Table 3.1) to obtain values of $dC_F/d\phi$.