

Loading for buildings —

Part 2: Code of practice for wind loads

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Committees responsible for this British Standard

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Foreword

This Part of this British Standard has been prepared by Subcommittee B/525/1, Actions (loadings) and basis of design, and supersedes BS 6399-2:1995.

This Part of BS 6399 is only applicable to sites in the UK. The climate dependent factors (for altitude, direction, season and probability) have been calibrated specifically for the UK. While the general methodology and pressure coefficients given in this standard may be used in other wind climates, it is essential to ensure that the reference wind data are consistent with the assumptions in this standard. The value of the site wind speed V_s should be obtained from the relevant meteorological authority. When the reference wind speed for the site is given as a peak gust, the hourly mean value for the site may be obtained by dividing the peak gust by the factor in Table 4, for the reference terrain and height above ground. When reference wind speeds apply to locations other than the site, expert advice will generally be needed. It should also be noted that adjustments to partial factors on loading may be necessary depending on:

- a) the probability factors implied in the data given; and
- b) whether or not the site is subject to hurricanes or typhoons.

BS 6399-2:1995 was a technical revision of CP3:Chapter V:Part 2 (now withdrawn) which incorporated the considerable advances made and experience gained in wind engineering since that time.

Changes introduced by Amendment 1 to this part of BS 6399 include: closer alignment of the pressure coefficients for pitched roofs in the standard method with those for the directional method; changes to the pressure coefficients for walls including the introduction of net pressure coefficients for estimating overall loads on buildings; reduction factors for free standing walls and parapets depending on their length to height ratios; clearer text for the clause dealing with asymmetry of wind loading. Opportunity has also been taken to incorporate editorial changes to some clauses for better clarity.

The basic wind speed in this British Standard is given as an hourly mean value; this differs from CP3:Chapter V:Part 2 in which it was based on a 3 s gust value. However, the hourly mean basic wind speed is subsequently converted into a gust wind speed for use in design (by a gust peak factor which takes account of gust duration time, height of structure above ground and the size of the structure). The adoption of the hourly mean value for the basic wind speed is for technical reasons. Primarily it allows a more accurate treatment of topography, but it also provides the starting point for serviceability calculations involving fatigue or dynamic response of the structure. Its use is also a move towards harmonization as mean values (sometimes 10 min means) are often the basis for wind loading calculations in European and International Standards.

Structure factors are used to check whether the response of the structure can be considered to be static, in which case the use of the calculation methods in this standard is appropriate. If the response is found to be mildly dynamic the methods can still be used but the resulting loads will need to be augmented. Structures which are dynamic will also be identified but their assessment is outside the scope of the standard.

Two alternative methods are given:

- a) a standard method, which uses a simplified procedure;
- b) a directional method, from which the simplified method was derived.

The standard method generally gives a conservative result within its range of applicability. Calibration has shown that loads on typical buildings obtained by the standard method are around 14 % larger than obtained from the directional method. The degree of conservatism can be much larger close to the ground and in towns, but decreases to zero around 100 m above the ground.

In addition to reduced conservatism, the directional method assesses the loading in more detail, but with the penalty of increased complexity and computational effort. Because of this it is anticipated that the standard method will be used for most hand-based calculations and that the directional method will be implemented principally by computer.

Procedures are also given to enable the standard effective wind speed to be used with the directional pressure coefficients and for the directional effective wind speeds to be used with the standard pressure coefficients.

CP3:Chapter V:Part 2 allowed for the effect of ground roughness, building size and height above ground by a single factor. This required the calculation of separate wind speeds for every combination of reference height above ground and the size of the loaded area. However, a simplification has been introduced in the standard method which involves the calculation of only a single wind speed for each reference height. The effect of size is allowed for by a separate factor, C_a .

BS 6399-2 also gives values for external pressure coefficients for a greater range of building configurations than did CP3:Chapter V:Part 2.

This new edition introduces Annex G in which empirical equations are provided to enable the topographic location factor (s) to be calculated. Also given are tables which have been derived directly from the equations which will be useful as an accuracy check to those wishing to implement the equations into computer software.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 115 and a back cover.

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Section 1. General

1.1 Scope

This Part of BS 6399 gives methods for determining the gust peak wind loads on buildings and components thereof that should be taken into account in design using equivalent static procedures.

Two alternative methods are given:

- a) a standard method which uses a simplified procedure to obtain a standard effective wind speed which is used with standard pressure coefficients to determine the wind loads for orthogonal design cases.

NOTE 1 This procedure is virtually the same as in CP3:Chapter V:Part 2.

- b) a directional method in which effective wind speeds and pressure coefficients are determined to derive the wind loads for each wind direction.

Other methods may be used in place of the two methods given in this standard, provided that they can be shown to be equivalent. Such methods include wind tunnel tests which should be taken as equivalent only if they meet the conditions defined in Annex A.

NOTE 2 Wind tunnel tests are recommended when the form of the building is not covered by the data in this standard, when the form of the building can be changed in response to the test results in order to give an optimized design, or when loading data are required in more detail than is given in this standard.

Specialist advice should be sought for building shapes and site locations that are not covered by this standard.

The methods given in this Part of BS 6399 do not apply to buildings which, by virtue of the structural properties, e.g. mass, stiffness, natural frequency or damping, are particularly susceptible to dynamic excitation. These should be assessed using established dynamic methods or wind tunnel tests.

NOTE 3 See references [1] to [4] for examples of established dynamic methods.

NOTE 4 If a building is susceptible to excitation by vortex shedding or other aeroelastic instability, the maximum dynamic response may occur at wind speeds lower than the maximum.

1.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this British Standard the following definitions apply.

1.3.1 Wind speed

1.3.1.1

basic wind speed

the hourly mean wind speed with an annual risk Q of being exceeded of 0.02, irrespective of wind direction, at a height of 10 m over completely flat terrain at sea level that would occur if the roughness of the terrain was uniform everywhere (including urban areas, inland lakes and the sea) and equivalent to typical open country in the United Kingdom

1.3.1.2

site wind speed

the basic wind speed modified to account for the altitude of the site and the direction of the wind being considered (and the season of exposure, if required)

NOTE In the standard method only, effects of topographic features are included in the site wind speed.

1.3.1.3

effective wind speed

the site wind speed modified to a gust speed by taking account of the effective height, size of the building or structural element being considered and of permanent obstructions upwind

NOTE In the directional method only: the effects of topographic features are omitted from the site wind speed.

1.3.2 Pressure

1.3.2.1

dynamic pressure

the potential pressure available from the kinetic energy of the effective wind speed

1.3.2.2

pressure coefficient

the ratio of the pressure acting on a surface to the dynamic pressure

1.3.2.3

external pressure

the pressure acting on an external surface of a building caused by the direct action of the wind

1.3.2.4

internal pressure

the pressure acting on an internal surface of a building caused by the action of the external pressures through porosity and openings in the external surfaces of the building

1.3.2.5

net pressure

the pressure difference between opposite faces of a surface

1.3.3 Height

1.3.3.1

altitude

- a) when topography is not significant: the height above mean sea level of the ground level of the site;
- b) when topography is significant: the height above mean sea level of the base of the topographic feature.

1.3.3.2

building height

the height of a building or part of a building above its base

1.3.3.3

reference height

the reference height for a part of a structure is the datum height above ground for the pressure coefficients and is defined with the pressure coefficients for that part

1.3.3.4

obstruction height

the average height above ground of buildings, structures or other permanent obstructions to the wind immediately upwind of the site

1.3.3.5

effective height

the height used in the calculations of the effective wind speed determined from the reference height with allowance for the obstruction height

1.3.4 Length

1.3.4.1

building length

the longer horizontal dimension of a building or part of a building¹⁾

1.3.4.2

building width

the shorter horizontal dimension of a building or part of a building¹⁾

¹⁾ For complex plan shapes, these lengths may be determined from the smallest enclosing rectangle or circle.

1.3.4.3**crosswind breadth**

the horizontal extent of a building or part of a building normal to the direction of the wind²⁾

1.3.4.4**inwind depth**

the horizontal extent of a building or part of a building parallel to the direction of the wind²⁾

1.3.4.5**diagonal dimension**

the largest diagonal dimension of a loaded area, i.e. the dimension between the most distant points on the periphery of the area

1.3.4.6**scaling length**

a reference length determined from the proportions of the building used to define zones over which the pressure coefficient is assumed to be constant

1.3.5 Distance**1.3.5.1****fetch**

the distance from the site to the upwind edge of each category of terrain, used to determine the effect of terrain roughness changes

1.4 Main symbols

For the purposes of this Part of BS 6399 the following symbols apply.

A	Area (2.1.3.5)
A_s	Area swept by wind (2.1.3.8)
a	Largest diagonal dimension of the loaded area envelope (Figure 5)
B	Crosswind breadth of building [Figure 2b)]
b	Scaling length used to define loaded areas for pressure coefficients (2.4.1.3, 2.5.1.2)
C_a	Size effect factor of standard method (2.1.3.4)
C_f	Frictional drag coefficient (2.1.3.8)
C_p	Net pressure coefficient (2.1.3.3)
C_{pe}	External pressure coefficient (2.1.3.1)
C_{pi}	Internal pressure coefficient (2.1.3.2)
C_r	Dynamic augmentation factor (1.6.1)
D	Inwind depth of building [Figure 2b)]
d	Diameter of circular cylinders (2.4.6)
G	Gap across recessed bay or well (Figure 34)
g_t	Gust peak factor (3.2.3.3)
H	Building height (Figure 2), ridge height, eaves height or height of inset or lower storey
H_d	Displacement height (1.7.3.3, E.2)
H_e	Effective height (1.7.3)
H_r	Reference height (1.7.3)
H_o	Obstruction height (1.7.3, Figure 2), or average height of roof tops of buildings or height of other permanent obstructions upwind of the building
h	Parapet height (2.5.1.4, Figure 17), free-standing wall height (2.8.1.4, Figure 23), or signboard height (2.8.2, Figure 24)

²⁾ For complex plan shapes, these lengths may be determined from the smallest enclosing rectangle or circle.

K_b	Building-type factor (1.6.1)
L	Building length (Figure 2) or length of element between free ends (2.7.3)
L_D	Length of downwind slope of topographic feature (2.2.2.2.5, Figure 8)
L_e	Effective slope length of topographic feature (2.2.2.2.4)
L_U	Length of upwind slope of topographic feature (2.2.2.2.4, Figure 8)
P	Net load (2.1.3.5)
P_f	Frictional drag force (2.1.3.8)
p	Net pressure (2.1.3.3)
p_e	Pressure on external surface (2.1.3.1)
p_i	Pressure on internal surface (2.1.3.2)
Q	Annual risk (probability) of the basic wind speed being exceeded (2.2.2.4, 2.2.2.5,)
q	Dynamic pressure (3.1.2.1)
q_e	Dynamic pressure of directional method for external pressures (3.1.2.2)
q_i	Dynamic pressure of directional method for internal pressures (3.1.2.2)
q_s	Dynamic pressure of standard method (2.1.2)
r	Radius (Figure 17)
S_a	Altitude factor (2.2.2.2)
S_b	Terrain and building factor (2.2.3.1)
S_c	Fetch factor (3.2.3.2)
S_d	Direction factor (2.2.2.3)
S_h	Topographic increment (3.2.3.4)
S_p	Probability factor (2.2.2.5)
S_s	Seasonal factor (2.2.2.4)
S_t	Turbulence factor (3.2.3.2)
s	Topographic location factor (2.2.2.2)
T_c	Fetch adjustment factor (3.2.3.2)
T_t	Turbulence adjustment factor (3.2.3.2)
V_b	Basic wind speed (2.2.1, Figure 6)
V_e	Effective wind speed (2.2.3, 3.2.3)
V_s	Site wind speed (2.2.2)
W	Building width (Figure 2)
w	Width of wedge in re-entrant corners (Figure 33)
X	Distance of site from crest of topographic feature (2.2.2.2.5, Figure 8)
X_0	Separation distance between buildings
Z	Height of crest of topographic feature above the upwind base altitude (Figure 8)
α	Pitch angle (from horizontal) of roof (2.5) or non-vertical walls (3.3.1.4)
β	Corner angle of walls (3.3.1.2)
Δ_S	Site altitude in metres above mean sea level (2.2.2.2)
Δ_T	Altitude of upwind base of topographic feature in metres above mean sea level (2.2.2.3)
κ	Reduction factor for length of elements (2.7.3)
ψ	Average slope of the ground
ψ_e	Effective slope of topographic feature (2.2.2.2.4)
ψ_D	Tangent of downwind slope of topographic feature (Figure 7)
ψ_U	Tangent of upwind slope of topographic feature (Figure 7, 2.2.2.2.4)
φ	Wind direction in degrees east of north (2.2.2.3)

- ζ Solidity ratio of walls or frames (2.8) or blockage ratio of canopies (2.5.9, Figure 24)
- θ Wind direction of degrees from normal to building faces (Figure 2) or angle around periphery of circular-plan building (2.4.6)

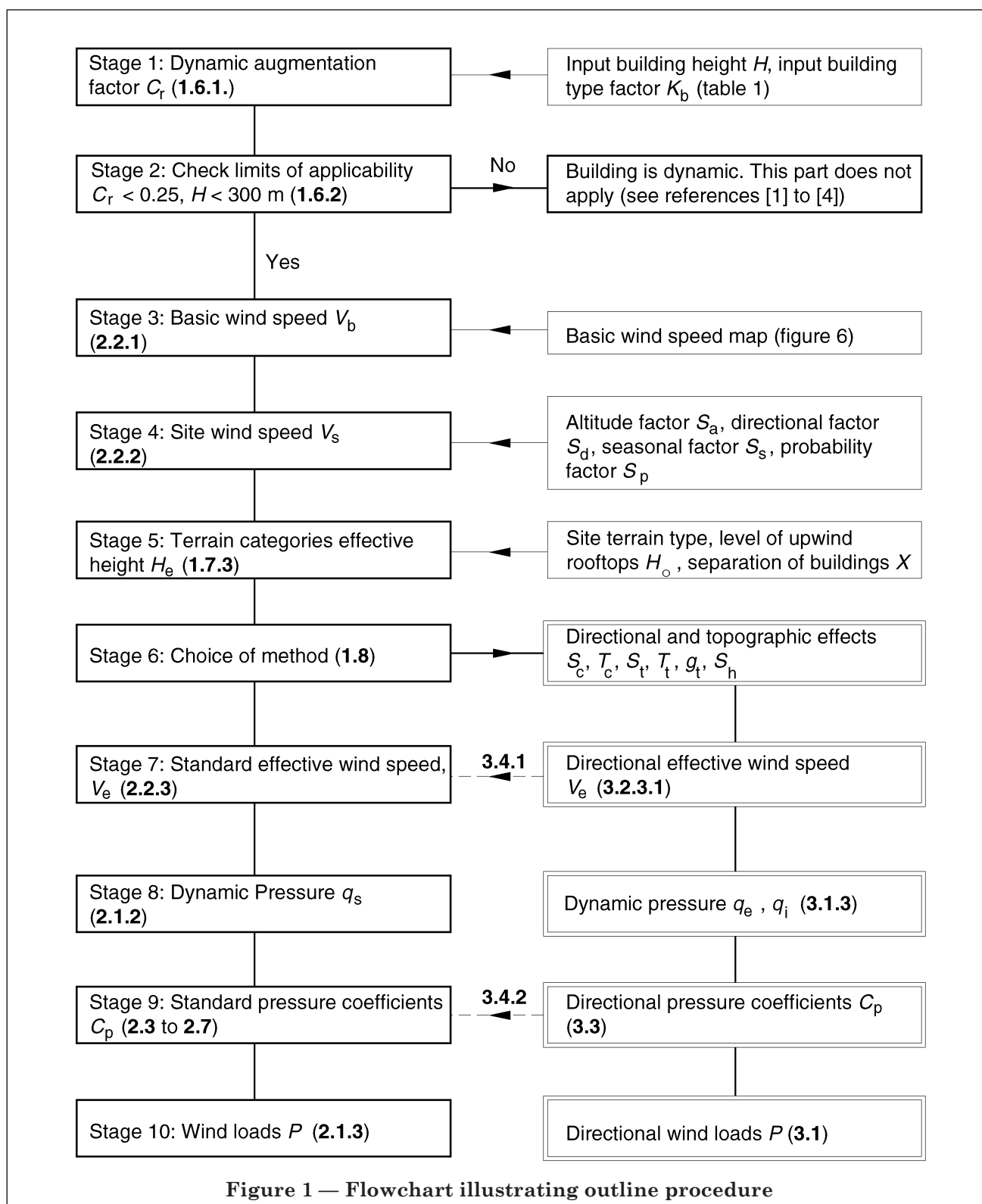
1.5 Outline of procedure for calculating wind loads

1.5.1 The outline of procedure is illustrated in the flowchart given in Figure 1. This shows the stages of the standard method, together with the relevant clause numbers, as the boxes outlined and connected by thick lines. The stages of the directional method are shown as boxes outlined with double lines and are directly equivalent to the stages of the standard method. Various input data are shown in boxes outlined with single lines.

1.5.2 The wind loads should be calculated for each of the loaded areas under consideration, depending on the dimensions of the building, defined in Figure 2. These may be:

- a) the structure as a whole;
- b) parts of the structure, such as walls and roofs;
- or
- c) individual structural components, including cladding units and their fixings.

NOTE Wind load on a partially completed structure may be critical and will be dependent on the method and sequence of construction.



Notes to Figure 1

Stage 1: Determines the dynamic augmentation factor from the basic geometric and structural properties of the building.

Stage 2: Depending on this value, a check is performed on the level of dynamic excitation to determine:

- a) whether the methods given in this Part of BS 6399 apply and the assessment may proceed; or
- b) whether the methods given in this Part of BS 6399 do not apply and the building should be assessed by one of the methods for dynamic buildings (see references [1] to [4]) or by wind tunnel tests (see Annex A).

Stage 3: Determines the basic hourly mean wind speed from the map for the UK.

Stage 4: Determines a site wind speed, still corresponding to the hourly mean wind speeds at a height of 10 m above ground in the standard exposure, from the basic wind speed by applying corrections for the site altitude, wind direction and season. Up to this point, no allowance for the exposure of the particular site has been made and the procedure is common (except in its treatment of the effects of topography) to both the standard and directional method.

NOTE The derivations of the basic wind speed map, the adjustments for site altitude, wind direction and season are given in Annex B.

Stage 5: Assesses the exposure of the site in terms of the terrain roughness and the effective height. Three categories of terrain roughness are used to define the site exposure. The effective height depends on the degree of shelter provided by neighbouring buildings or other permanent obstructions.

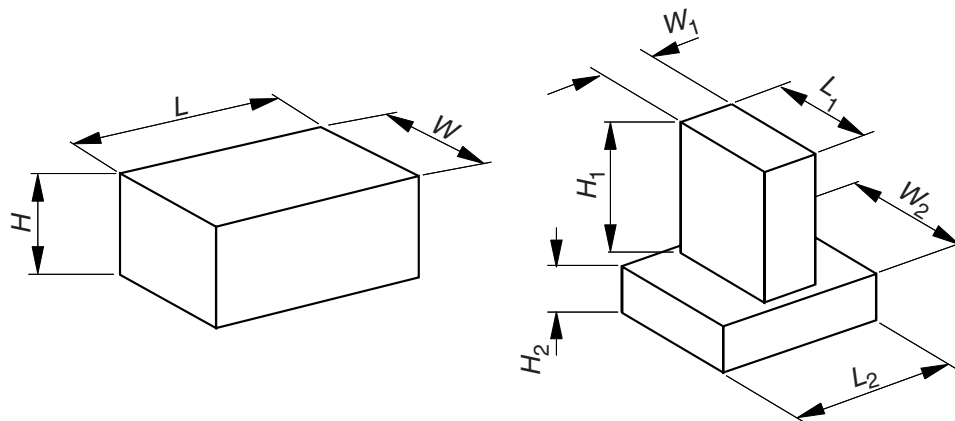
Stage 6: Having assessed the exposure of the site, this stage offers the choice between the standard method and the directional method. The standard method gives conservative values for standard orthogonal load cases, and a simplified method for buildings up to 100 m in height and for significant topography. The directional method gives a more precise value for any given wind direction, particularly for sites in towns, and where topography is significant. A simple rule for assessing the significance of topography is provided.

Stage 7: Determines the effective wind speeds required by either method. The effective wind speed is a gust wind speed appropriate to the site exposure and the height of the building. In the standard method this corresponds to a datum size of loaded area, while in the directional method this corresponds to the size of the loaded area under consideration.

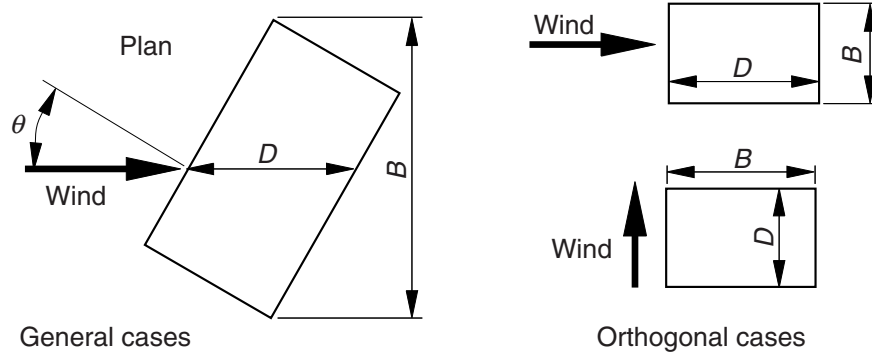
Stage 8: Converts the effective wind speed into an equivalent dynamic pressure.

Stage 9: Selects pressure coefficients corresponding to the form of the building. In the standard method these coefficients correspond to a number (usually two or three) of orthogonal load cases, while in the directional method they correspond to the wind directions being considered (usually twelve).

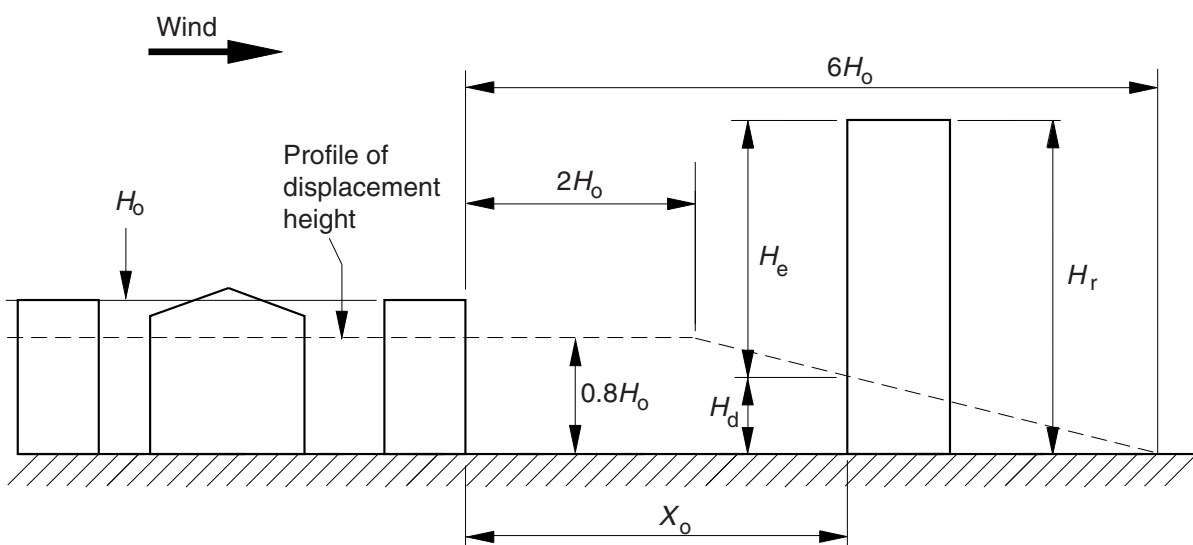
Stage 10: Determines the wind loads from the dynamic pressure, pressure coefficients, dynamic augmentation factor and, in the standard method, by the size effect factor, to give the characteristic wind load for static design.



a) Fixed dimensions: length, width, height



b) Variable dimensions: crosswind breadth, inwind depth, wind angle



c) Displacement height and effective height

Figure 2 — Basic definitions of building dimensions

1.6 Dynamic classification

1.6.1 Dynamic augmentation factor

The methods of this standard employ equivalent static loads to represent the effect of fluctuating loads which is applicable only to buildings which are not susceptible to dynamic excitation.

The standard permits equivalent static loads to be used for the design of mildly dynamic structures by the introduction of a dynamic augmentation factor. The value of this factor depends upon the actual height H of the building above ground and on a building-type factor K_b obtained from Table 1, for the form of construction of the building.

The dynamic augmentation factor C_r is given for typical buildings in Figure 3.

Table 1 — Building-type factor K_b

Type of building	K_b
Welded steel unclad frames	8
Bolted steel and reinforced concrete unclad frames	4
Portal sheds and similar light structures with few internal walls	2
Framed buildings with structural walls around lifts and stairs only (e.g. office buildings of open plan or with partitioning)	1
Framed buildings with structural walls around lifts and stairs with additional masonry subdivision walls (e.g. apartment buildings), buildings of masonry construction and timber-framed housing	0.5

NOTE The values of the factors K_b and C_r have been derived for typical building structures with typical frequency and damping characteristics, under typical UK wind speeds, without accounting for topography or terrain roughness effects. More accurate values of these factors may be derived using Annex C when the building characteristics are not typical, or when the effects of topography and terrain roughness need to be taken into account.

1.6.2 Limits of applicability

This Part of BS 6399 does not apply when the value of dynamic augmentation factor exceeds the limits shown in Figure 3. Buildings falling outside these limits should be assessed using established dynamic methods.

NOTE See references [1] to [4] for further information on analysis of dynamic structures.

1.7 Site exposure

1.7.1 General

The site wind speed V_s refers to a standard open country exposure at a height of 10 m above ground. To obtain the effective wind speed the effects of varying ground roughness, the height and distance of obstructions upwind of the site and the effects of topography should be taken into account.

1.7.2 Ground roughness categories

Three categories of terrain are considered:

- a) *sea*: the sea, and inland areas of water extending more than 1 km in the wind direction when closer than 1 km upwind of the site;
- b) *country*: all terrain which is not defined as sea or town;
- c) *town*: built up areas not less than 0.1 km upwind of the site with an average level of roof tops at least $H_o = 5$ m above ground level.

NOTE 1 Permanent forest and woodland may be treated as town category.

NOTE 2 Terrain categories are explained in more detail in Annex E.

1.7.3 Reference height, effective height and displacement height

1.7.3.1 The reference height H_r is defined for the building form in the appropriate pressure coefficient tables and definition figures, but can conservatively be taken as the maximum height of the building above ground level.

1.7.3.2 The effective height H_e may be conservatively taken as the reference height H_r .

1.7.3.3 Buildings or other permanent obstructions upwind of the site displace the wind upwards, providing shelter near the ground.

The displacement height H_d is given by:

- a) $H_d = 0.8H_0$ for $X_0 \leq 2H_0$
- b) $H_d = 1.2H_0 - 0.2X_0$ for $2H_0 < X_0 < 6H_0$
- c) $H_d = 0$ for $X_0 \geq 6H_0$

where

H_0 is the average level of rooftops of the buildings or height of other permanent obstructions upwind of the site, as defined in Figure 2c);

X_0 is the upwind spacing, as defined in Figure 2c).

The effective height H_e is determined from each reference height H_r , as:

$$H_e = H_r - H_d; \text{ or}$$

$$H_e = 0.4H_r,$$

whichever is greater.

NOTE 1 In the absence of more accurate information, the obstruction height H_0 may be estimated from the average number of storeys of upwind buildings by taking the typical storey height as 3 m. Further guidance is given in Annex E.

NOTE 2 Buildings or other permanent obstructions should extend at least 100 m upwind of the site and occupy at least 8 % of the total area within a 30° sector centred on the wind direction being considered.

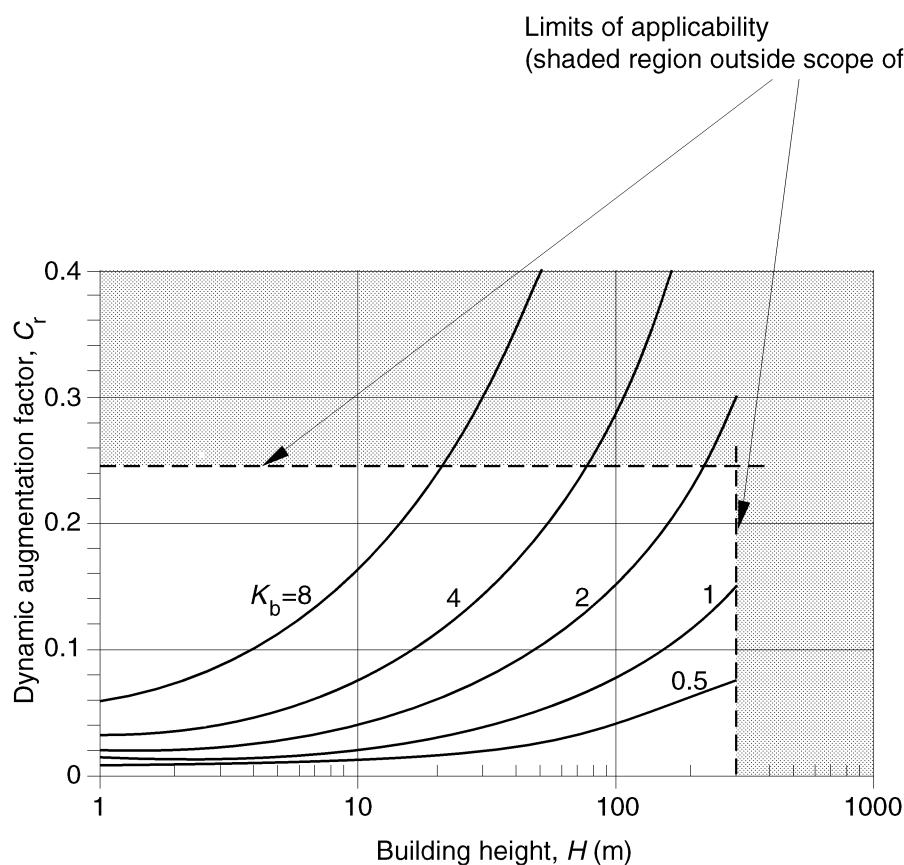


Figure 3 — Dynamic augmentation factor C_r

1.7.3.4 Accelerated wind speeds occur close to the base of buildings which are significantly taller than the average height of the roof tops of the surrounding buildings. When considering low rise buildings which are close to other tall buildings the rules for effective height will not necessarily lead to conservative values and specialist advice should be sought.

1.8 Choice of method

1.8.1 For all structures where the wind loading can be represented by equivalent static loads (see **1.6**), the wind loading can be obtained either by the standard method described in Section 2 or by the directional method given in Section 3.

1.8.2 The standard method provides values of effective wind speed to be used with the standard pressure coefficient (clauses **2.3**, **2.4** and **2.5**) to determine orthogonal load cases, corresponding to the wind direction notionally normal or parallel to the faces of the building. The standard method uses a simplified allowance for significant topography, as defined in Figure 7.

1.8.3 The directional method gives values of the effective wind speed for different wind directions, taking into account the terrain appropriate to the wind direction being considered, to be used with the directional pressure coefficients. It gives better estimates of effective wind speeds in towns and for sites affected by topography.

1.8.4 However, as the standard method gives conservative values of both effective wind speed (below 100 m) and pressure coefficient, it may sometimes be appropriate to use a hybrid combination of both methods, either:

- a) standard effective wind speeds with directional pressure coefficients; or
- b) directional effective wind speeds with standard pressure coefficients.

Combination a) is appropriate when the form of the building is well defined, but the site is not; the cases of relocatable buildings or standard mass-produced designs are typical examples. Combination b) is appropriate when only the standard orthogonal load cases are required, but a better allowance for site exposure is desired because topography is significant and/or the site is in a town. Such hybrid combinations should be applied only in accordance with **3.4**.

Section 2. Standard method

2.1 Standard wind loads

2.1.1 Wind direction

2.1.1.1 The standard method requires assessment for orthogonal load cases for wind directions normal to the faces of the building, as shown in Figure 2b). When the building is doubly-symmetric, e.g. rectangular-plan with flat, equal-duopitch or hipped roof, the two orthogonal cases shown in Figure 2b) are sufficient. When the building is singly-symmetric, three orthogonal cases are required, e.g. for rectangular-plan monopitch buildings: wind normal to high eaves; wind normal to low eaves; wind parallel to eaves. When the building is asymmetric, four orthogonal cases are required.

2.1.1.2 For each orthogonal case, the range of wind directions $\pm 45^\circ$ either side of the direction normal to the building face should be considered. When symmetry is used to reduce the number of orthogonal load cases, both opposing wind directions, e.g. $\theta = 0^\circ$ and $\theta = 180^\circ$ should be considered and the more onerous direction used.

2.1.2 Dynamic pressure

2.1.2.1 The value of the dynamic pressure q_s of the standard method is given by

$$q_s = 0.613 V_e^2 \quad (1)$$

where

q_s is the dynamic pressure (in Pa³⁾);

V_e is the effective wind speed from 2.2.3 (in m/s).

2.1.2.2 Values of dynamic pressure q_s for various values of V_e are given in Table 2.

2.1.3 Wind load

2.1.3.1 External surface pressures

The pressure acting on the external surface of a building p_e is given by

$$p_e = q_s C_{pe} C_a \quad (2)$$

where

q_s is the dynamic pressure from 2.1.2;

C_{pe} is the external pressure coefficient for the building surface given in 2.4 and 2.5;

C_a is the size effect factor for external pressures defined in 2.1.3.4.

2.1.3.2 Internal surface pressures

The pressure acting on the internal surface of a building, p_i , is given by

$$p_i = q_s C_{pi} C_a \quad (3)$$

where

q_s is the dynamic pressure from 2.1.2;

C_{pi} is the internal pressure coefficient for the building given in 2.6;

C_a is the size effect factor for internal pressures defined in 2.1.3.4.

³⁾ 1 Pa = 1 N/m²

2.1.3.3 Net surface pressures

The net pressure p acting across a surface is given by the following.

a) For enclosed buildings

$$p = p_e - p_i \quad (4)$$

where

p_e is the external pressure given in 2.1.3.1;

p_i is the internal pressure given in 2.1.3.2.

b) For free-standing canopies and building elements

$$p = q_s C_p C_a \quad (5)$$

where

q_s is the dynamic pressure from 2.1.2;

C_p is the net pressure coefficient for the canopy surface or element given in 2.5.9 and 2.7;

C_a is the size effect factor for external pressures defined in 2.1.3.4.

Table 2 — Dynamic pressure q_s (in Pa)

V_e m/s	+0	+1.0	+2.0	+3.0	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0
10	61	74	88	104	120	138	157	177	199	221
20	245	270	297	324	353	383	414	447	481	516
30	552	589	628	668	709	751	794	839	885	932
40	981	1 030	1 080	1 130	1 190	1 240	1 300	1 350	1 410	1 470
50	1 530	1 590	1 660	1 720	1 790	1 850	1 920	1 990	2 060	2 130
60	2 210	2 280	2 360	2 430	2 510	2 590	2 670	2 750	2 830	2 920

2.1.3.4 Size effect factor

The size effect factor C_a of the standard method accounts for the non-simultaneous action of gusts across an external surface and for the response of internal pressures. Values of size effect factor are given in Figure 4, dependent on the site exposure (see 1.7) and the diagonal dimension a .

For external pressures the diagonal dimension a is the largest diagonal of the area over which load sharing takes place, as illustrated in Figure 5. For internal pressures an effective diagonal dimension is defined in 2.6 which is dependent on the internal volume.

For all individual structural components, cladding units and their fixings, the diagonal dimension should be taken as $a = 5$ m, unless there is adequate load sharing capacity to justify the use of a diagonal length greater than 5 m.

2.1.3.5 Surface loads

The net load P on an area of a building surface or element is given by:

$$P = pA \quad (6)$$

where

p is the net pressure across the surface;

A is the loaded area.

Load effects, for example bending moments and shear forces, at any level in a building should be based on the diagonal dimension of the loaded area above the level being considered, as illustrated in Figure 5c).

2.1.3.6 Overall loads

The overall load P on a building is taken as the sum of the loads on individual surfaces with allowances for non-simultaneous action between faces and for mildly dynamic response.

The overall horizontal loads are given by

$$P = 0.85(\Sigma P_{\text{front}} - \Sigma P_{\text{rear}}) (1 + C_r) \quad (7)$$

where

ΣP_{front} is the horizontal component of surface load summed over the windward-facing walls and roofs;

ΣP_{rear} is the horizontal component of surface load summed over the leeward-facing walls and roofs;

C_r is the dynamic augmentation factor from 1.6.1;

NOTE 1 The factor 0.85 accounts for the non-simultaneous action between faces.

NOTE 2 As the effect of internal pressure on the front and rear faces is equal and opposite when they are of equal size, internal pressure can be ignored in the calculation of overall horizontal loads on enclosed buildings on level ground.

NOTE 3 In equation 7 ($\Sigma P_{\text{front}} - \Sigma P_{\text{rear}}$) for contribution to walls may be taken as $\Sigma q_s C_p C_a A$, where C_p is the net pressure coefficient given in Table 5a.

Where the combination of the orthogonal loads is critical to the design, for example in deriving stresses in corner columns, the maximum stresses caused by wind in any component may be taken as 80 % of the sum of the wind stresses resulting from each orthogonal pair of load cases.

2.1.3.7 Asymmetric loads

Unless specific pressure coefficients or guidance are given for particular forms of building or element [e.g. pitched roofs (see 2.5.2 and 2.5.3), free-standing canopies (see 2.5.9.1) and signboards (see 2.8.2)], an allowance for asymmetry of loading should be made.

NOTE 1 The effects of asymmetric loading may be accounted for by reducing the design wind load by 40 % on those parts of the structure where the effect of the load is beneficial.

NOTE 2 Torsional effects on buildings may be accounted for by displacing the loads on each face horizontally by 10 % of the face width from the centre of the face.

2.1.3.8 Frictional drag component

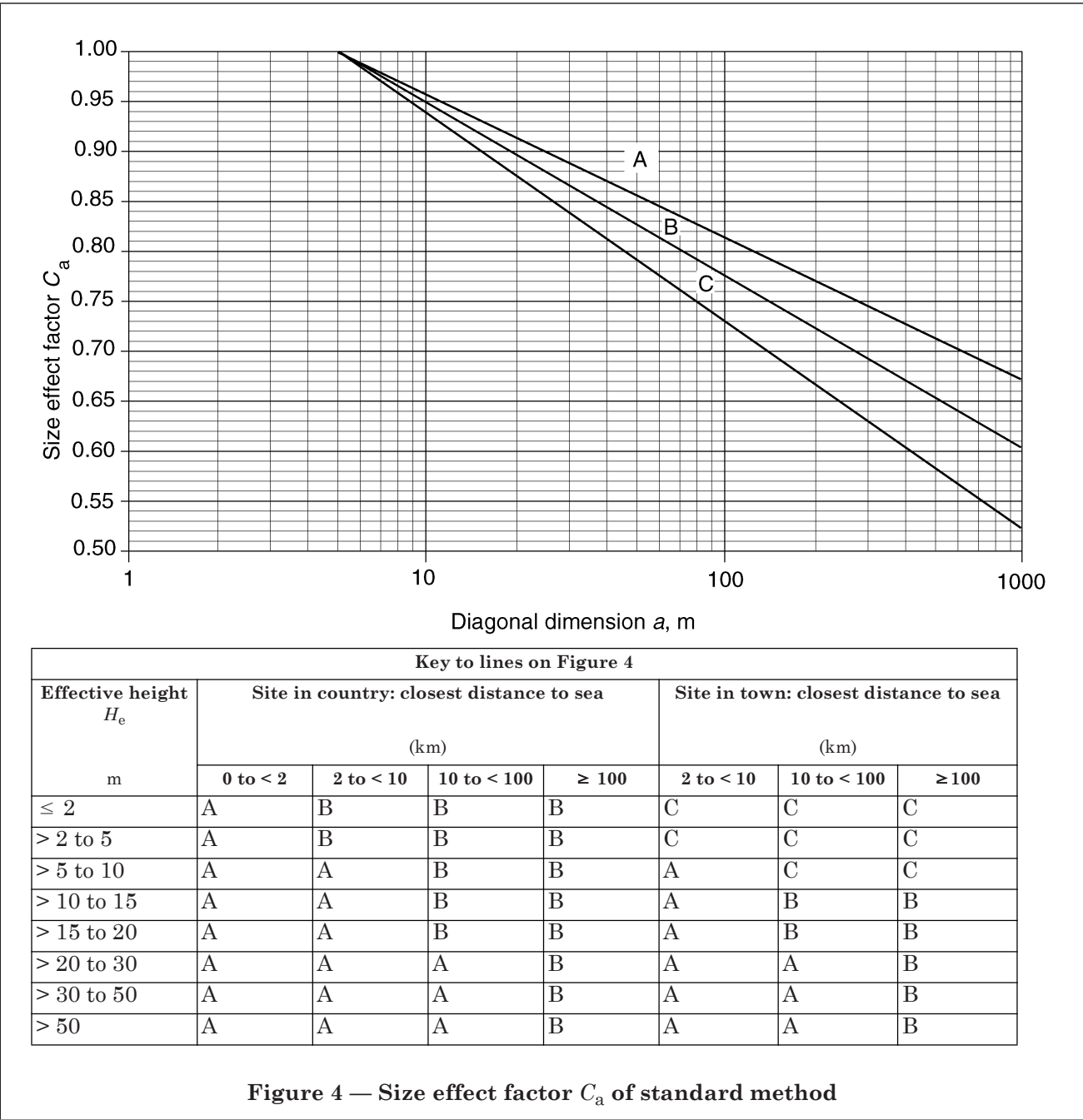
When deriving overall forces on the building (see 2.4.5 and 2.5.10) the contribution of the frictional forces P_f [see equation 7a] should be taken to act in the direction of the wind and should be added to the contribution of the normal pressure forces from 2.1.3.6 using vectorial summation.

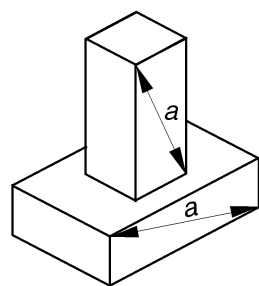
$$P_f = q_s C_f A_s C_a \quad (7a)$$

where

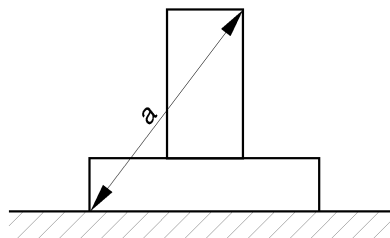
A_s is the area swept by the wind (see 2.4.5 and 2.5.10)

C_f is the frictional drag coefficient (see Table 6)

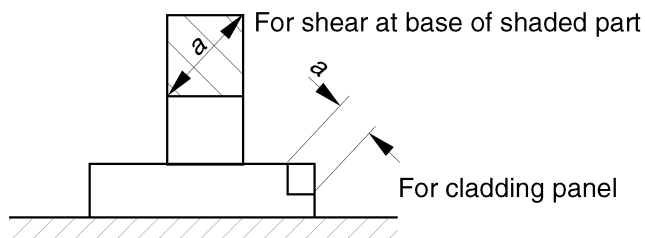




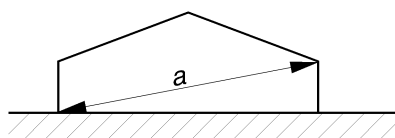
a) Diagonals for load on individual faces



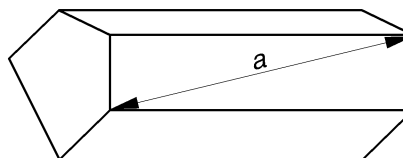
b) Diagonal for total load on combined faces



c) Diagonals for load on elements of faces



d) Diagonal for total load on gable



e) Diagonal for total load on pitch roof

Figure 5 — Definition of diagonal of loaded areas

2.2 Standard wind speeds

2.2.1 Basic wind speed

The geographical variation of basic wind speed V_b should be obtained directly from Figure 6.

NOTE The method used to derive the basic wind speed from the meteorological data is described in Annex B.

2.2.2 Site wind speed

2.2.2.1 General

The site wind speed V_s for any particular direction should be calculated from where

$$V_s = V_b \times S_a \times S_d \times S_s \times S_p \quad (8)$$

where

V_b is the basic wind speed from 2.2.1;

S_a is an altitude factor (see 2.2.2.2);

S_d is a direction factor (see 2.2.2.3);

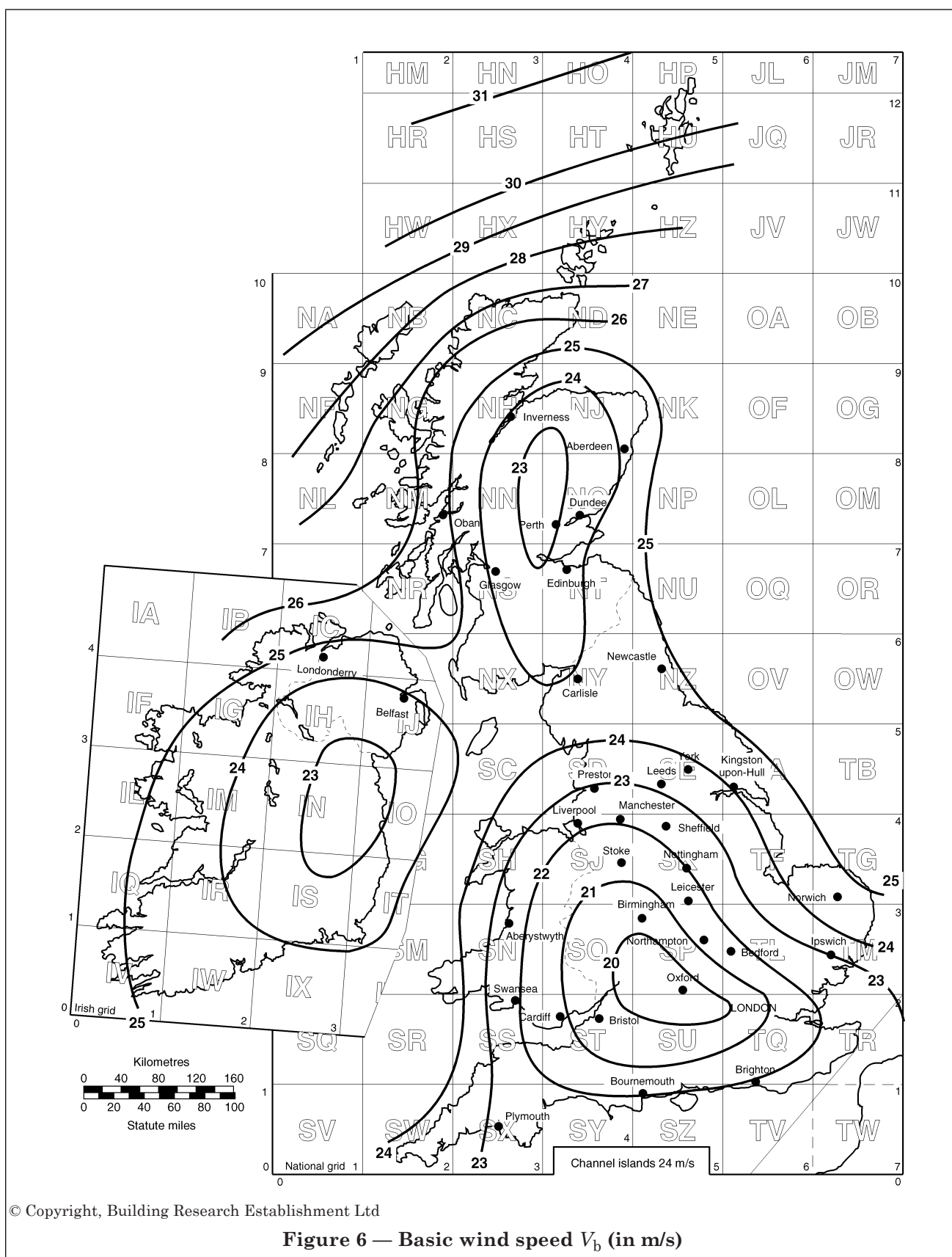
S_s is a seasonal factor (see 2.2.2.4);

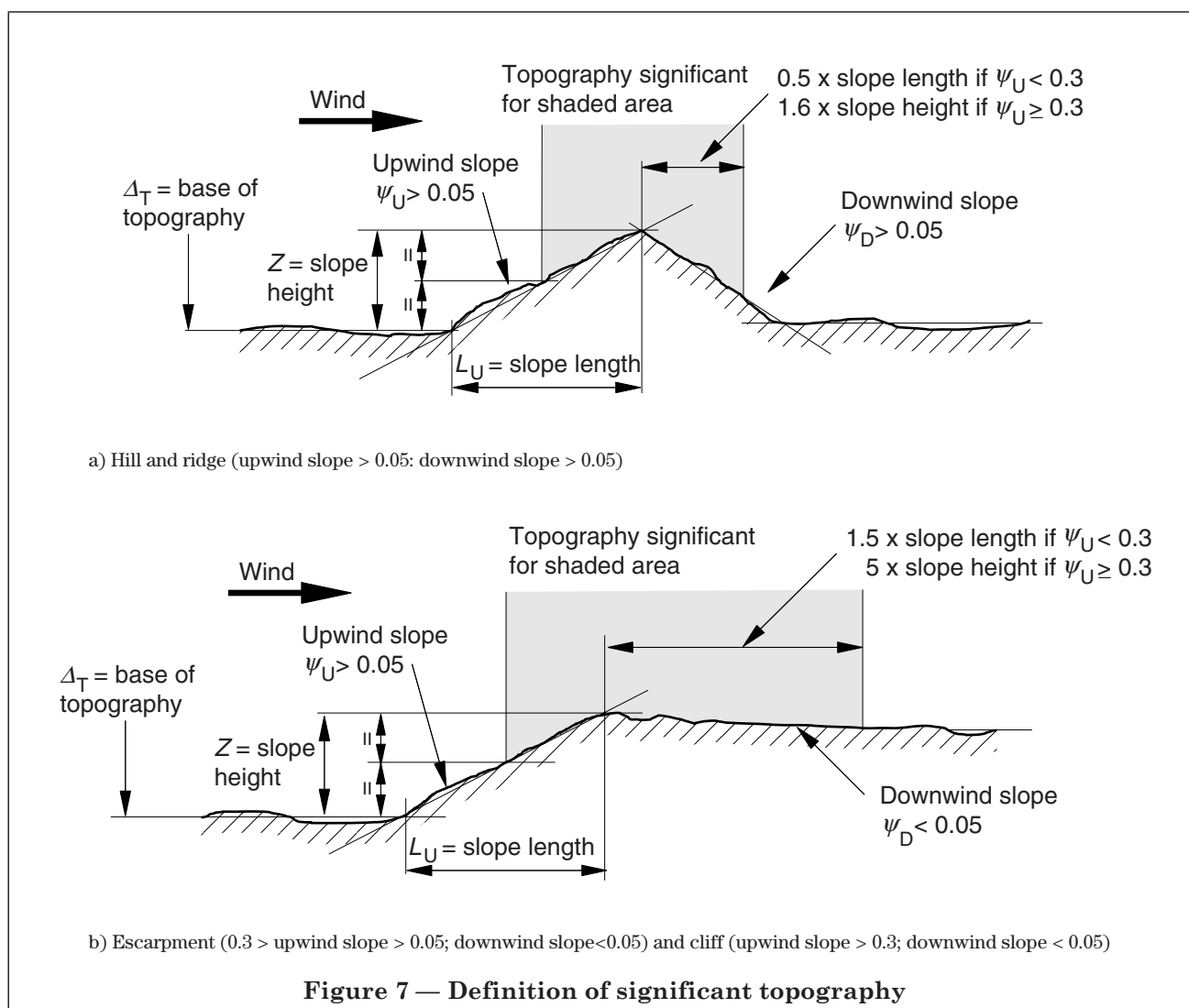
S_p is a probability factor (see 2.2.2.5).

NOTE In considering the range of wind directions $\pm 45^\circ$, in accordance with 2.1.1.2, two approaches are possible:

- a) the most onerous value of each factor in equation 8 is taken, leading to a single conservative value of V_s ;
- b) assessments of V_s are made at intervals through the range of direction and the largest value used.

In practice, option b) will not produce significantly lower values than a) unless the combination of location, exposure and topography of the site is unusual.





2.2.2.2 Altitude factor

2.2.2.2.1 The altitude factor S_a should be used to adjust the basic wind speed V_b for the altitude of the site above sea level. Its calculation in the standard method depends on whether topography is considered to be significant, as indicated by the simple criteria in Figure 7. When topography is not considered significant, S_a should be calculated using the procedure in 2.2.2.2.2. When topography is significant, S_a should be calculated using the procedure in 2.2.2.2.3 for the wind direction yielding the largest value of S_a , typically the direction with the steepest slope upwind of the site.

2.2.2.2.2 When topography is not considered significant S_a should be calculated from

$$S_a = 1 + 0.001\Delta_S \quad (9)$$

where

Δ_S is the site altitude (in metres above mean sea level).

NOTE In this case the value of S_a , based on the site altitude, compensates for residual topography effects.

2.2.2.2.3 When topography is considered significant S_a should be taken as the greater of:

$$S_a = 1 + 0.001\Delta_S \quad (10)$$

where

Δ_S is the site altitude (in metres above mean sea level); or

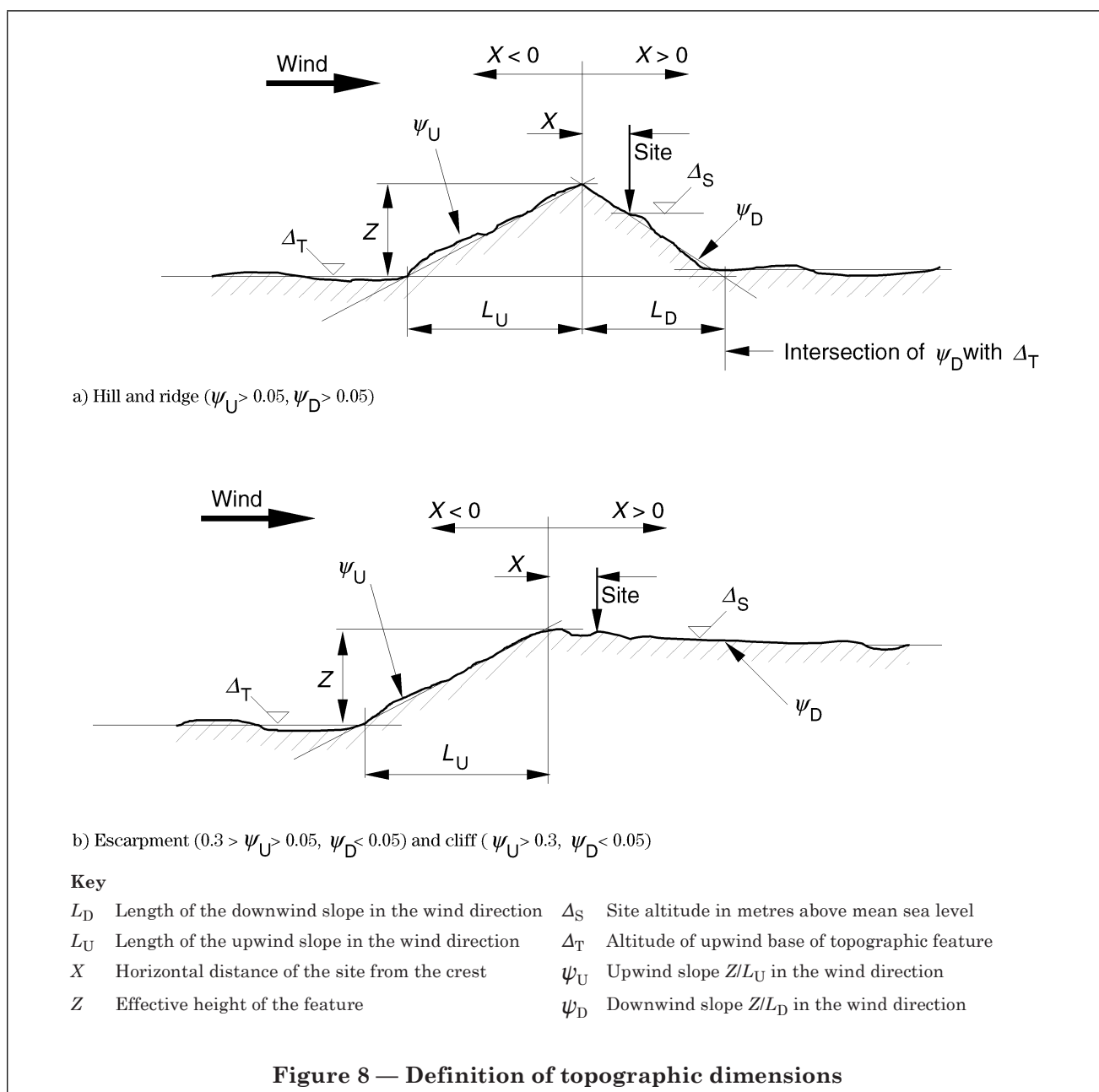
$$S_a = 1 + 0.001\Delta_T + 1.2\psi_e s \quad (11)$$

where

Δ_T is the altitude of the upwind base of significant topography (in metres above mean sea level);

ψ_e is the effective slope of the topographic feature;

s is a topographic location factor.



2.2.2.2.4 The relevant dimensions of the topography are defined in Figure 8. Two parameters, effective slope ψ_e and effective slope length L_e are defined in terms of these dimensions by the following.

- a) For shallow upwind slopes $0.05 < \psi_U < 0.3$: $\psi_e = \psi_U$ and $L_e = L_U$;
- b) For steep upwind slopes $\psi_U \geq 0.3$: $\psi_e = 0.3$ and $L_e = Z/0.3$.

2.2.2.2.5 Values of the topographic location factor s are given for hills and ridges in Figure 9a and Figure 9b and for cliffs and escarpments in Figure 10a and Figure 10b. In reading the value of s from these figures, the location with respect to the crest of the feature is scaled to the lengths of the upwind L_U or downwind L_D slopes as follows:

- a) upwind of the crest ($X < 0$), the horizontal position ratio is X/L_U for all types of topography;
- b) downwind of the crest ($X > 0$), the horizontal position ratio is X/L_D for hills and ridges, and X/L_e for cliffs and escarpments.

In all cases, the height above ground ratio is H/L_e . The basis for the derivation of the values in Figure 9a and Figure 9b and Figure 10a and Figure 10b is given in Annex G.

NOTE In cases transitional between hills and ridges in Figure 8a) and cliffs and escarpments in Figure 8b), i.e. when the downwind slope length L_D is much longer than the upwind slope length L_U it may be difficult to decide which model is the more appropriate. In this case, a value of s may be derived from Figure 9a and Figure 9b and Figure 10a and Figure 10b, and the smaller value used.

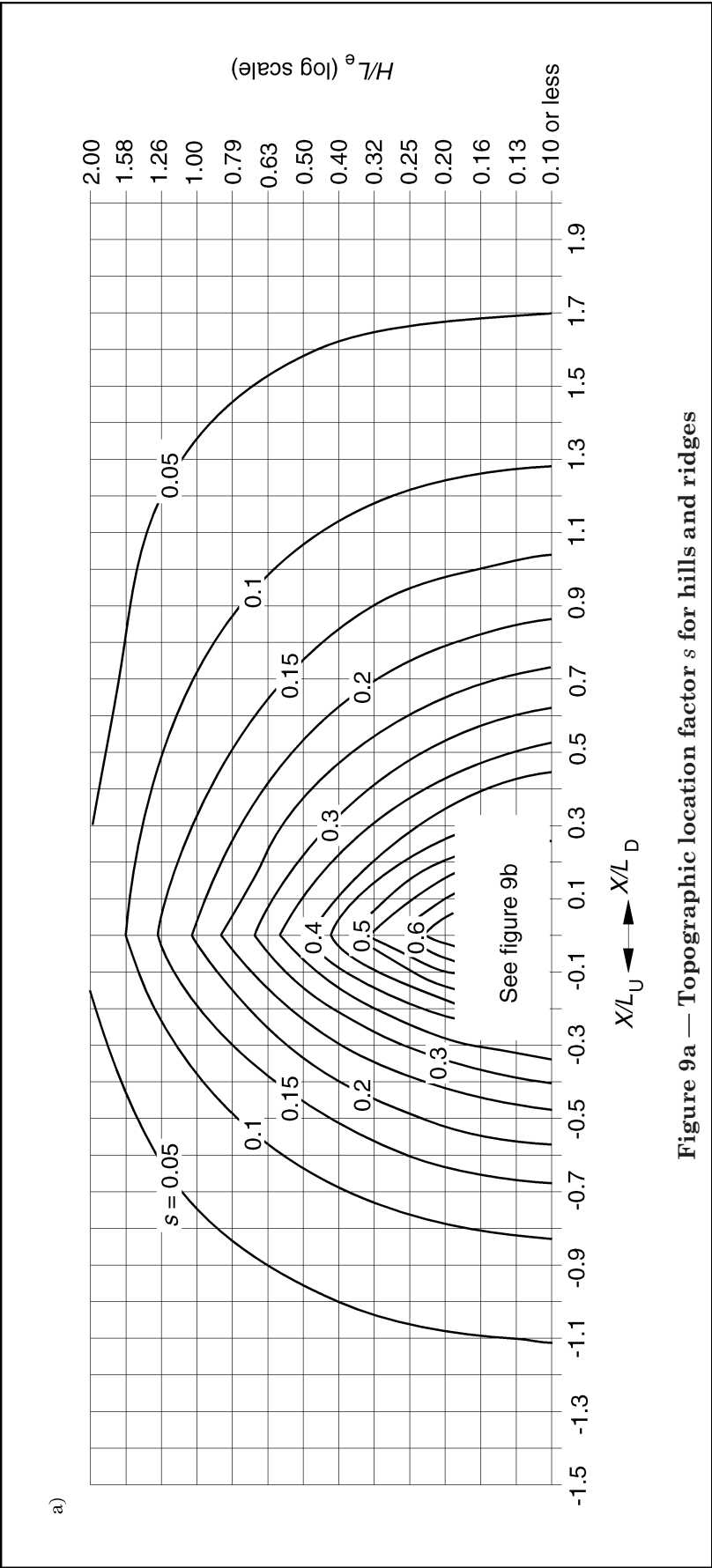
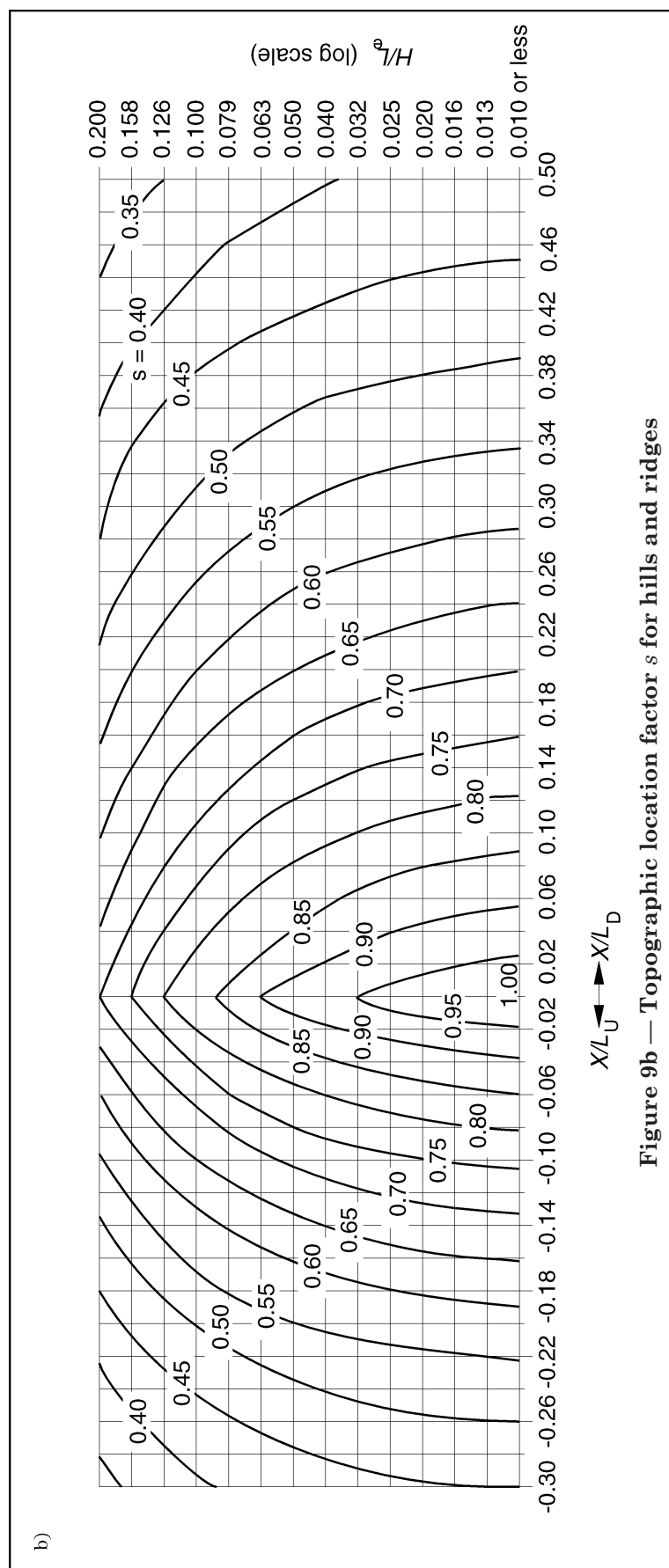
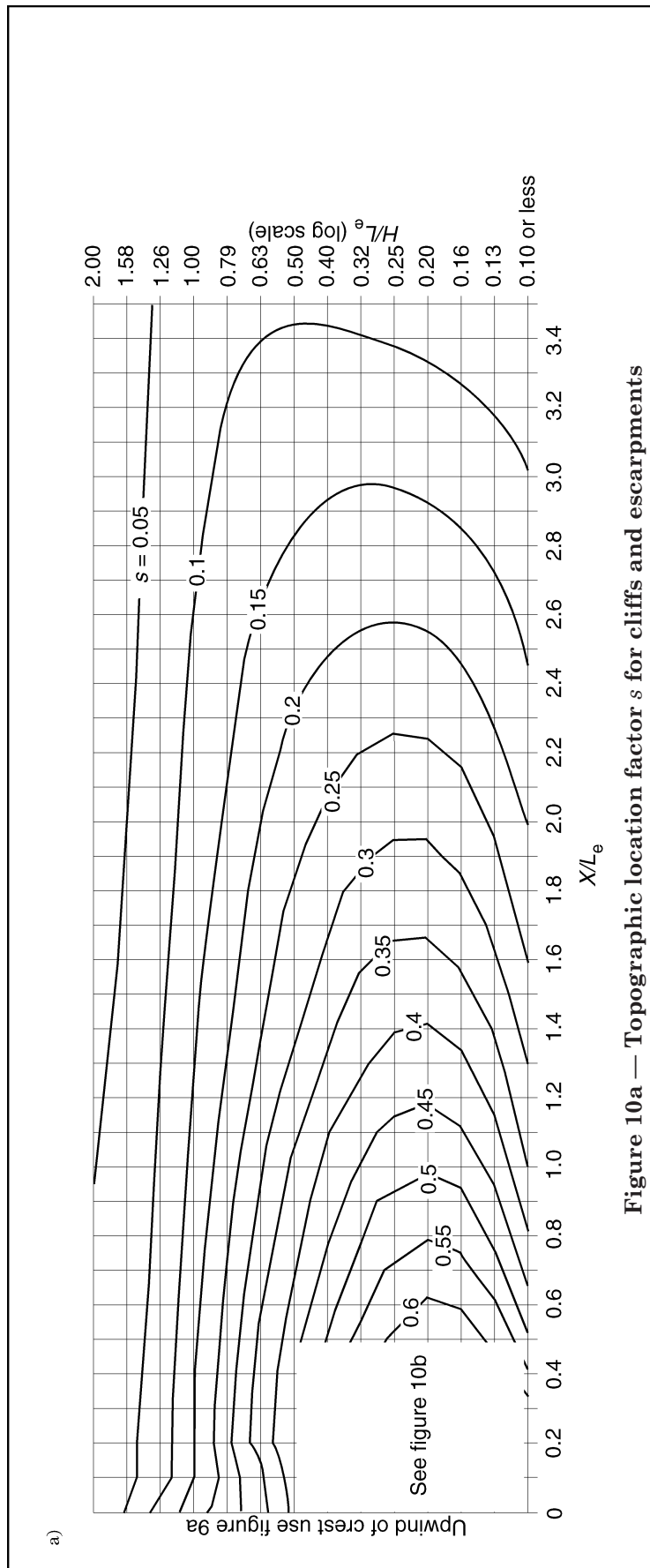
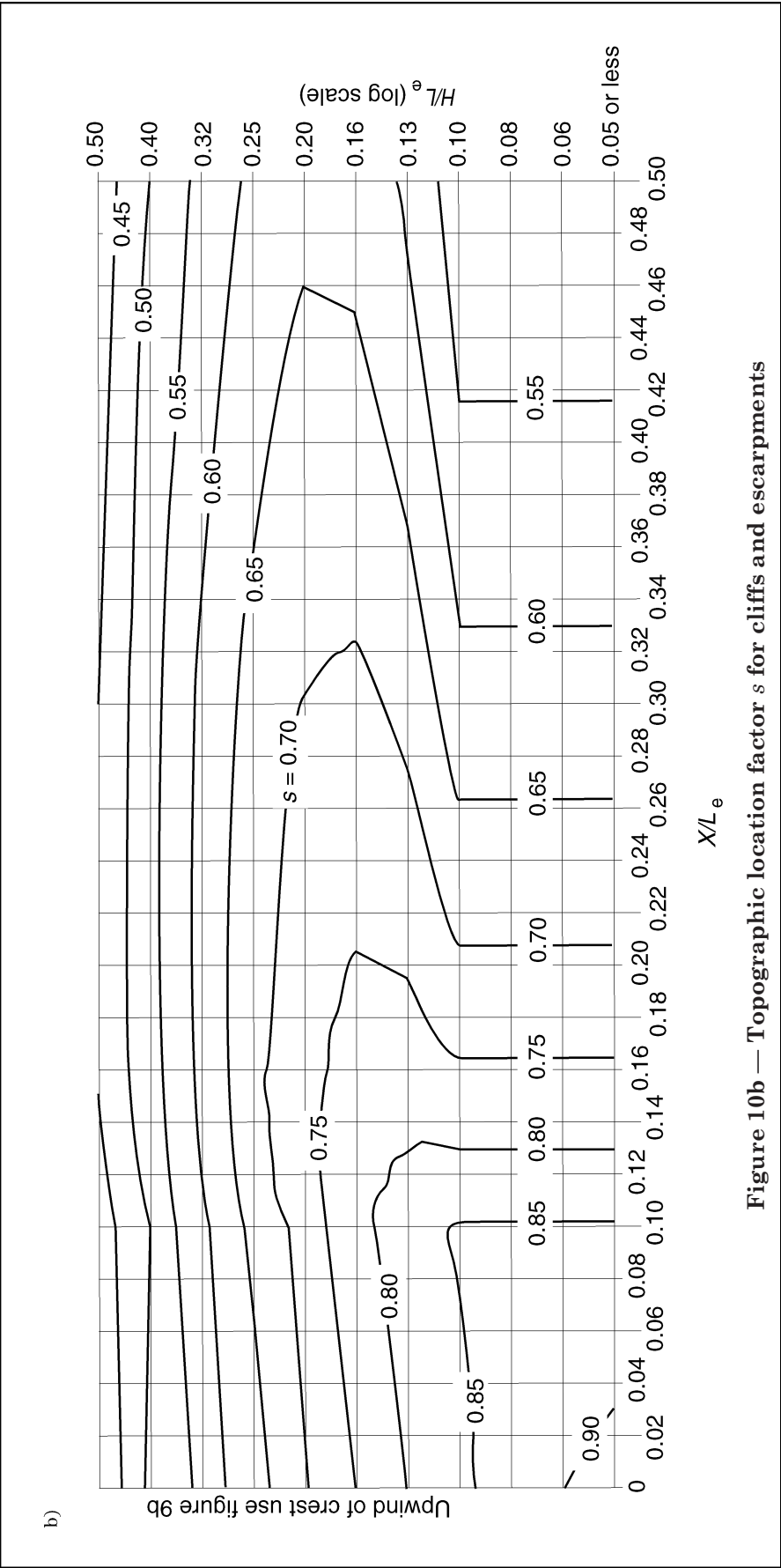


Figure 9a — Topographic location factor s for hills and ridges



Figure 10a — Topographic location factor s for cliffs and escarpments



2.2.2.3 Direction factor

The direction factor S_d may be used to adjust the basic wind speed to produce wind speeds with the same risk of being exceeded in any wind direction. Values are given in Table 3 for all wind directions in 30° intervals (where the wind direction is defined in the conventional manner: an east wind is a wind direction of ($\varphi = 90^\circ$ and blows from the east to the site). If the orientation of the building is unknown or ignored, the value of the direction factor should be taken as $S_d = 1.00$ for all directions.

NOTE When the direction factor is used with other factors that have a directional variation, values from Table 3 should be interpolated for the specific direction being considered, or the largest tabulated value in the range of wind direction may be selected.

Table 3 — Values of direction factor S_d

Direction φ	Direction factor S_d
0° North	0.78
30°	0.73
60°	0.73
90° East	0.74
120°	0.73
150°	0.80
180° South	0.85
210°	0.93
240°	1.00
270° West	0.99
300°	0.91
330°	0.82
360° North	0.78
NOTE Interpolation may be used within this table.	

2.2.2.4 Seasonal factor

The seasonal factor S_s may be used to reduce the basic wind speed for buildings which are expected to be exposed to the wind for specific subannual periods, in particular for temporary works and buildings during construction. Values which maintain the risk (probability) of being exceeded of $Q = 0.02$ in the stated period are given in Annex D.

For permanent buildings and buildings exposed to the wind for a continuous period of more than 6 months a value of 1.0 should be used for S_s .

2.2.2.5 Probability factor

A probability factor S_p may be used to change the risk of the basic wind speed being exceeded from the standard value of $Q = 0.02$ annually, or in the stated subannual period if S_s is also used. Equation D.1 gives S_p , together with a number of values for other levels of risk.

For all normal design applications, where adjustments for risk are made through the partial factors, the standard value of risk, $Q = 0.02$, is used and $S_p = 1.0$.

2.2.3 Effective wind speed

2.2.3.1 The effective wind speed V_e should be calculated from:

$$V_e = V_s \times S_b \quad (12)$$

where

V_s is the site wind speed obtained from **2.2.2**, for the range $\theta = \pm 45^\circ$ around the notional orthogonal wind directions defined with the pressure coefficient data for each form of building;

S_b is the terrain and building factor obtained from **2.2.3.3**.

2.2.3.2 For buildings with height H greater than the crosswind breadth B for the wind direction being considered, some reduction in overall loads may be obtained by dividing the building into a number of parts as follows:

- a) buildings with height H less than or equal to B should be considered to be one part, as in Figure 11a);
- b) buildings with height H greater than B but less than $2B$ should be considered to be two parts, comprising a lower part extending upwards from the ground by a height equal to B and an upper part which is the remainder, as in Figure 11b);
- c) buildings with height H greater than $2B$ should be considered to be multiple parts, comprising a lower part extending upwards from the ground by a height equal to B , an upper part extending downwards from the top by a height equal to B , and a middle region between upper and lower parts which may be divided into a number of horizontal parts, as in Figure 11c).

The reference height H_r for each part should be taken as the height to the top of that part. The diagonal dimension, α , should be taken for the loaded area being considered.

2.2.3.3 The terrain and building factor S_b should be obtained directly from Table 4 and takes account of:

- a) the effective height H_e determined from 1.7.3;
- b) the closest upwind distance of the site from the sea in the range of wind direction $\theta = \pm 45^\circ$ around the notional wind direction for the orthogonal load case, as defined with the pressure coefficient data for each form of building;
- c) whether the site is in country terrain or at least 2 km inside town terrain.

NOTE For all sites inside towns (except exactly at the upwind edge or at a distance of 2 km from the upwind edge) the simplifications of the standard method produce a larger value of S_b than the directional method. If the loads produced by the standard method are critical to the design, the use of the hybrid combination given in 3.4.2 should be considered.

Table 4 — Factor S_b for standard method

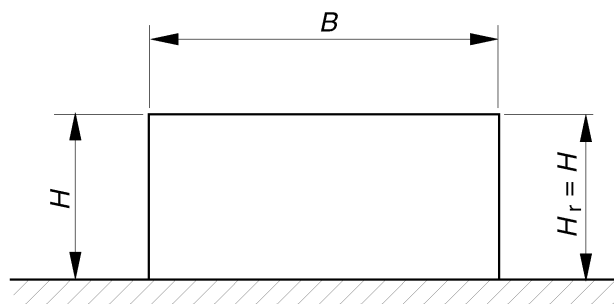
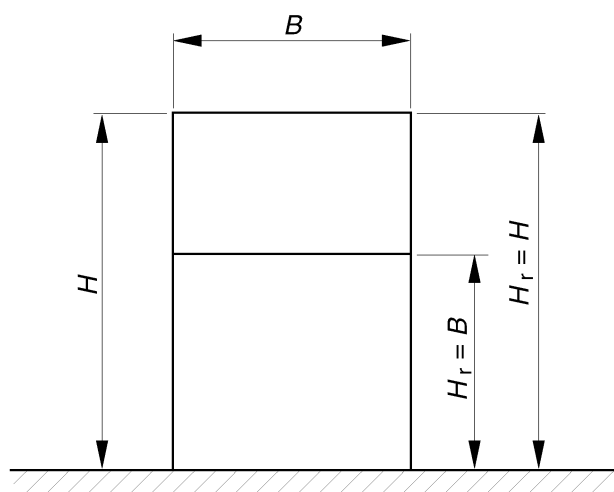
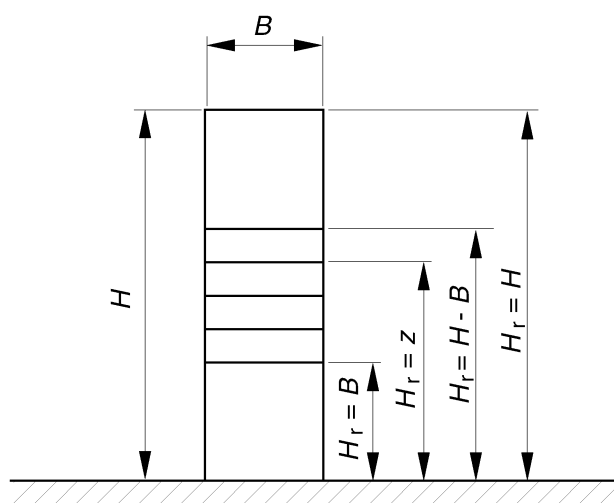
Site in country or up to 2 km into town					Site in town, extending ≥ 2 km upwind from the site			
Effective height H_e	Closest distance to sea upwind km				Effective height H_e	Closest distance to sea upwind km		
m	≤ 0.1	2	10	≥ 100	m	2	10	≥ 100
≤ 2	1.48	1.40	1.35	1.26	≤ 2	1.18	1.15	1.07
5	1.65	1.62	1.57	1.45	5	1.50	1.45	1.36
10	1.78	1.78	1.73	1.62	10	1.73	1.69	1.58
15	1.85	1.85	1.82	1.71	15	1.85	1.82	1.71
20	1.90	1.90	1.89	1.77	20	1.90	1.89	1.77
30	1.96	1.96	1.96	1.85	30	1.96	1.96	1.85
50	2.04	2.04	2.04	1.95	50	2.04	2.04	1.95
100	2.12	2.12	2.12	2.07	100	2.12	2.12	2.07

NOTE 1 Interpolation may be used within each table.

NOTE 2 The figures in this table have been derived from reference [5].

NOTE 3 Values assume a diagonal dimension $\alpha = 5$ m.

NOTE 4 If $H_e > 100$ m use the directional method of Section 3.

a) One part when $H \leq B$ b) Two parts when $B < H \leq 2B$ b) Multiple parts when $H > 2B$ **Figure 11 — Division of buildings by parts for overall loads**

2.3 Standard pressure coefficients

2.3.1 General

2.3.1.1 The wind force on a building or element should be calculated by the procedure given in **2.1.3** using appropriate pressure coefficients that are dependent on the shape and form of the building.

NOTE The standard pressure coefficients may be used for buildings and elements of generally similar shape. Where the building or element shape falls outside the scope of the tabulated pressure coefficients in **2.4** to **2.5** or in **3.3**, or where more detailed data are required, pressure coefficients may be obtained from wind tunnel tests as defined in **1.1**.

2.3.1.2 The standard external pressure coefficients set out in **2.4** and **2.5** apply to building structures that are predominantly flat faced, and to walls of circular-plan buildings. The majority of conventional buildings, such as cuboidal, or composed of cuboidal elements, with different roof forms such as flat, monopitch, duopitch, hipped and mansard, are included.

Where considerable variation of pressure occurs over a surface it has been subdivided into zones and pressure coefficients have been provided for each zone.

2.3.1.3 When calculating the wind load on individual structural components and cladding units and their fixings, it is essential to take account of the pressure difference between opposite faces of each elements. External pressure coefficients are given in **2.4** and **2.5** and internal pressure coefficients in **2.6** for use with procedures given in **2.1**.

2.3.1.4 Pressure coefficients are given for specific surfaces, or parts of surfaces, of buildings or elements. When the procedure of **2.1.3.5** is applied, they give the wind loads acting in a direction normal to that particular surface.

2.3.1.5 For certain buildings a wind load due to frictional drag should be taken into account (see **2.1.3.8**, **2.4.5** and **2.5.10**).

2.4 External pressure coefficients for walls

2.4.1 Rectangular-plan buildings

2.4.1.1 External pressure coefficients for vertical walls of rectangular plan buildings are given in Table 5, dependent on the proportions of the buildings as shown in Figure 12.

2.4.1.2 Values of pressure coefficient for windward and leeward faces are given in Table 5 for buildings with $D/H \leq 1$ and for buildings with $D/H \geq 4$ where D is the inwind depth of the building, which varies with the wind direction being considered (see Figure 2), and H is the height of the wall including any parapet.

NOTE Values of pressure coefficient for intermediate D/H ratios may be interpolated.

2.4.1.3 The loaded zones on the side face should be divided into vertical strips from the upwind edge of the face with the dimensions shown in Figure 12, in terms of the scaling length b given by $b = B$ or $b = 2H$, whichever is the smaller, where B is the crosswind breadth of the building, which depends on the wind direction being considered [see Figure 2b)] and H is the height of the wall, including any parapet or gable.

2.4.1.4 Where walls of two buildings face each other and the gap between them is less than b , funnelling will accelerate the flow and make the pressure coefficient more negative. Values of pressure coefficient for the side faces are given in Table 5 for each of the cases denoted “isolated” and “funnelling” to be applied as follows.

- a) Where the gap between the buildings is less than $b/4$, or greater than b , the isolated values should be used;
- b) where the gap between the buildings is greater than $b/4$ and less than b :
 - 1) either use the funnelling values, conservatively;
 - or
 - 2) take the funnelling values to apply at a gap width of $b/2$ and the isolated values to apply at gap widths of $b/4$ and at b , and interpolate linearly between these values for the actual gap width in the range from $b/4$ to $b/2$ or the range from $b/2$ to b .
- c) where the two buildings are sheltered by upwind buildings such that the effective height for the lower of the two buildings is $0.4H_f$ in accordance with **1.7.3.3**, funnelling may be disregarded.