

Loading for buildings

Part 2. Code of practice for wind loads

ICS 91.080.01

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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 : Part 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, 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 : Part 2 : 1995 was a technical revision of CP3 : Chapter V : Part 2 which incorporated the considerable advances made and experience gained in wind engineering since that time. CP3 : Chapter V : Part 2 will not be withdrawn immediately so as to allow an overlap period with this Part of BS 6399.

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 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 : Part 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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 90, an inside back cover and a back cover.

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 building.¹⁾

1.3.4.2 building width

The shorter horizontal dimension of a building or part of a building.¹⁾

1.3.4.3 crosswind breadth

The horizontal extent of a building or part of a building normal to the direction of the wind.¹⁾

1.3.4.4 inwind depth

The horizontal extent of a building or part of a building parallel to the direction of the wind.¹⁾

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_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 upwind of the building
h	Parapet height (2.5.1.4, figure 17), free-standing wall height (2.7.5.4, figure 23), or signboard height (2.7.6, figure 24)
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)

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

L_U	Length of upwind slope of topographic feature (2.2.2.2.4, figure 8)	κ	Reduction factor for length of elements (2.7.3)
P	Net load (2.1.3.5)	ψ	Average slope of the ground
P_f	Frictional drag force (2.1.3.8)	ψ_e	Effective slope of topographic feature (2.2.2.2.4)
p	Net pressure (2.1.3.3)	ψ_D	Tangent of downwind slope of topographic feature (figure 7)
p_e	Pressure on external surface (2.1.3.1)	ψ_U	Tangent of upwind slope of topographic feature (figure 7, 2.2.2.2.4)
p_i	Pressure on internal surface (2.1.3.2)	ϕ	Wind direction in degrees east of north (2.2.2.3)
Q	Annual risk (probability) of the basic wind speed being exceeded (2.2.2.4, 2.2.2.5,)	ζ	Solidity ratio of walls or frames (2.7.5) or blockage ratio of canopies (2.5.9, figure 24)
q	Dynamic pressure (3.1.2.1)	θ	Wind direction of degrees from normal to building faces (figure 2) or angle around periphery of circular-plan building (2.4.6)
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) or distance in wind direction for building spacing (1.7.3.3)		
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)		

1.5 Outline of procedure for calculating wind loads

1.5.1 The outline of procedure is illustrated in the flow chart 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.

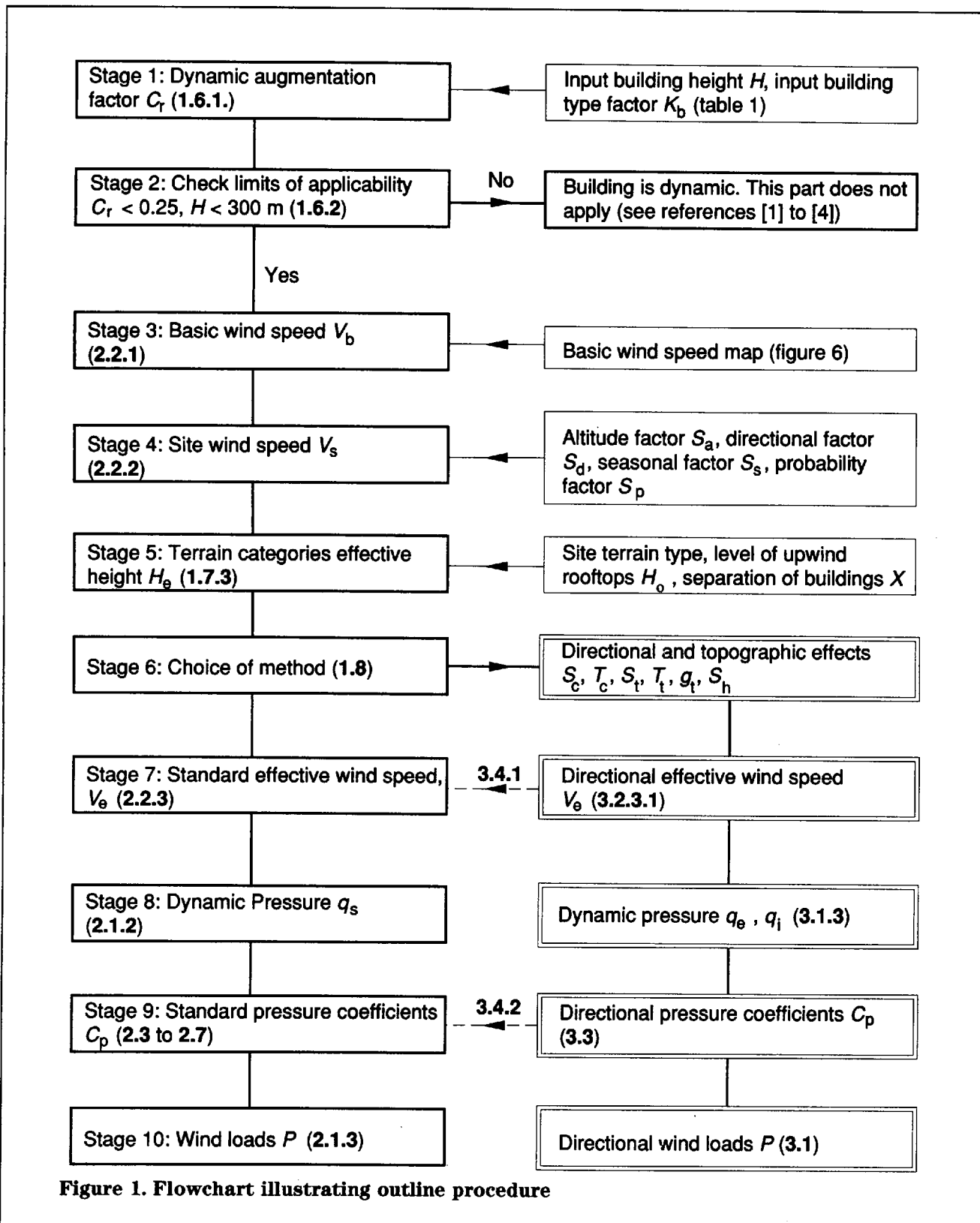


Figure 1. Flowchart illustrating outline procedure

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.

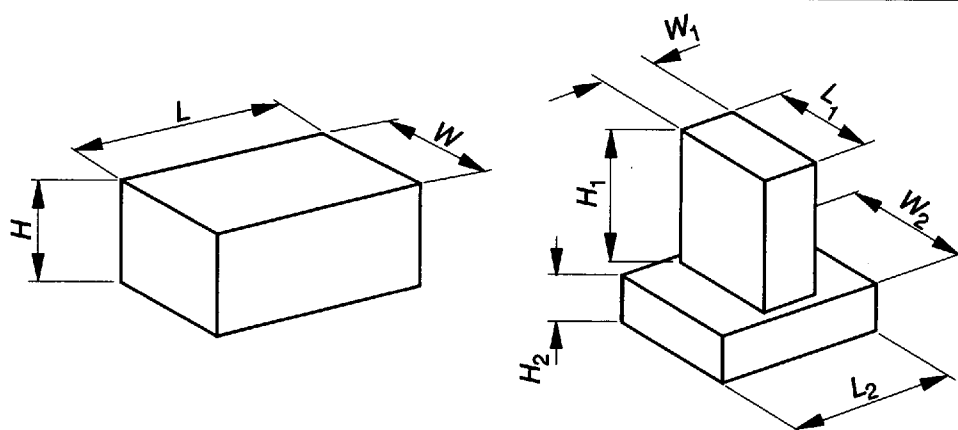
Stage 6: Having assessed the exposure of the site, this stage offers the choice between the standard method and the directional method. The standard method gives conservative values for standard orthogonal load cases, and a simplified method for buildings up to 100 m in height and for significant topography. 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.

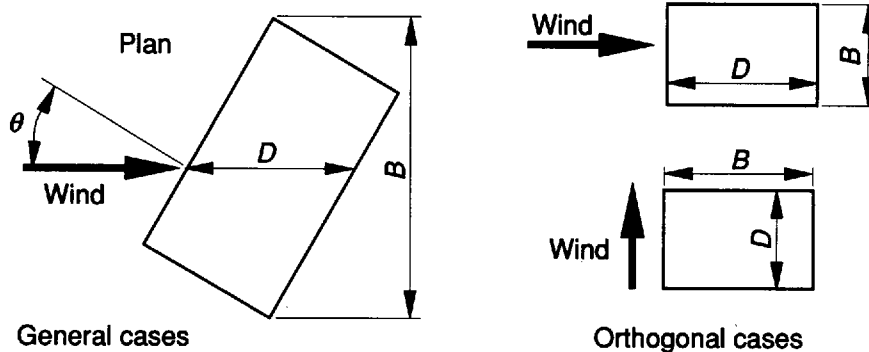
Stage 8: Converts the effective wind speed into an equivalent dynamic pressure.

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).

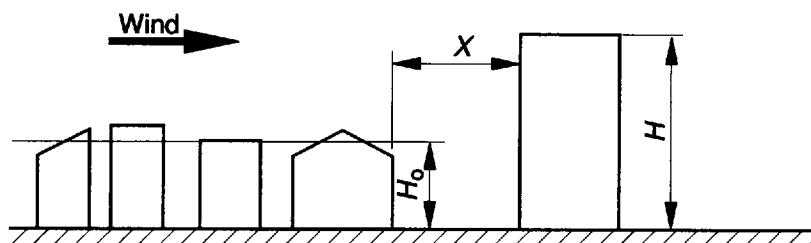
Stage 10: Determines the wind loads from the dynamic pressure, pressure coefficients, dynamic augmentation factor and, in the standard method, by the size effect factor, to give the characteristic wind load for static design.



a) Fixed dimensions: length, width, height



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



c) Obstruction height and upwind spacing

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_T is given for typical buildings in figure 3.

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_T 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:

- 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;
- country*: all terrain which is not defined as sea or town;
- town*: built up areas with an average level of roof tops at least $H_0 = 5$ 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 and effective 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.

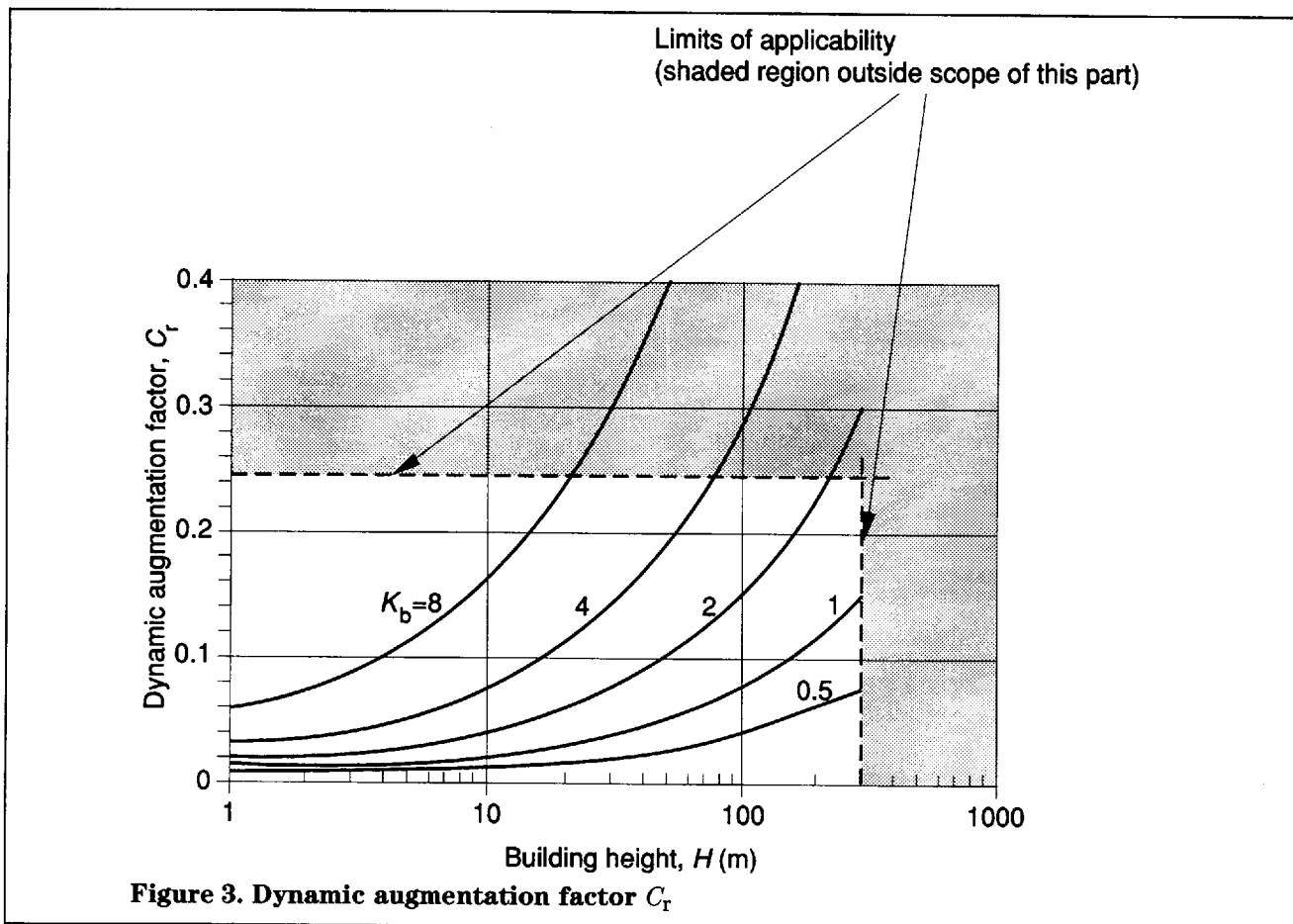
1.7.3.2 For buildings in country terrain, or conservatively for buildings in town terrain, the effective height H_e should be taken as the reference height H_r .

1.7.3.3 For buildings in town terrain, the effective height H_e depends on the shelter afforded by the average level of the height H_0 of the roof tops of the buildings, or of the height of other permanent obstructions, upwind of the site and their upwind spacing X . These dimensions are defined in figure 2. The effective height H_e should be determined as follows.

- If $X \leq 2H_0$
then H_e is the greater of
 $H_e = H_r - 0.8H_0$ or $H_e = 0.4H_r$;
- If $X \geq 6H_0$
then H_e is given by $H_e = H_r$;
- In the range $2H_0 < X < 6H_0$
 H_e is the greater of
 $H_e = H_r - 1.2H_0 + 0.2X$ or $H_e = 0.4H_r$.

NOTE. 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.

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 to 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

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

where

q_s is the dynamic pressure (in Pa*);

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.

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.

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	1030	1080	1130	1190	1240	1300	1350	1410	1470
50	1530	1590	1660	1720	1790	1850	1920	1990	2060	2130
60	2210	2280	2360	2430	2510	2590	2670	2750	2830	2920

* 1 Pa = 1 N/m²

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;

but taking the inwind depth of the building, D , as the smaller of width W or length L in the determination of P_{front} and P_{rear} .

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.

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 rules are given for particular forms of building (e.g. free-standing canopies (2.5.9.1) and signboards (2.7.6)), an allowance for asymmetry of loading should be made, as follows.

For overall loads on enclosed buildings, 60 % of the load on each wall or roof pitch should be applied in turn, keeping the loads on the rest of the building at the design values.

Where the influence function for a structural component has regions of negative value, 100 % of the design loads to areas contributing to the positive regions and 60 % of the design loads to areas contributing to the negative regions should be applied.

NOTE. This procedure should be used to account for torsional effects on buildings and is equivalent to a horizontal displacement of the force on each face of 10 % of the face width from the centre of the face.

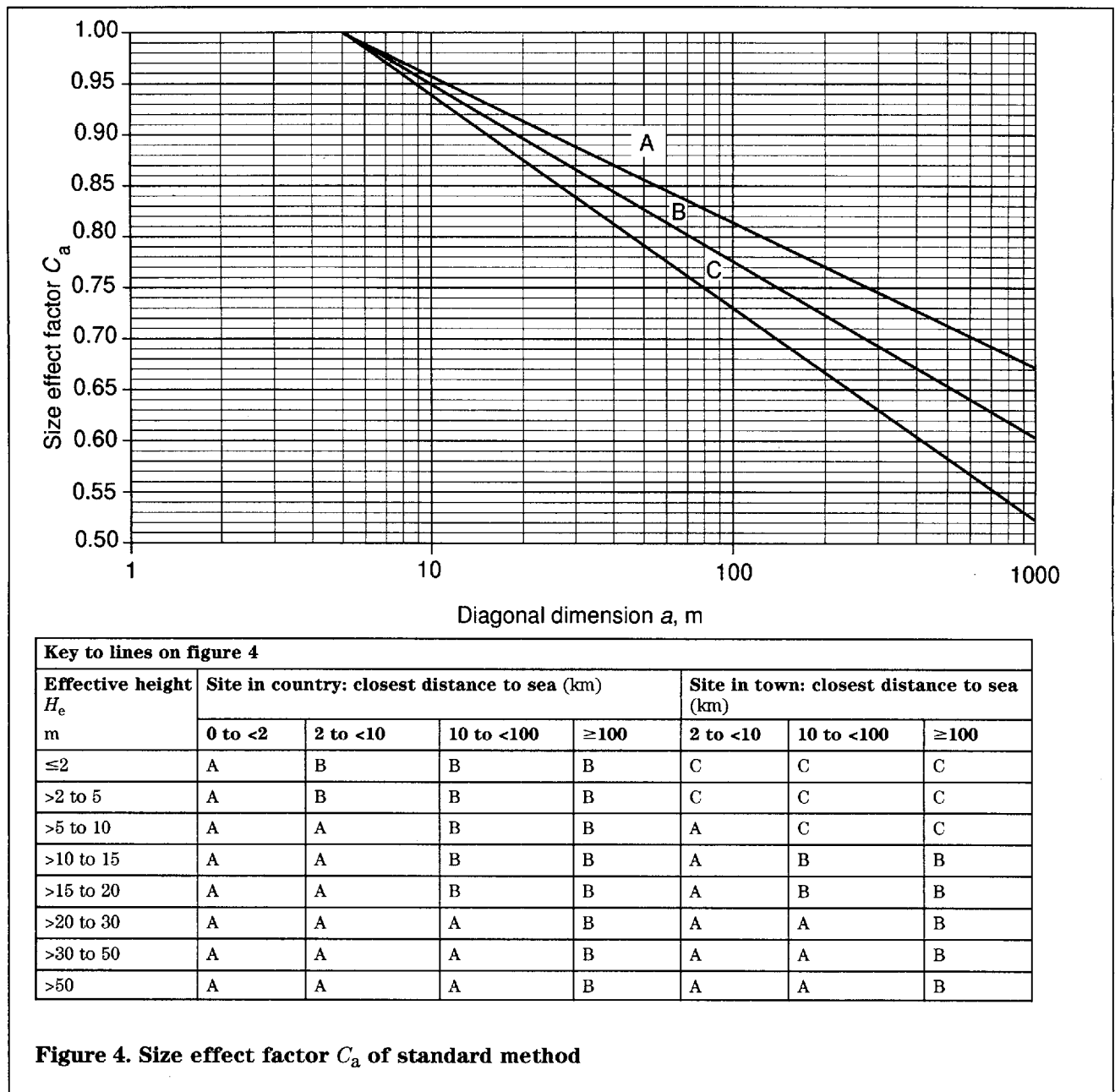
2.1.3.8 Frictional drag component

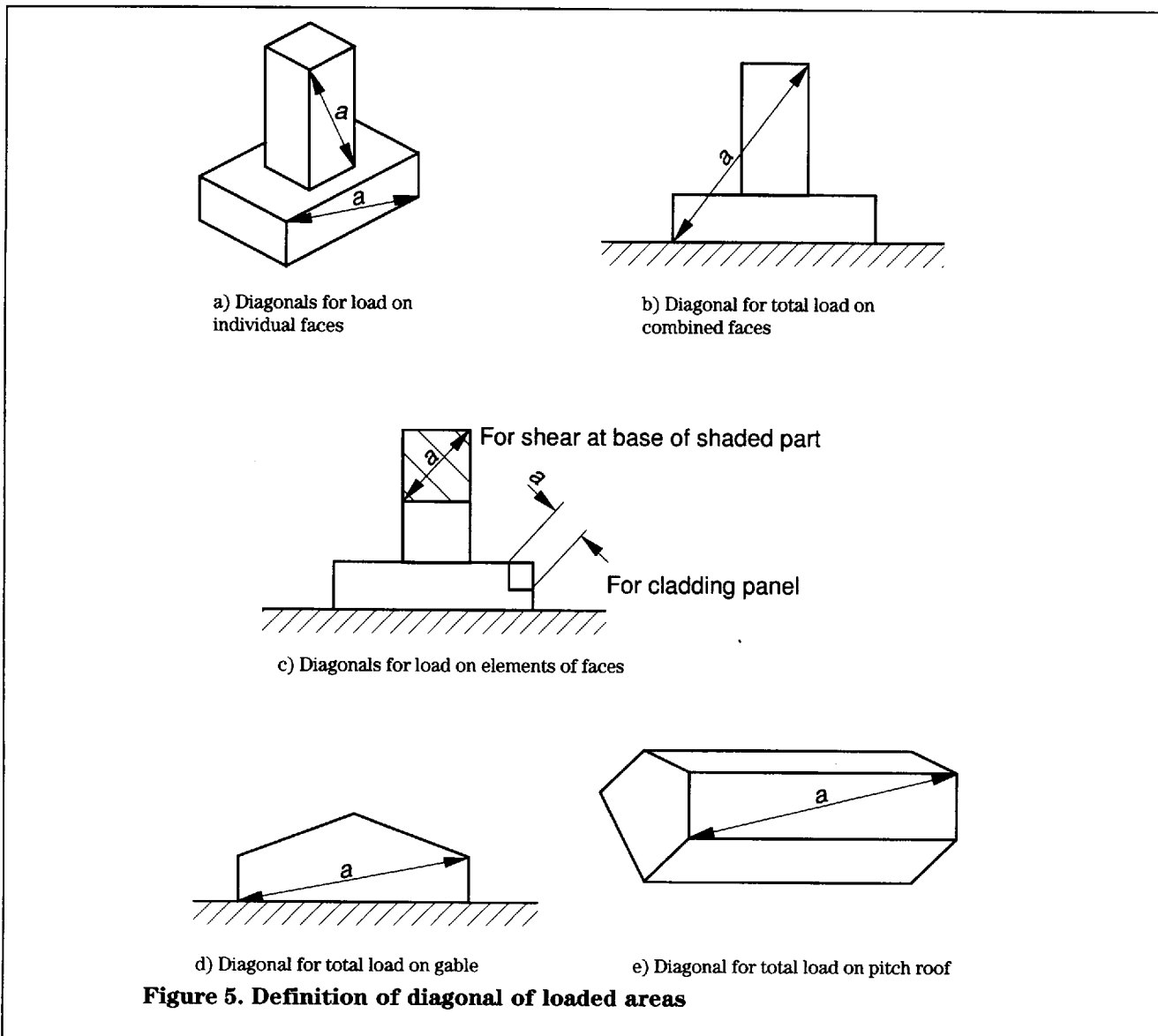
When deriving overall forces on the building (see 2.4.5 and 2.5.10) the contribution of the frictional forces P_f (see equation 7a) should be taken to act in the direction of the wind and should be added to the contribution of the normal pressure forces from 2.1.3.6 using vectorial summation.

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

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)





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

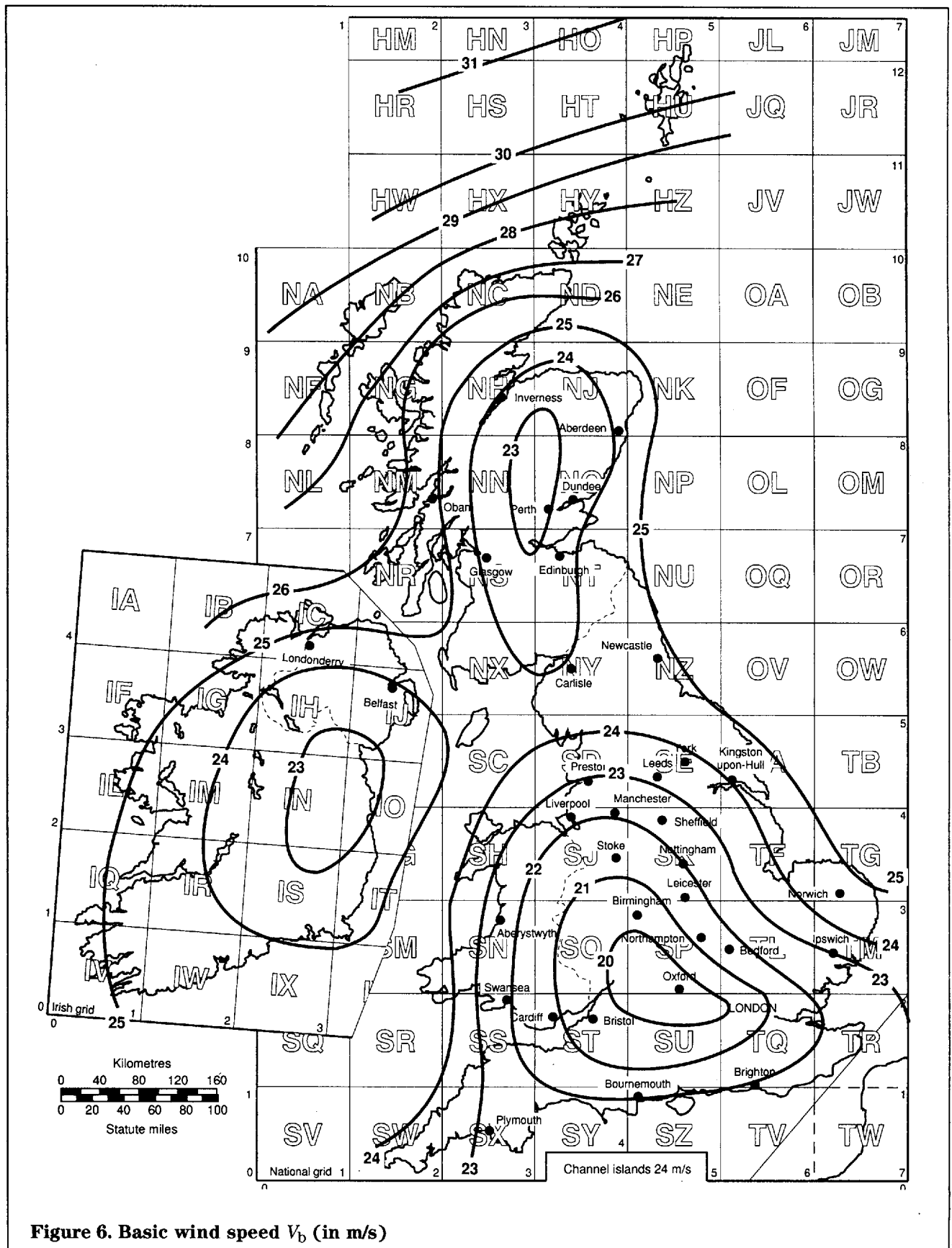
$$V_s = V_b \times S_a \times S_d \times S_s \times S_p \quad (8)$$

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.



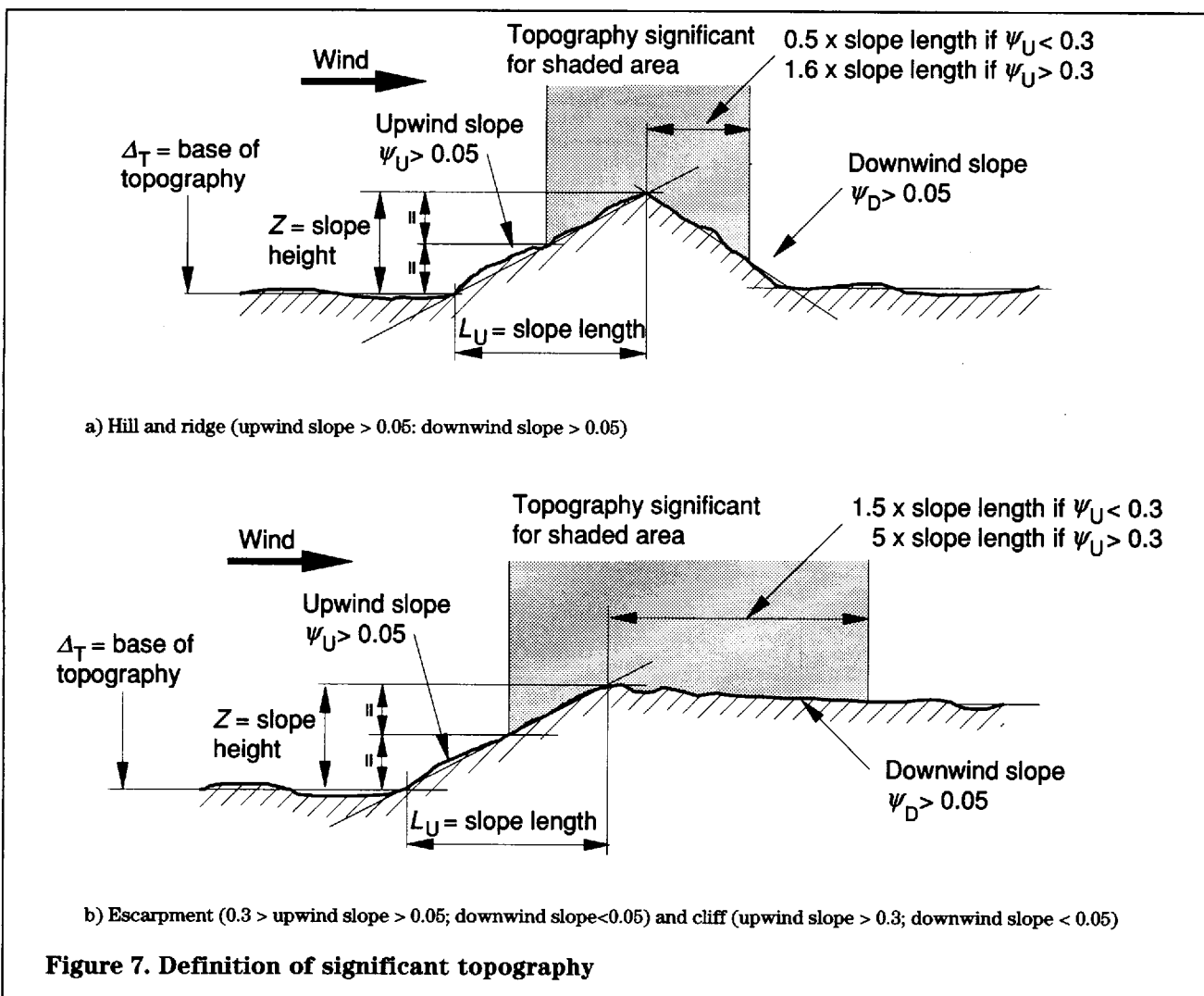


Figure 7. Definition of significant topography

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

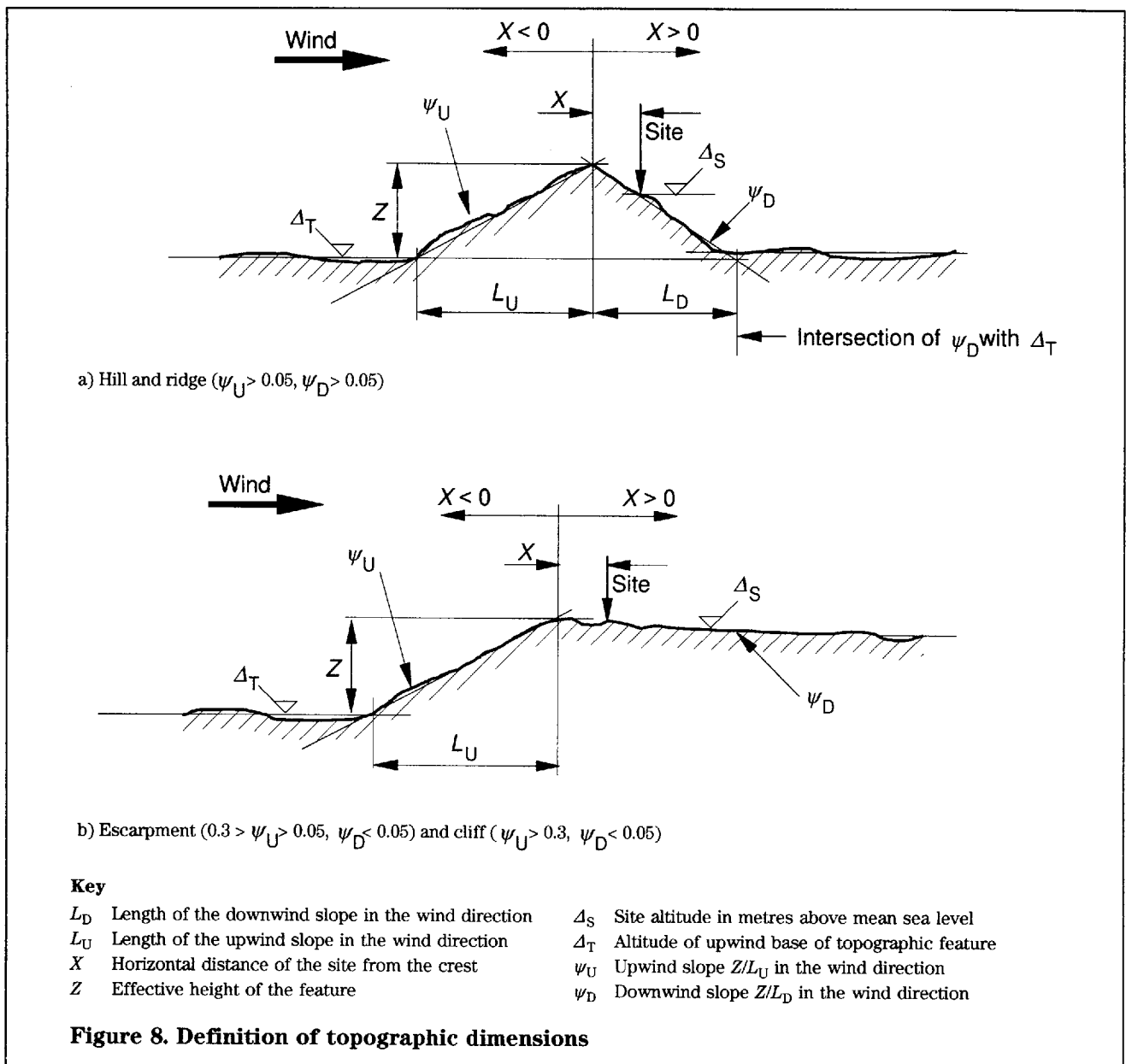
$$S_a = 1 + 0.001\Delta_T + 1.2\psi_e s \quad (11)$$

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.

- For shallow upwind slopes $0.05 < \psi < 0.3$: $\psi_e = \psi_U$ and $L_e = L_U$;
- For steep upwind slopes $\psi > 0.3$: $\psi_e = 0.3$ 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 figures 9a) and 9b) and for cliffs and escarpments in figures 10a) and 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:

- upwind of the crest ($X < 0$), the horizontal position ratio is X/L_U for all types of topography;
- 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 figures 9a) and 9b) and 10a) and 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 figures 9a) and 9b) and 10a) and 10b), and the smaller value used.

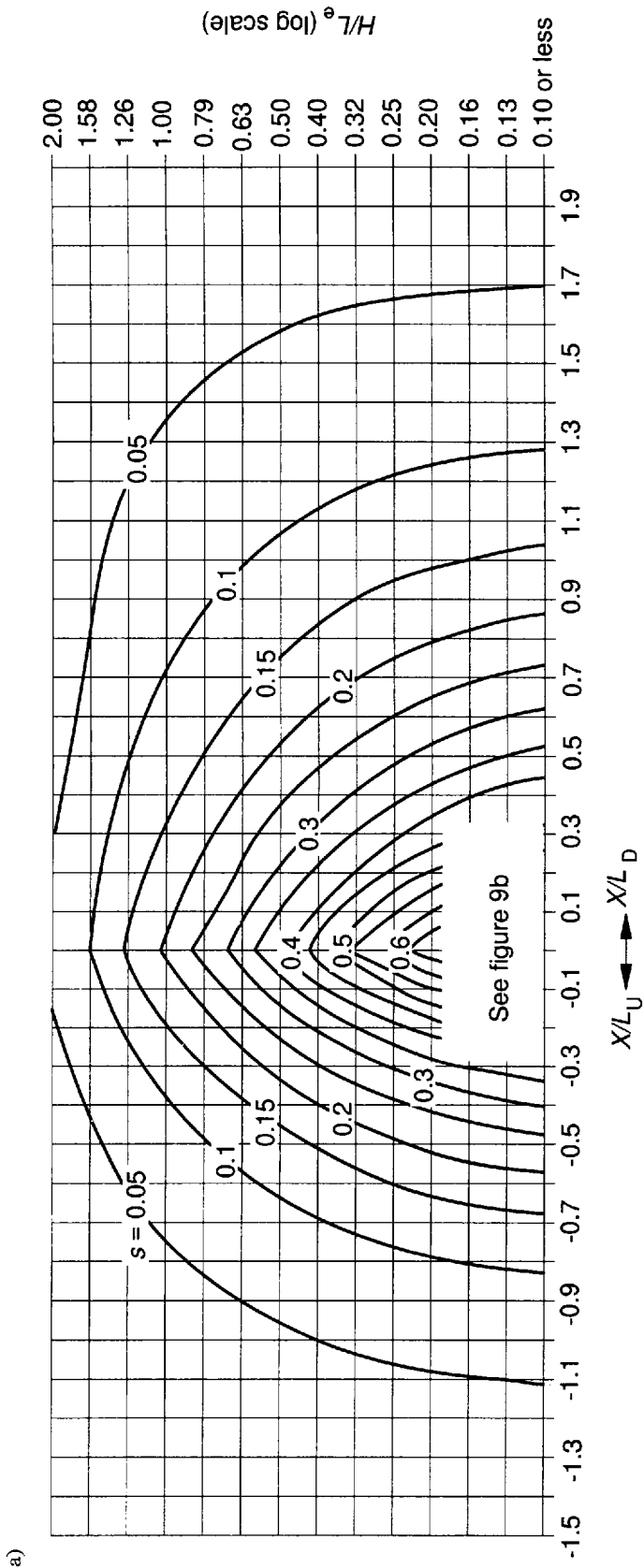


Figure 9a. Topographic location factor s for hills and ridges

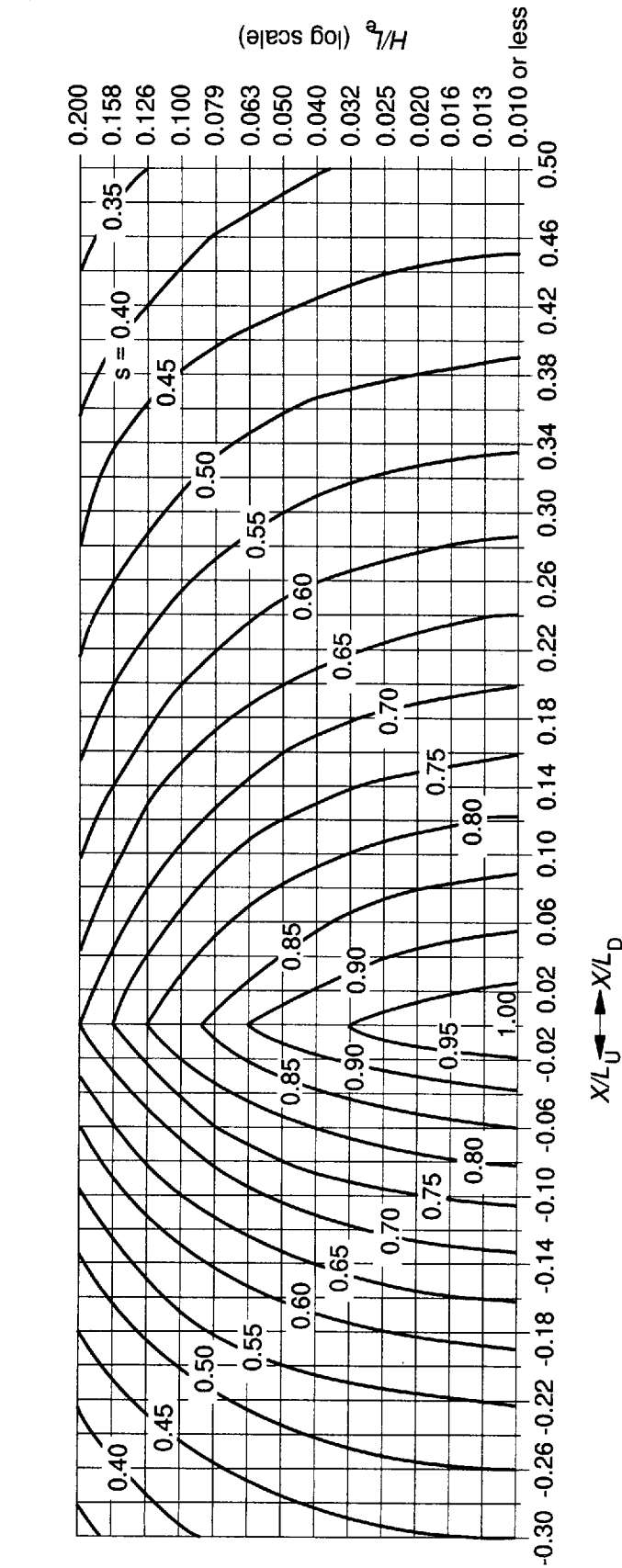


Figure 9b. Topographic location factor s for hills and ridges

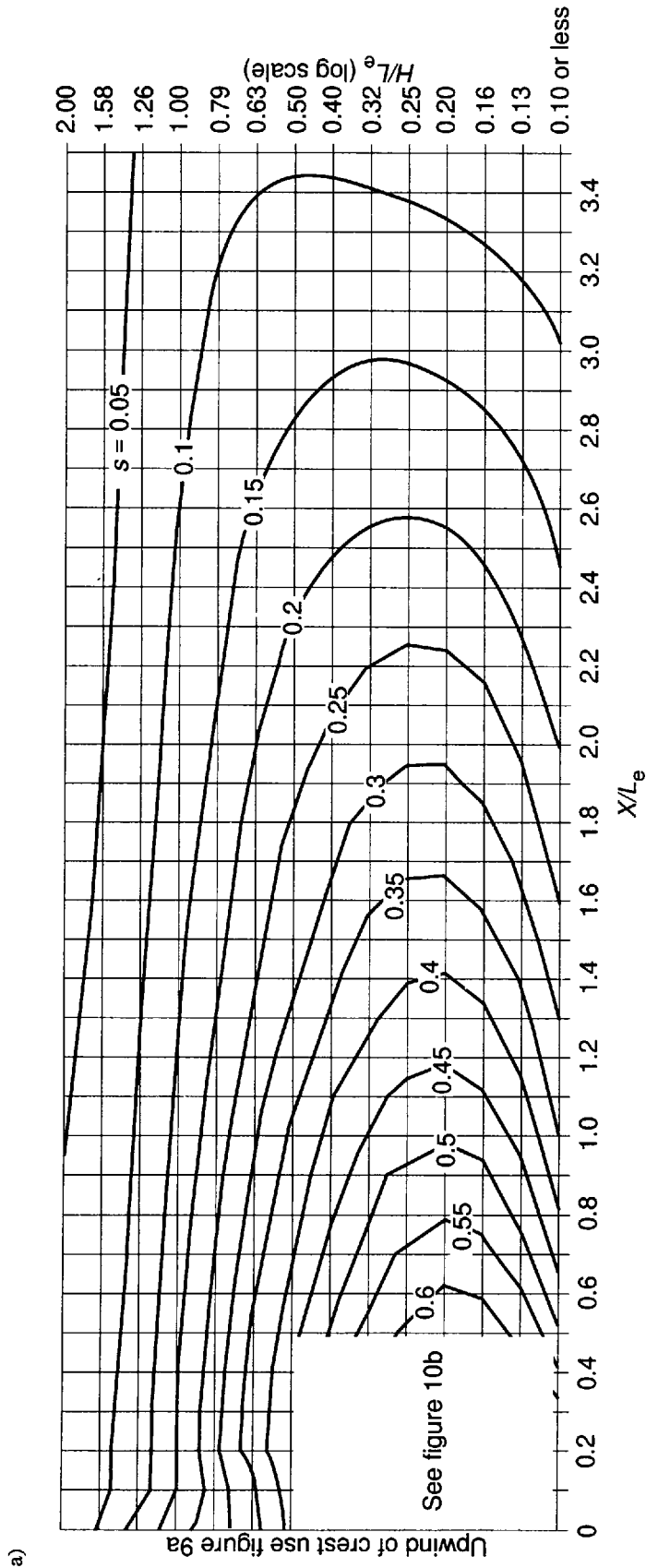


Figure 10a. Topographic location factor s for cliffs and escarpments

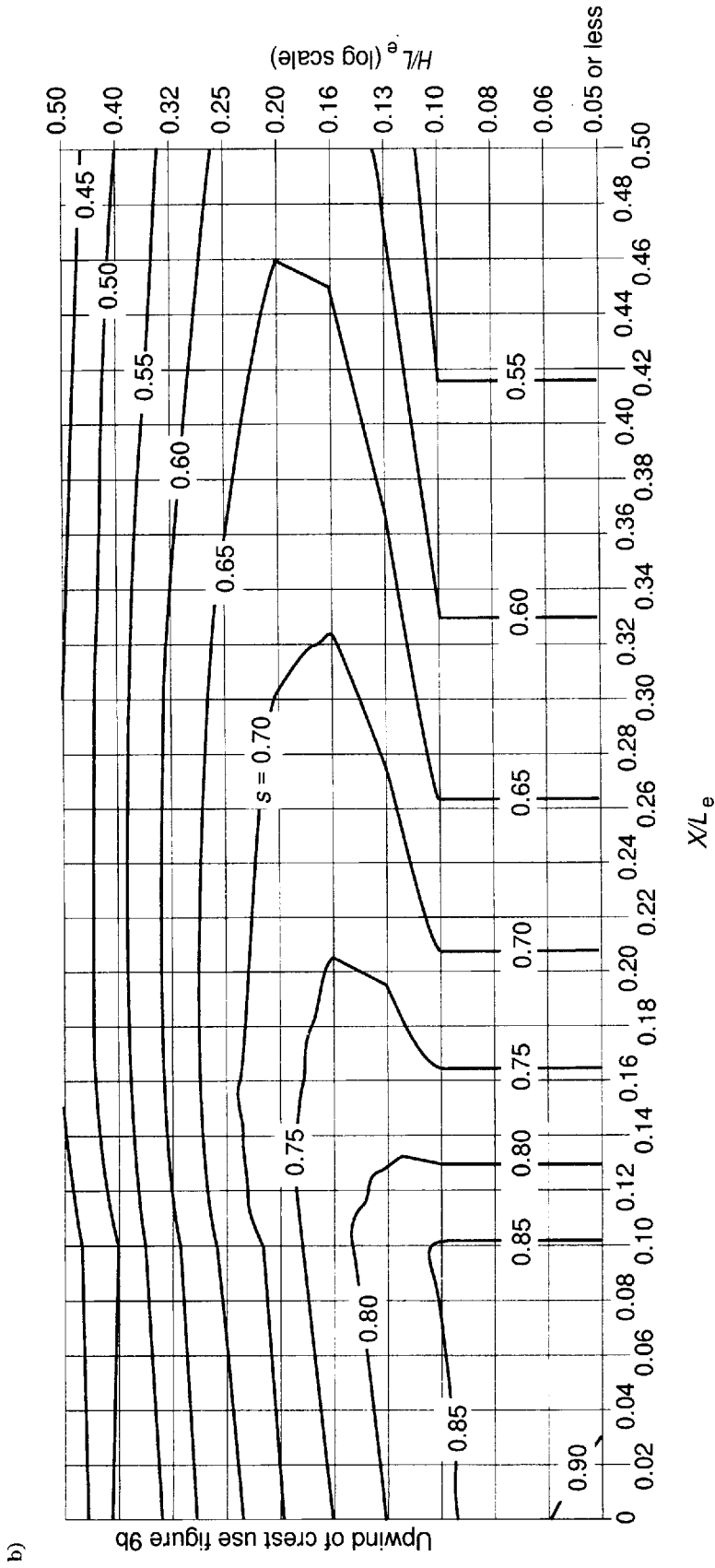


Figure 10b. Topographic location factor s for cliffs and escarpments

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.

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 lateral loads may be obtained by dividing the building into a number of parts as follows:

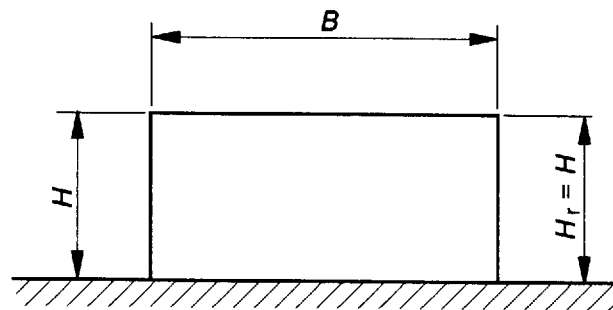
- buildings with height H less than or equal to B should be considered to be one part, as in figure 11a;
- buildings with height H greater than B but less than $2B$ should be considered to be two parts, comprising a lower part extending upwards from the ground by a height equal to B and an upper part which is the remainder, as in figure 11b;
- 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, a , should be taken for the loaded area being considered.

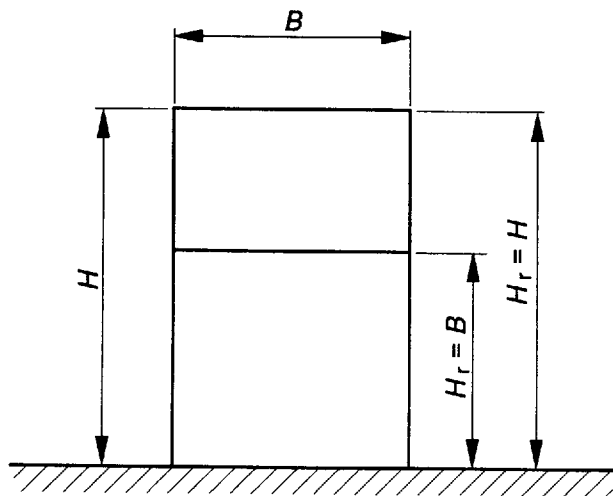
2.2.3.3 The terrain and building factor S_b should be obtained directly from table 4 and takes account of:

- the effective height H_e determined from 1.7.3;
- the closest 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;
- whether the site is in country terrain or at least 2 km inside town terrain.

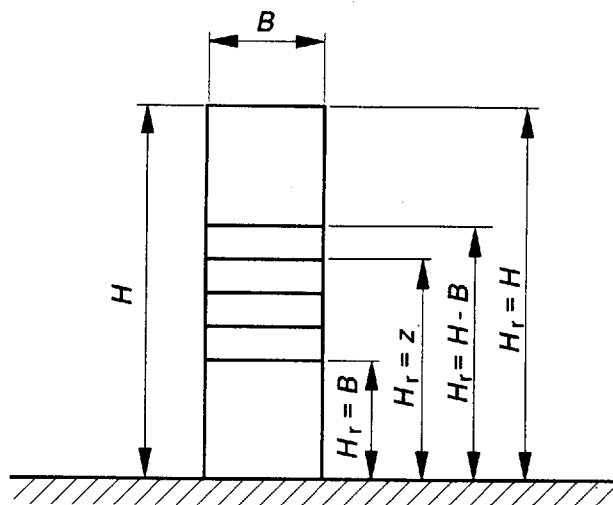
NOTE. For all sites inside towns (except exactly at the upwind edge or at a distance of 2 km from the upwind edge) the simplifications of the standard method produce a larger value of S_b than the directional method. If the loads produced by the standard method are critical to the design, the use of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



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 lateral 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.

Table 4. Factor S_b for standard method

Site in country					Site in town, extending ≥ 2 km upwind from the site				
Effective height H_e m	Closest distance to sea km				Effective height H_e m	Closest distance to sea km			
	0	2	10	≥ 100		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 $a = 5$ m.

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

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 .

2.4.1.5 The values in table 5 are also valid for non-vertical walls within $\pm 15^\circ$ of the vertical. Values outside this range should be obtained from 3.3.1.4.

2.4.2 Polygonal buildings

External pressure coefficients for the vertical walls of buildings with corner angles other than 90° should be obtained using the procedures set out in 3.3.1.2.

Overall forces may be calculated using the pressure coefficients of table 5 together with equation 23 of 3.1.3.3.2.

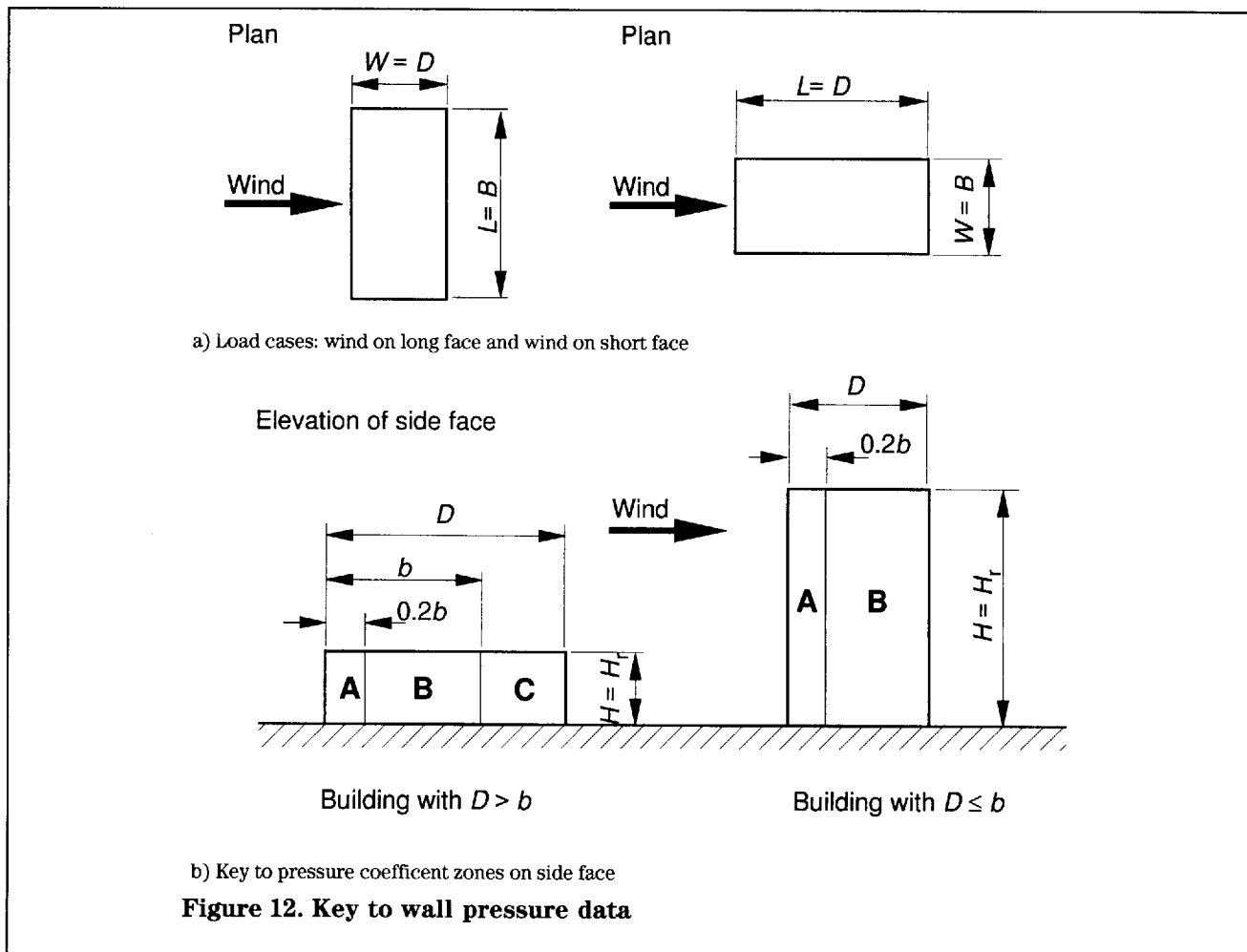


Table 5. External pressure coefficients C_{pe} for vertical walls

Vertical wall face	Span ratio of building		Vertical wall face	Exposure case		
	$D/H \leq 1$	$D/H \geq 4$		Isolated	Funnelling	
Windward (front) face	+0.8	+0.6	Side face	Zone A	-1.3	-1.6
Leeward (rear) face	-0.3	-0.1		Zone B	-0.8	-0.9
				Zone C	-0.4	-0.9

NOTE. Interpolation may be used in the range $1 < D/H < 4$. See 2.4.1.4 for interpolation between isolated and funnelling.

2.4.3 Buildings with re-entrant corners, recessed bays or internal wells

2.4.3.1 The external pressure coefficients given in table 5 should be used for the vertical walls of buildings containing re-entrant corners or recessed bays, as shown in figure 13, subject to the following.

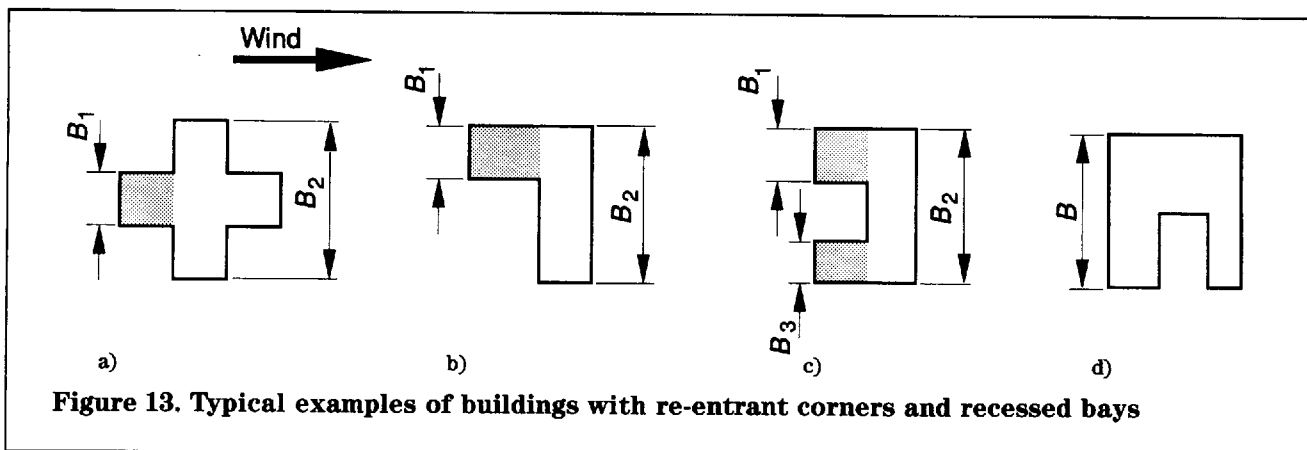
- Where the re-entrant corner or recessed bay results in one or more upwind wings to the building, shown shaded in figures 13a, 13b and 13c, the zones on the side walls are defined using the crosswind breadth $B = B_1$ and B_3 and the height H of the wing.
- The zones on the side walls of the remainder of the building are defined using the crosswind breadth $B = B_2$ and the height H of the building.
- The side walls of re-entrant corners and recessed bays facing downwind, for example the downwind wing of figure 13a, should be assumed to be part of the leeward (rear) face.

2.4.3.2 For internal wells and recessed bays in side faces (see figure 13d) where the gap across the well or bay is smaller than the scaling length b , the following apply.

- External pressure coefficient for the walls of a well is assumed to be equal to the roof coefficient at the location of the well given in clause 2.5;
- External pressure coefficient for the walls of the bay is assumed to be equal to the side wall coefficient at the location of the bay.

Where the well or bay extends across more than one pressure zone, the area-average of the pressure coefficients should be taken.

2.4.3.3 If the gap across the well or bay is greater than the scaling length b , the external pressure coefficients should be obtained from 3.3.1.5.



2.4.4 Buildings with irregular or inset faces

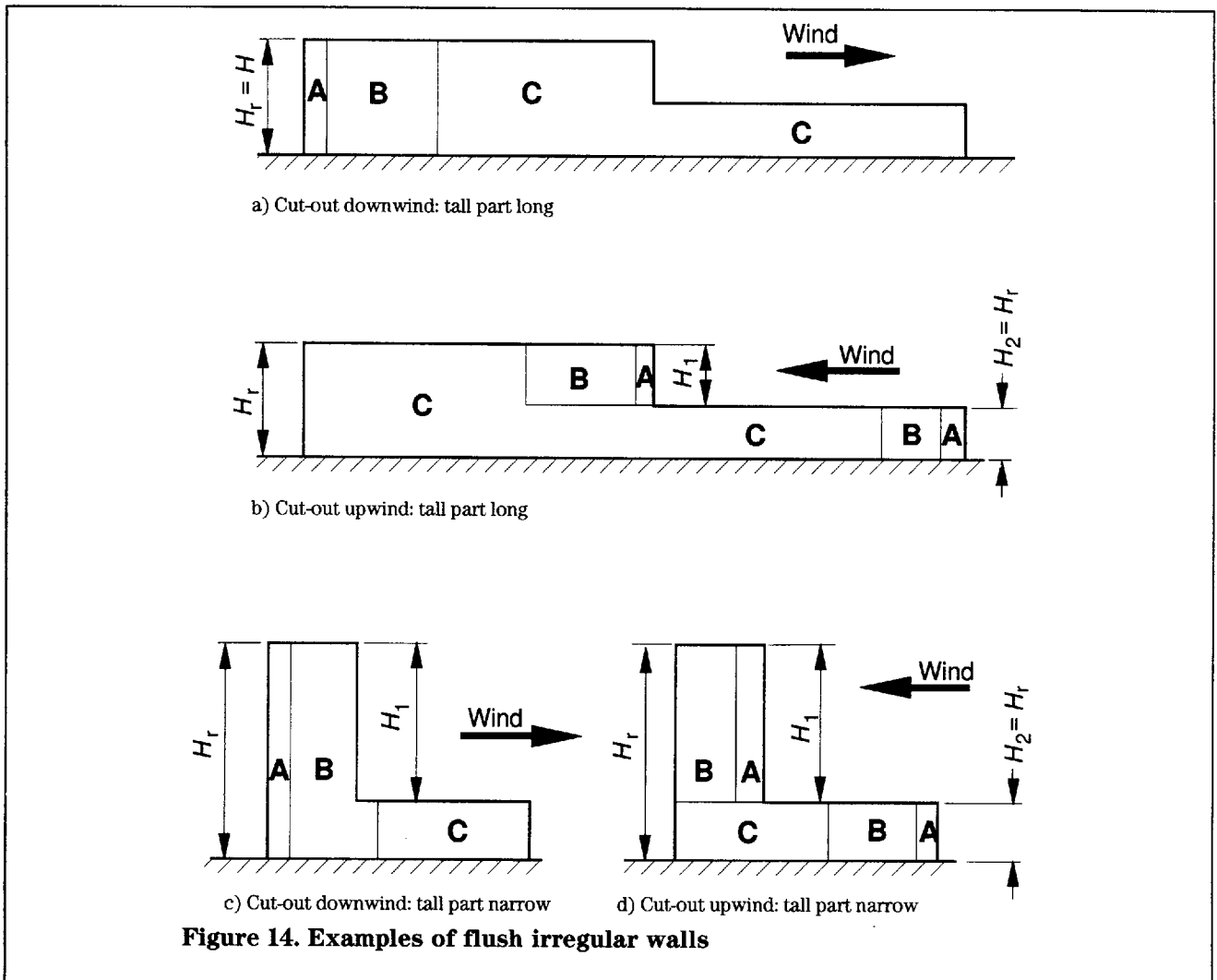
2.4.4.1 Irregular flush faces

External pressure coefficients for the flush walls of buildings with corner cut-outs in elevation, as illustrated in figure 14, which include, for example, buildings with a lower wing or extension built flush with the main building, should be derived as follows.

a) *Cut-out downwind*, as in figure 14a and 14c. The loaded zones on the 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 , making no special allowance for the presence of the cutout. The scaling length b is determined from the height H and crosswind breadth B of the windward face.

b) *Cut-out upwind*, as in figure 14b and 14d. The loaded zones on the face are divided into vertical strips immediately downwind of the upwind edges of the upper and lower part of the face formed by the cut-out. The scaling length b_1 for the zones of the upper part is determined from the height H_1 and crosswind breadth B_1 of the upper inset windward face. The scaling length b_2 for the zones of the lower part is determined from the height H_2 and crosswind breadth B_2 of the lower windward face. The reference height for the upper and lower part is the respective height above ground for the top of each part.

The pressure coefficients for zones A, B and C may then be obtained from table 5.



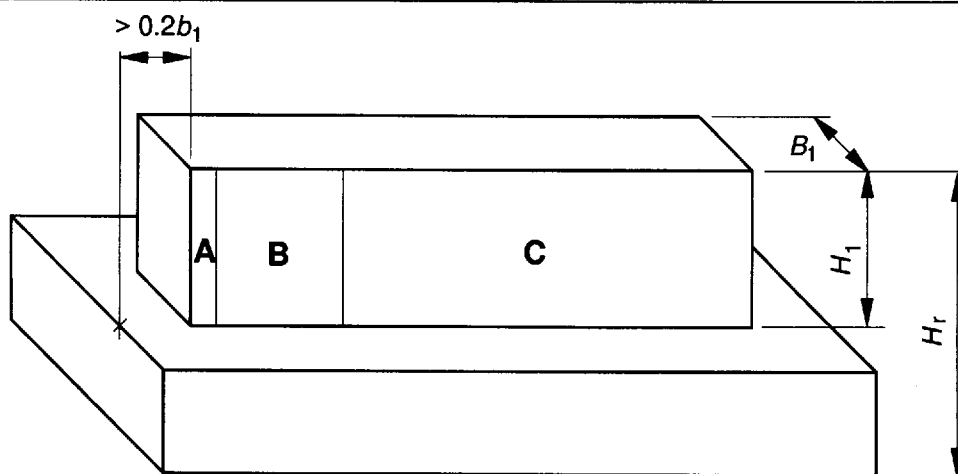
2.4.4.2 Walls of inset storeys

External pressure coefficients for the walls of inset storeys, as illustrated in figure 15, should be derived as follows.

a) *Edge of face inset from edge of lower storey* (see figure 15a). For the inset walls, provided that the upwind edge of the wall is inset a distance of at least $0.2b_1$ from the upwind edge of the lower storey (where b_1 is the scaling length for the upper storey), the loaded zones are defined from the proportions of the upper storey, assuming the lower roof to be the ground plane. However, the reference height H_r is taken as the actual height of the top of the wall above ground.

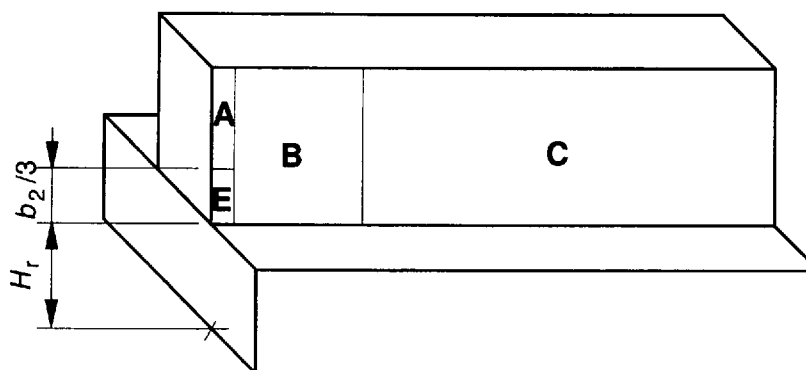
b) *Edge of face flush with edge of lower storey* (see figure 15b). Where the upwind edge of the wall is flush, or inset a distance of less than $0.2b_1$ from the upwind edge of the lower storey, the procedure in item a) should be followed, but an additional zone E should be included as defined in figure 15b with an external pressure coefficient of $C_{pe} = -2.0$. The reference height for zone E should be taken as the top of the lower storey. The greater negative pressure (suction) determined for zone E or for the underlying zone A in item a), should be used.

The pressure coefficients for zones A, B and C may then be obtained from table 5.



NOTE: b_1 is scaling length of upper storey

a) Edge of face inset from edge of lower storey



NOTE: b_2 is scaling length of lower storey

b) Edge of face flush with edge of lower storey

Figure 15. Keys for walls of inset storey

2.4.5 Friction-induced loads on walls

Friction forces should be calculated for long walls with $D > b$ when the wind is parallel to the wall. The frictional drag coefficient should be assumed to act over all zone C of such walls, with values as given in table 6. The resulting frictional forces should be added to the normal forces as described in 2.1.3.8.

Type of surface	Frictional drag coefficient
Smooth surfaces without corrugations or ribs across the wind direction	0.01
Surfaces with corrugations across the wind direction	0.02
Surfaces with ribs across the wind direction	0.04

2.4.6 Circular-plan buildings

The distribution of external pressure coefficient around the periphery of a circular-plan building is given in table 7. These pressure coefficients are also applicable to silos, tanks, stacks and chimneys.

Position on periphery θ	Surface rough or with projections		Surface smooth	
	$H/d \geq 10$	$H/d \leq 2.5$	$H/d \geq 10$	$H/d \geq 2.5$
0°	+1.0	+1.0	+1.0	+1.0
10°	+0.9	+0.9	+0.9	+0.9
20°	+0.7	+0.7	+0.7	+0.7
30°	+0.4	+0.4	+0.35	+0.35
40°	0	0	0	0
50°	-0.5	-0.4	-0.7	-0.5
60°	-0.95	-0.8	-1.2	-1.05
70°	-1.25	-1.1	-1.4	-1.25
80°	-1.2	-1.05	-1.45	-1.3
90°	-1.0	-0.85	-1.4	-1.2
100°	-0.8	-0.65	-1.1	-0.85
120°	-0.5	-0.35	-0.6	-0.4
140°	-0.4	-0.3	-0.35	-0.25
160°	-0.4	-0.3	-0.35	-0.25
180°	-0.4	-0.3	-0.35	-0.25

NOTE 1. Interpolation may be used in the range $2.5 < H/d < 10$.

NOTE 2. Valid for diameters greater than $d = 1$ m.

NOTE 3. The position on the periphery at $\theta = 40^\circ$ where $C_{pe} = 0$ is a region where the pressure will change rapidly with time, due to fluctuations in wind direction caused by atmospheric turbulence, over the range $C_{pe} = \pm 0.7$. It is therefore the region with the highest risk of fatigue damage to cladding fixings.

2.5 External pressure coefficients for roofs

2.5.1 Flat roofs

2.5.1.1 Scope

The data in this section should be used for all roofs of pitch α less than 5° . Pressure coefficients are given for the orthogonal load cases and are upper bound values to cater for all wind directions $\theta \pm 45^\circ$ from normal to the eaves being considered.

2.5.1.2 Loaded zones

The roof should be subdivided into zones behind each upwind eaves/verge as shown in figure 16 for a rectangular roof. The loaded zones, shown in figure 16, are defined 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 is equal to W or L , depending on the wind direction being considered, as defined in figure 16a, and H is the height of the wall, including any parapet.

2.5.1.3 Flat roofs with sharp eaves

External pressure coefficients for each zone of flat roofs with sharp eaves are given in table 8.

2.5.1.4 Flat roofs with parapets

2.5.1.4.1 A parapet along any eaves or edge will reduce the pressure coefficients for the roof in the local edge areas only. External pressure coefficients for flat roofs with edge parapets are given in table 8, dependent upon the ratio of the height h of the parapet, defined in figure 17a, to the scaling length b .

2.5.1.4.2 Loading on the parapet walls, including the effects of corners where appropriate, should be determined as for free-standing walls from 2.8.1.

2.5.1.5 Flat roofs with curved eaves

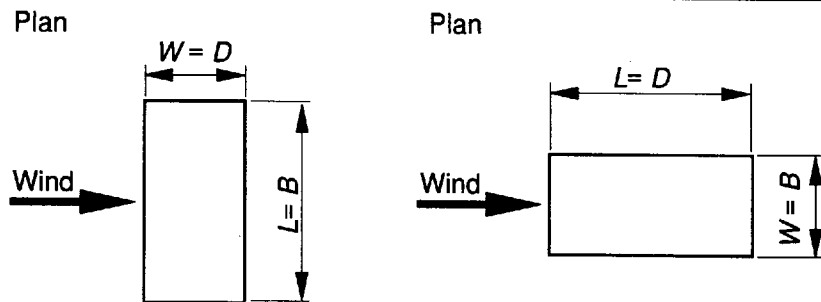
2.5.1.5.1 External pressure coefficients for each zone are given in table 8 and are dependent on the ratio of the radius r of the eaves to the scaling length b , defined in 2.5.1.2, for that eaves. The zones start from the edge of the flat part of the roof as defined in figure 17b.

2.5.1.5.2 The pressure on the curved eaves should be linearly interpolated around the arc between the adjacent wall and roof pressures.

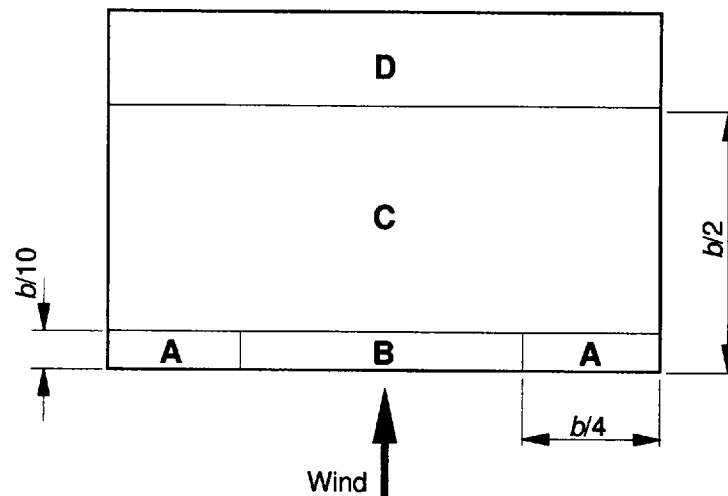
2.5.1.6 Flat roofs with mansard eaves

2.5.1.6.1 External pressure coefficients for each zone are given in table 8 and are dependent on the pitch angle α of the mansard eaves. The zones start from the edge of the flat part of the roof as defined in figure 17c.

2.5.1.6.2 The pressure on the sloping mansard eaves should be assessed using the procedure in 2.5.4.



a) Load cases: wind on long face and wind on short face



b) Key to pressure coefficient zones on flat roof

Figure 16. Key for flat roofs

Table 8. External pressure coefficients C_{pe} for flat roofs of buildings

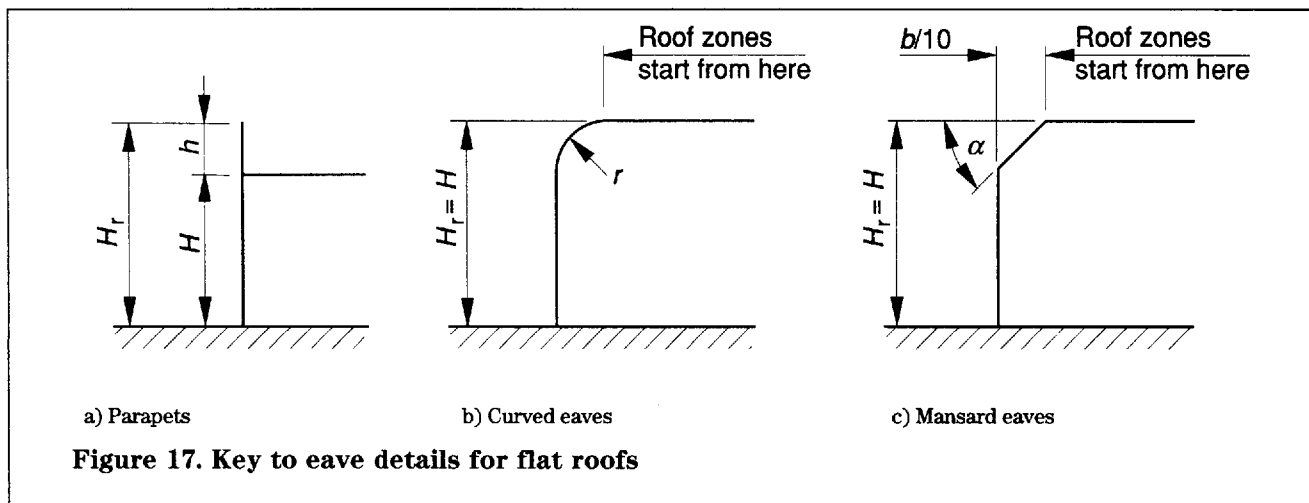
Flat roof type		Zone			
		A	B	C	D
Sharp eaves		-2.0	-1.4	-0.7	± 0.2
With parapets	$h/b = 0.05$	-1.8	-1.25	-0.7	± 0.2
	$h/b = 0.10$	-1.75	-1.2	-0.7	± 0.2
	$h/b \geq 0.20$	-1.4	-1.0	-0.7	± 0.2
Curved eaves	$r/b = 0.05$	-1.0	-1.2	-0.4	± 0.2
	$r/b = 0.10$	-0.75	-0.8	-0.3	± 0.2
	$r/b = 0.20$	-0.55	-0.55	-0.3	± 0.2
Mansard eaves	$\alpha = 30^\circ$	-0.95	-1.0	-0.3	± 0.2
	$\alpha = 45^\circ$	-1.2	-1.3	-0.4	± 0.2
	$\alpha = 60^\circ$	-1.3	-1.25	-0.6	± 0.2

NOTE 1. For roofs with parapets or curved eaves, interpolation may be used for intermediate values of h/b and r/b .NOTE 2. For roofs with mansard eaves, interpolation between $\alpha = 30^\circ$ and $\alpha = 60^\circ$ may be used. For $\alpha > 60^\circ$ interpolate between the values for $\alpha = 60^\circ$ and the values for flat roofs with sharp eaves.

NOTE 3. In zone D, where both positive and negative values are given, both values should be considered.

NOTE 4. Values of coefficients for other wind directions are given in 3.3.2.

NOTE 5. For pitched roofs with curved or mansard eaves, the values in this table may be compared with the appropriate values in tables 9, 10 or 11 and the least negative values used.

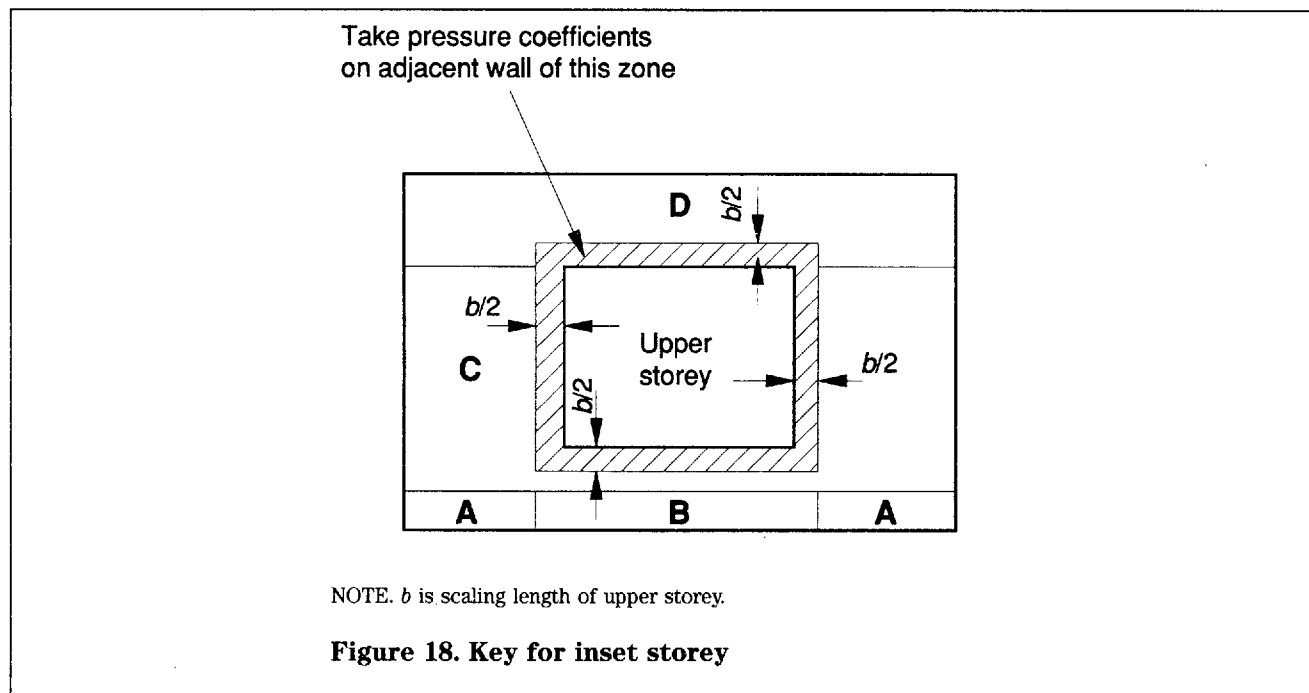


2.5.1.7 Flat roofs with inset storeys

For flat roofs with inset storeys, defined in figure 18, external pressure coefficients for both the upper roofs and lower roofs should be derived as follows.

a) For the upper roof the appropriate procedure of 2.5.1.3, 2.5.1.4, 2.5.1.5 or 2.5.1.6, depending on the form of the eaves, should be used, taking the reference height H_r as the actual height to the upper eaves, and H as the height of the inset storey (from the upper eaves to the lower roof level) for determining the scaling length b .

b) For the lower roof the appropriate procedure of 2.5.1.3, 2.5.1.4, 2.5.1.5 or 2.5.1.6, depending on the form of the eaves, should be used, where $H_r = H$ and is the actual height of the lower storey, ignoring the effect of the inset storeys. However, a further zone around the base of the inset storeys extending $b/2$ from each facing wall should be included, where b is the scaling parameter from 2.5.1.2 appropriate to the relevant walls of the inset storey. The pressure coefficient in this zone should be taken as that of the zone in the adjacent wall of the upper storey (as determined from 2.4).



2.5.2 Monopitch and duopitch roofs

2.5.2.1 General

Monopitch and duopitch roofs of buildings are defined as roofs with gable ends.

NOTE. Hipped roof forms are treated separately in 2.5.3.

2.5.2.2 Loaded zones

Zones over which the external pressure coefficient is assumed to be constant for both monopitch and duopitch roofs are shown in figures 19 and 20. These zones are strips parallel to the eaves and verge and are defined in terms of the scaling lengths b_L and b_W where $b_L = L$ or $b_L = 2H$, whichever is the smaller, and $b_W = W$ or $b_W = 2H$, whichever is the smaller.

2.5.2.3 Monopitch roofs

External pressure coefficients for monopitch roofs should be obtained from table 9, using the key in figure 19. Owing to the asymmetry of this roof form, values are given for three orthogonal load cases: wind normal to the low eaves ($\theta = 0^\circ$), wind normal to the gable ($\theta = 90^\circ$) and wind normal to the high eaves ($\theta = 180^\circ$).

2.5.2.4 Duopitch roofs

2.5.2.4.1 External pressure coefficients for duopitch roofs should be obtained from table 10, using the key in figure 20. Values are given for two wind directions: wind normal to the low eaves ($\theta = 0^\circ$) and wind normal to the gable ($\theta = 90^\circ$). These coefficients are appropriate to duopitch faces of equal pitch but may be used without modification provided the upwind and downwind pitch angles are within 5° of each other. For duopitch roofs of greater disparity in pitch angles see reference [6].

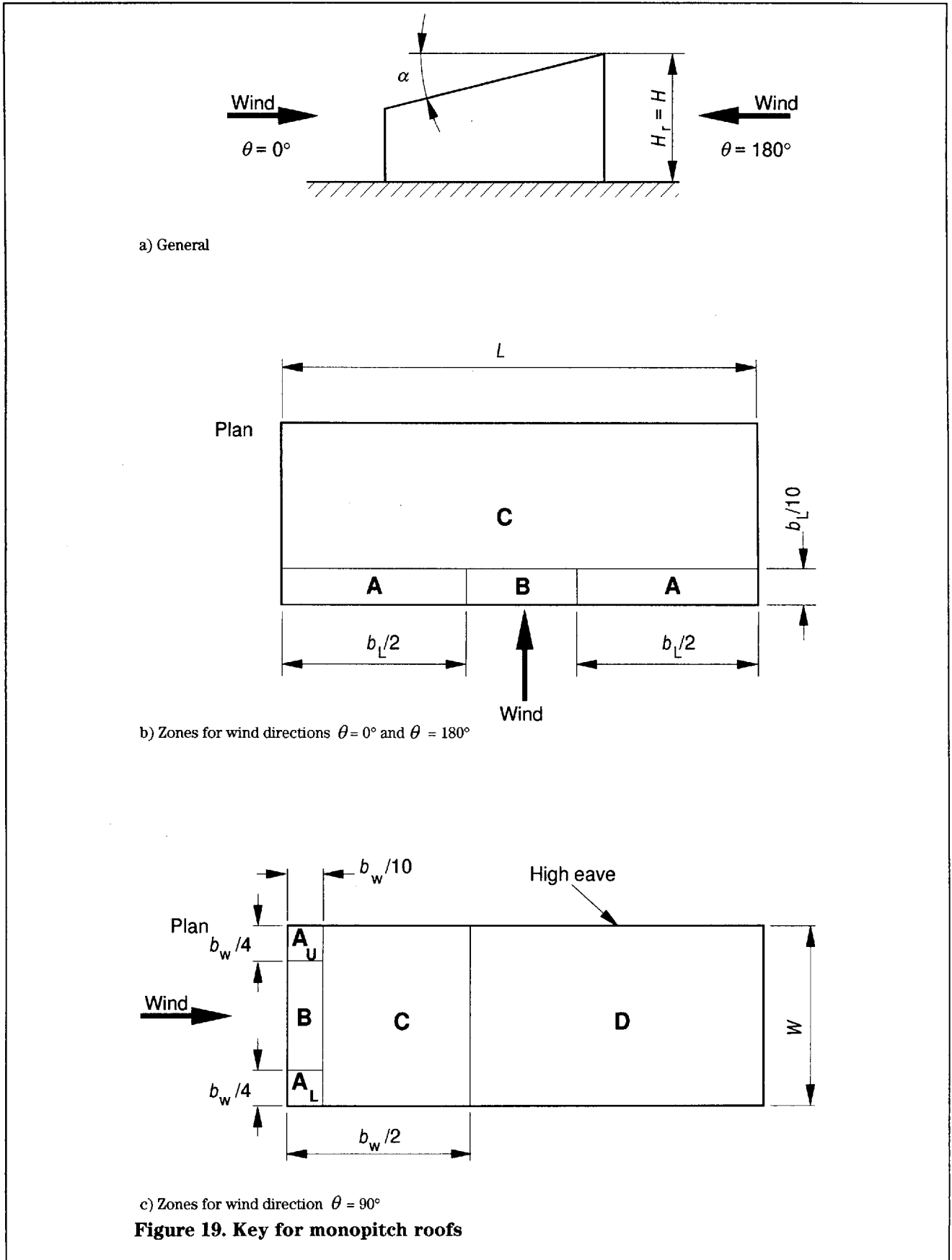
2.5.2.4.2 When $\alpha < 7^\circ$ and $W < b_L$, zone C for the load case $\theta = 0^\circ$ should be considered to extend for a distance $b_L/2$ downwind from the windward eave (as shown for flat roofs in figure 16), replacing ridge zones E and F and part of zone G.

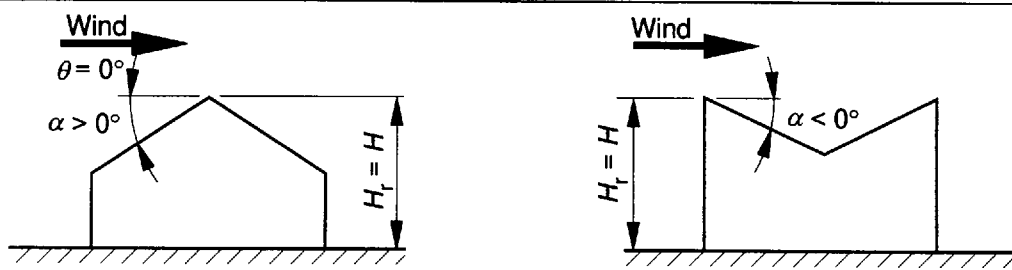
2.5.3 Hipped roofs

External pressure coefficients for conventional hipped roofs on cuboidal-plan buildings, where all faces of the roof have the same pitch angle and are in the range $\alpha = -45^\circ$ to $+75^\circ$, are given in table 11. The definitions of loaded zones and pitch angles are given in figure 21. The data in table 11 may be applied to hipped roofs where main faces and hipped faces have different pitch angles, provided the pitch angle of the upwind face is used for each wind direction, as indicated in figure 21. Negative pitch angles occur when the roof is a hipped-trough form. For pressure coefficients for skew-hipped roofs and other hipped roof forms see reference [6].

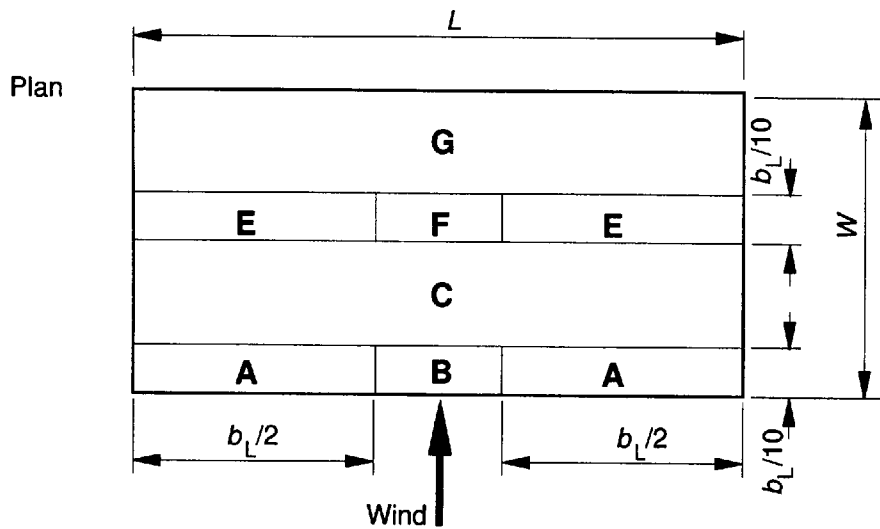
2.5.4 Mansard roofs

External pressure coefficients for mansard roofs and other multi-pitch roofs should be derived for each plane face by the procedure given in 2.5.2 for roofs with gable verges or the procedure given in 2.5.3 for roofs with hipped verges, using the pitch angle for each plane face. The key in figure 22 indicates where edge zones should be omitted.

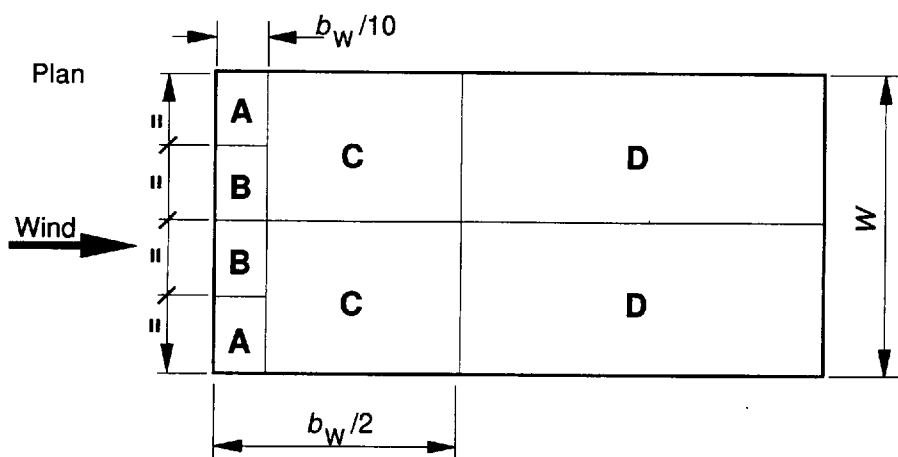




a) General



b) Zones for wind direction $\theta = 0^\circ$



b) Zones for wind direction $\theta = 90^\circ$

Figure 20. Key for duopitch roofs

Pitch angle α	Zone for $\theta = 0^\circ$			Zone for $\theta = 90^\circ$					Zone for $\theta = 180^\circ$		
	A	B	C	A _U	A _L	B	C	D	A	B	C
5°	-1.8	-1.2	-0.6	-2.2	-2.1	-1.7	-0.6	-0.5	-2.3	-1.2	-0.8
15°	-1.3 +0.2	-0.8 +0.2	-0.3 +0.2	-2.8	-1.6	-1.6	-0.8	-0.7	-2.6	-1.0	-0.8
30°	-1.1 +0.8	-0.5 +0.5	-0.2 +0.4	-1.7	-1.3	-1.2	-1.0	-0.8	-2.3	-1.2	-0.8
45°	-1.1 +0.8	-0.3 +0.6	+0.7	-1.5	-1.3	-1.2	-1.0	-0.9	-1.3	-1.0	-0.8
60°	+0.8	+0.8	+0.8	-1.2	-1.2	-1.2	-0.4 +0.4	-0.4	-1.0	-0.7	-0.7
75°	+0.8	+0.8	+0.8	-1.2	-1.2	-1.2	-0.4 +0.5	-0.2 +0.4	-1.1	-0.7	-0.7

NOTE 1. At $\theta = 0^\circ$ the pressure changes rapidly between positive and negative values in the range of pitch angle $15^\circ < \alpha < 30^\circ$, so both positive and negative values are given. At $\theta = 90^\circ$ with high roof pitches, the pressure changes between positive and negative with fluctuations of wind direction, so both positive and negative values are again given.

NOTE 2. Interpolation for intermediate pitch angles may be used between values of the same sign.

Pitch angle α	Zone for $\theta = 0^\circ$						Zone for $\theta = 90^\circ$			
	A	B	C	E	F	G	A	B	C	D
-45°	-1.0	-1.0	-0.8	-1.0	-0.7	-0.7	-1.5	-1.3	-1.0	-0.2
-30°	-1.2	-1.2	-0.8	-0.9	-0.7	-0.7	-1.7	-1.3	-1.0	-0.2
-15°	-2.6	-1.0	-0.9	-0.7	-0.5	-0.5	-2.7	-1.4	-0.8	-0.3
-5°	-2.3	-1.2	-0.8	-0.3	-0.3	-0.3	-2.2	-1.5	-0.7	-0.4
+5°	-1.8	-1.2	-0.6	-0.5	-0.3	-0.3	-2.0	-1.1	-0.6	-0.4
+15°	-1.3 +0.2	-0.8 +0.2	-0.3 +0.2	-1.1	-0.9	-0.5	-1.6	-1.5	-0.6	-0.3
+30°	-1.1 +0.8	-0.5 +0.5	-0.2 +0.4	-0.7	-0.4	-0.4	-1.2	-1.1	-0.6	-0.2
+45°	-1.1 +0.8	-0.3 +0.6	+0.7	-0.4	-0.3	-0.3	-1.2	-1.2	-0.6	-0.2
+60°	+0.8	+0.8	+0.8	-0.7	-0.7	-0.3	-1.2	-1.2	-0.7	-0.2
+75°	+0.8	+0.8	+0.8	-0.7	-0.7	-0.3	-1.2	-1.2	-0.7	-0.2

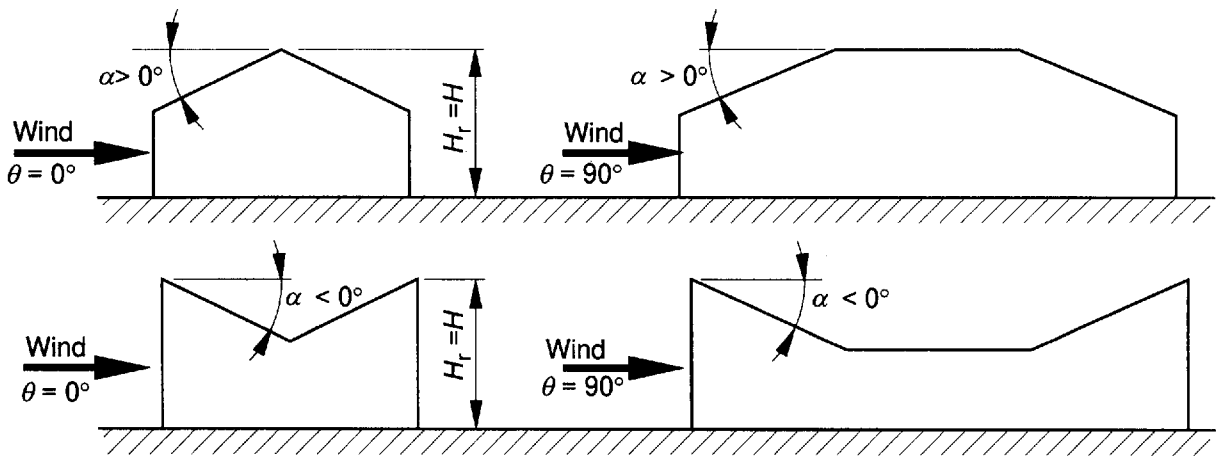
NOTE 1. At $\theta = 0^\circ$ the pressure changes rapidly between positive and negative values in the range of pitch angle $+15^\circ < \alpha < +30^\circ$, so both positive and negative values are given.

NOTE 2. Interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. (Do not interpolate between $\alpha = +5^\circ$ and $\alpha = -5^\circ$; use the data for flat roofs in 2.5.1.)

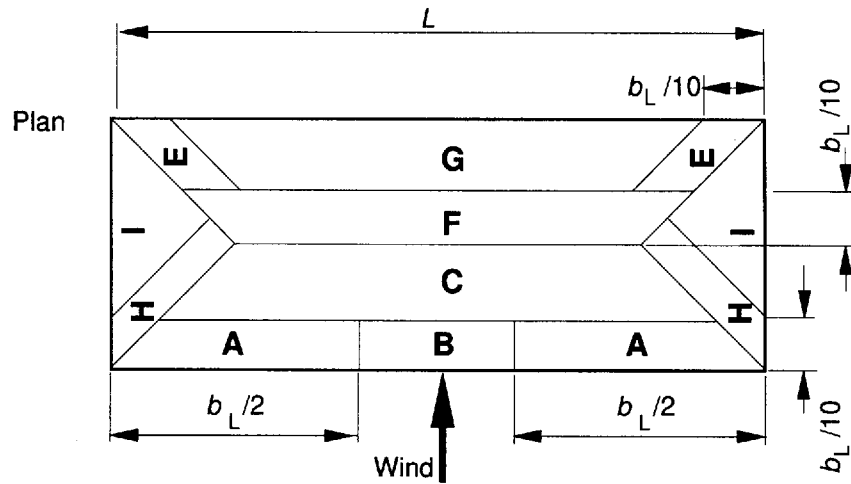
Table 11. External pressure coefficients C_{pe} for hipped roofs of buildings									
Pitch angle α	Zone for $\theta = 0^\circ$ and $\theta = 90^\circ$								
	A	B	C	E	F	G	H	I	J
-45°	-1.3	-0.6	-0.8	-0.7	-0.7	-0.7	-0.8	-0.8	-0.2
-30°	-2.3	-0.8	-0.8	-0.7	-0.7	-0.7	-0.8	-0.8	-0.2
-15°	-2.6	-1.0	-0.9	-0.5	-0.5	-0.5	-0.6	-0.6	-0.3
-5°	-2.3	-1.2	-0.8	-0.3	-0.3	-0.3	-0.6	-0.6	-0.4
+5°	-1.8	-1.2	-0.6	-0.6	-0.6	-0.3	-1.2	-0.6	-0.4
+15°	-1.3 +0.2	-0.8 +0.2	-0.3 +0.2	-1.0	-1.2	-0.5	-1.4	-0.6	-0.3
+30°	-1.1 +0.8	-0.5 +0.5	-0.2 +0.4	-0.7	-0.5	-0.4	-1.4	-0.8	-0.2
+45°	-1.1 +0.8	-0.3 +0.6	+0.7	-0.6	-0.3	-0.3	-1.3	-0.8	-0.2
+60°	+0.8	+0.8	+0.8	-0.6	-0.3	-0.3	-1.2	-0.4	-0.2
+75°	+0.8	+0.8	+0.8	-0.6	-0.3	-0.3	-1.2	-0.4	-0.2

NOTE 1. At $\theta = 0^\circ$ the pressure changes rapidly between positive and negative values in the range of pitch angle $+15^\circ < \alpha < +30^\circ$, so both positive and negative values are given.

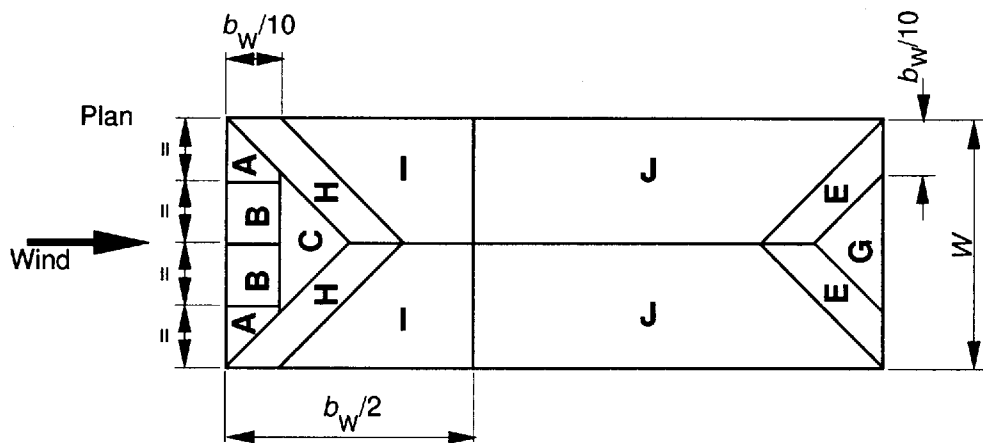
NOTE 2. Interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. (Do not interpolate between $\alpha = +5^\circ$ and $\alpha = -5^\circ$; use the data for flat roofs in 2.5.1.)



a) General

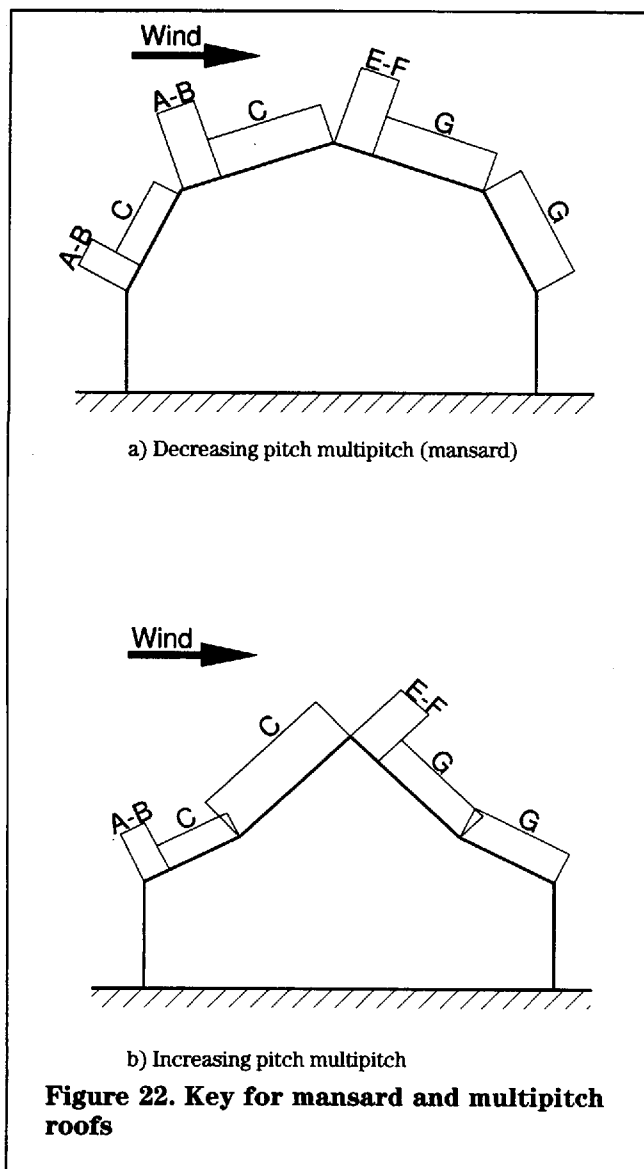


b) Zones for wind direction $\theta = 0^\circ$ using α_0



c) Zones for wind direction $\theta = 90^\circ$ using α_{90}

Figure 21. Key for hipped roofs



2.5.5 Multi-bay roofs

External pressure coefficients on downwind bays of monopitch and duopitch multi-bay roofs as defined in figure 23 may conservatively be taken to be the same as for a single-bay roof.

However, reduced values of external pressure coefficients may be derived from table 9 or table 10, as appropriate, as follows:

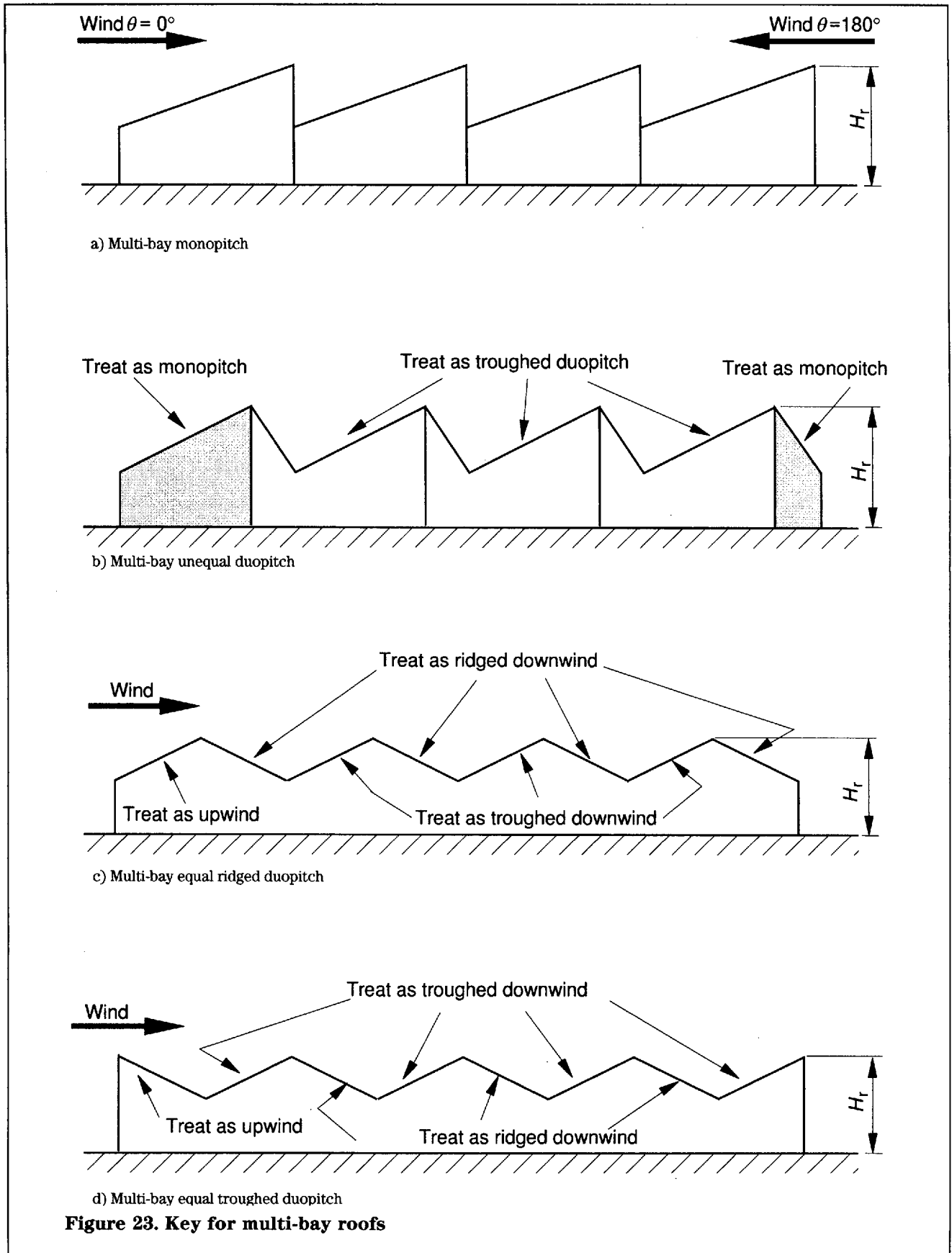
- For monopitch roofs as shown in figure 23a), any positive pressure coefficient obtained from table 9 should be replaced on the second and any subsequent downwind bays by $C_{pe} = -0.4$.
- For unequal-pitch duopitch roofs, all roof slopes downwind of the first ridge should be treated as being troughed (negative pitch angle), even when the upwind slope is ridged as shown in figure 23(b), so that the local coefficients behind each ridge are given by the more onerous A and B eave zones for negative pitch angles.
- For equal-pitch duopitch roofs, all roof slopes downwind of the upward slope should be treated as alternatively downwind ridged (positive pitch angle) and troughed (negative pitch angle) as shown in figures 23(c) and (d), so that the local coefficients behind each ridge are given by the less onerous E and F ridge zones for positive pitch angles.

NOTE. The provisions of c) above may be applied to unequal-pitch duopitch roofs when the pitch angles differ by less than 10° .

For winds from $\theta = 0^\circ$ and $\theta = 180^\circ$, in all the above cases, a further reduction in external pressure may be obtained by applying the reduction factors of table 12 to the second and subsequent downwind bays.

Table 12. Reduction factor for multi-bay roofs

Bay	Upwind bay	Second bay	All remaining bays
Reduction factor	1.0	0.8	0.6



2.5.6 Pitched roofs with inset storeys

The procedure given for inset storeys on flat roofs in 2.5.1.7 should be followed, but using the appropriate zones for pitched roofs as derived from 2.5.2 to 2.5.5.

2.5.7 Effect of parapets on pitched roofs

Parapets reduce the high suction in the edge zones around the periphery of the roof and neglecting these effects will give a conservative result for roof pitches less than $\alpha = 30^\circ$. For steeper roofs, the effects of parapets should be taken into account by using the procedure given in 3.3.3.7.

2.5.8 Roof overhangs**2.5.8.1 General**

Where the roof overhangs the walls by an amount less than $b/10$, pressure coefficients should be assessed using the procedure given in 2.5.8.2.

Larger overhangs should be treated as open-sided buildings, with internal pressure coefficients determined using the provisions of 2.6.3.

2.5.8.2 Small overhangs

The net pressure across a small roof overhang should be calculated taking the pressure coefficient on the upper surface from 2.5.2 to 2.5.5, as appropriate, and the pressure coefficient on the lower surface as that on the adjacent wall from 2.4.

2.5.9 Canopies, grandstands and open-sided buildings**2.5.9.1 Free-standing canopies**

2.5.9.1.1 Net pressure coefficients C_p for free-standing canopy roofs are given in tables 13, 14 and 15, which take account of the combined effect of the wind on both upper and lower surfaces of the canopy for all wind directions.

Table 13. Net pressure coefficients C_p for free-standing monopitch canopy roofs

Pitch angle α	Load case	Overall coefficients	Local coefficients		
			A	B	C
0°	Maximum, all ζ	+0.2	+0.5	+1.8	+1.1
	Minimum $\zeta = 0$	-0.5	-0.6	-1.3	-1.4
	Minimum $\zeta = 1$	-1.2	-1.3	-1.8	-2.2
5°	Maximum, all ζ	+0.4	+0.8	+2.1	+1.3
	Minimum $\zeta = 0$	-0.7	-1.1	-1.7	-1.8
	Minimum $\zeta = 1$	-1.4 (-1.2)	-1.4 (-1.2)	-2.6	-2.6 (-2.1)
10°	Maximum, all ζ	+0.5	+1.2	+2.4	+1.6
	Minimum $\zeta = 0$	-0.9	-1.5	-2.0	-2.1
	Minimum $\zeta = 1$	-1.4 (-1.1)	-1.4 (-1.1)	-2.6	-2.7 (-1.8)
15°	Maximum, all ζ	+0.7	+1.4	+2.7	+1.8
	Minimum $\zeta = 0$	-1.1	-1.8	-2.4	-2.5
	Minimum $\zeta = 1$	-1.5 (-1.0)	-1.5 (-1.0)	-2.9	-2.8 (-1.6)
20°	Maximum, all ζ	+0.8	+1.7	+2.9	+2.1
	Minimum $\zeta = 0$	-1.3	-2.2	-2.8	-2.9
	Minimum $\zeta = 1$	-1.5 (-0.9)	-1.5 (-0.9)	-2.9	-2.7 (-1.5)
25°	Maximum, all ζ	+1.0	+2.0	+3.1	+2.3
	Minimum $\zeta = 0$	-1.6	-2.6	-3.2	-3.2
	Minimum $\zeta = 1$	-1.4 (-0.8)	-1.4 (-0.8)	-2.5	-2.5 (-1.4)
30°	Maximum, all ζ	+1.2	+2.2	+3.2	+2.4
	Minimum $\zeta = 0$	-1.8	-3.0	-3.8	-3.6
	Minimum $\zeta = 1$	-1.4 (-0.8)	-1.4 (-0.8)	-2.0	-2.3 (-1.2)

NOTE 1. Interpolation may be used for solidity ratio in the range $0 < \zeta < 1$ and for intermediate pitch angles.

NOTE 2. Where two values are given for $\zeta = 1$, the first value is for blockage to the low downwind eaves and the second value (in parentheses) is for blockage to the high downwind eaves.

NOTE 3. Load cases cover all possible wind directions. When using directional effective wind speeds, use:

- these values of C_p with the largest value of V_e found; or
- directional values of C_p from reference [6].

Pitch angle α	Load case	Overall coefficients	Local coefficients			
			A	B	C	D
-20°	Maximum, all ζ	+0.7	+0.8	+1.6	+0.6	+1.7
	Minimum $\zeta = 0$	-0.7	-0.9	-1.3	-1.6	-0.6
	Minimum $\zeta = 1$	-1.5	-1.5	-2.4	-2.4	-1.2
-15°	Maximum, all ζ	+0.5	+0.6	+1.5	+0.7	+1.4
	Minimum $\zeta = 0$	-0.6	-0.8	-1.3	-1.6	-0.6
	Minimum $\zeta = 1$	-1.5	-1.5	-2.7	-2.6	-1.2
-10°	Maximum, all ζ	+0.4	+0.6	+1.4	+0.8	+1.1
	Minimum $\zeta = 0$	-0.6	-0.8	-1.3	-1.5	-0.6
	Minimum $\zeta = 1$	-1.4	-1.4	-2.5	-2.5	-1.2
-5°	Maximum, all ζ	+0.3	+0.5	+1.5	+0.8	+0.8
	Minimum $\zeta = 0$	-0.5	-0.7	-1.3	-1.6	-0.6
	Minimum $\zeta = 1$	-1.4	-1.4	-2.3	-2.4	-1.2
+5°	Maximum, all ζ	+0.3	+0.6	+1.8	+1.3	+0.4
	Minimum $\zeta = 0$	-0.6	-0.6	-1.4	-1.4	-1.1
	Minimum $\zeta = 1$	-1.2	-1.2	-2.0	-1.8	-1.5
+10°	Maximum, all ζ	+0.4	+0.7	+1.8	+1.4	+0.4
	Minimum $\zeta = 0$	-0.7	-0.7	-1.5	-1.4	-1.4
	Minimum $\zeta = 1$	-1.2	-1.2	-1.8	-1.6	-1.6
+15°	Maximum, all ζ	+0.4	+0.9	+1.9	+1.4	+0.4
	Minimum $\zeta = 0$	-0.8	-0.9	-1.7	-1.4	-1.8
	Minimum $\zeta = 1$	-1.2	-1.2	-1.6	-1.3	-1.7
+20°	Maximum, all ζ	+0.6	+1.1	+1.9	+1.5	+0.4
	Minimum $\zeta = 0$	-0.9	-1.2	-1.8	-1.4	-2.0
	Minimum $\zeta = 1$	-1.2	-1.2	-1.5	-1.2	-1.7
+25°	Maximum, all ζ	+0.7	+1.2	+1.9	+1.6	+0.5
	Minimum $\zeta = 0$	-1.0	-1.4	-1.9	-1.4	-2.0
	Minimum $\zeta = 1$	-1.2	-1.2	-1.4	-1.1	-1.6
+30°	Maximum, all ζ	+0.9	+1.3	+1.9	+1.6	+0.7
	Minimum $\zeta = 0$	-1.0	-1.4	-1.9	-1.4	-2.0
	Minimum $\zeta = 1$	-1.2	-1.2	-1.3	-1.1	-1.6

NOTE 1. Interpolation for solidity ratio may be used in the range $0 < \zeta < 1$.

NOTE 2. Interpolation for intermediate pitch angles may be used between values of the same sign.

NOTE 3. Load cases cover all possible wind directions. When using directional effective wind speeds, use:

- these values of C_p with the largest value of V_e found; or
- directional values of C_p from reference [6].

Location	Factors for all solidity ratio ζ	
	On maximum	On minimum
End bay	1.00	0.81
Second bay	0.87	0.64
Third and subsequent bays	0.68	0.63

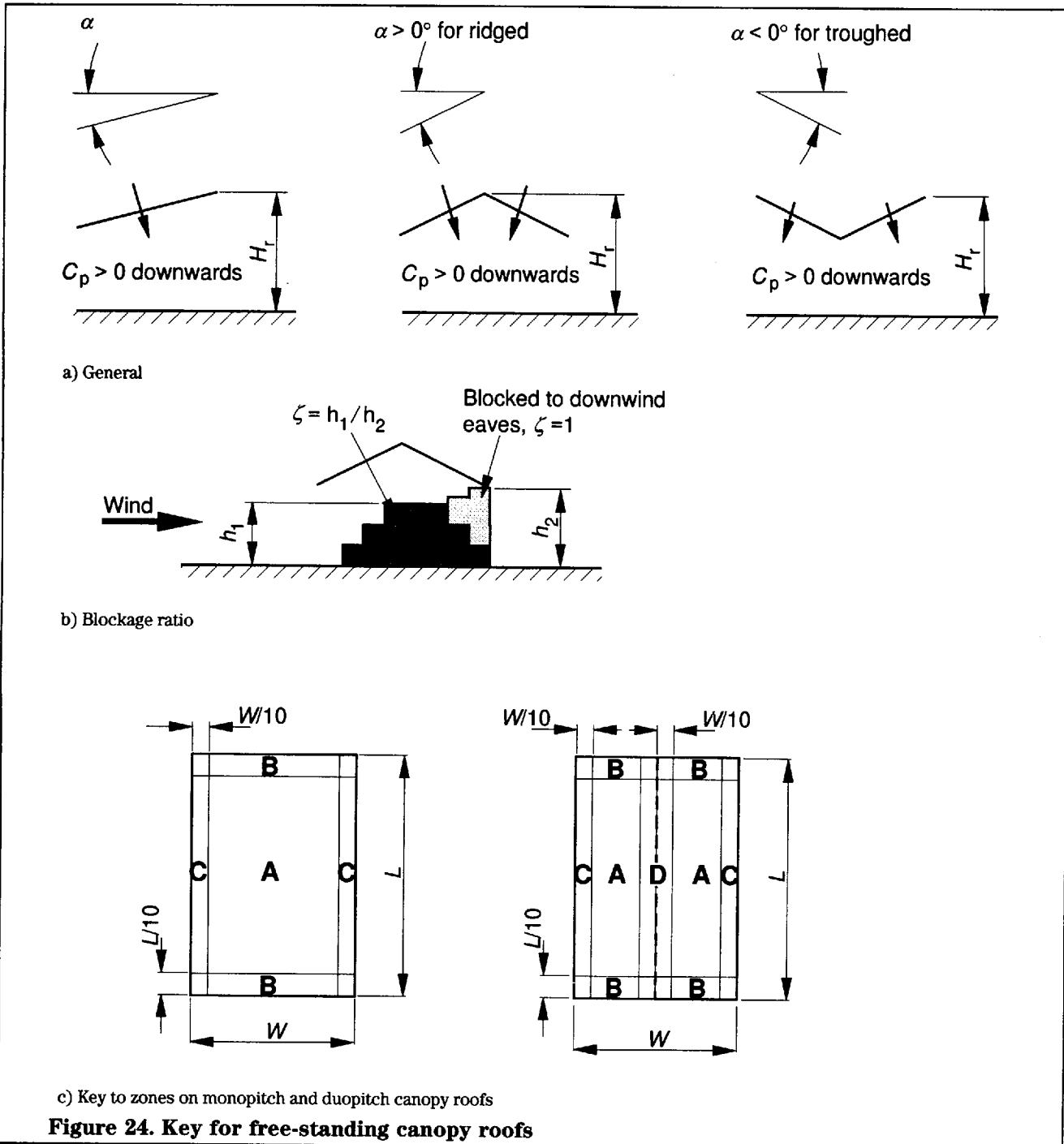


Figure 24. Key for free-standing canopy roofs

2.5.9.1.2 Canopies should be able to resist the maximum (largest positive) and the minimum (largest negative) net pressures, the latter depending on the degree of blockage under the canopy. The blockage ratio ζ at any cross section is equal to the height of obstruction under the canopy divided by the smallest height of the canopy at the location of the obstruction, both areas normal to the wind direction. The value $\zeta = 0$ represents a canopy with no obstructions underneath. The value $\zeta = 1$ represents the canopy fully blocked with contents to the downwind eaves. Values of C_p for intermediate blockages may be linearly

interpolated between these two extremes, and applied upwind of the position of maximum blockage only. Downwind of the position of maximum blockage the coefficients for $\zeta = 0$ may be used.

2.5.9.1.3 The values in the columns with the multi-column heading 'Local coefficients', corresponding to the loaded areas defined in figure 24, should be used for the design of the respective areas of the canopy. Where the local coefficient areas overlap the greater of the two given values should be taken.

2.5.9.1.4 The values in the columns headed 'Overall coefficients' should be used for the design of the members supporting the canopy. For monopitch canopies the centre of pressure should be taken to act at $0.3W$ from the windward edge. For duopitch canopies the centre of pressure should be taken to act at the centre of each slope. Additionally, duopitch canopies should be able to support forces with one slope at the maximum or minimum and the other slope unloaded.

2.5.9.1.5 In addition to the pressure normal to the canopy, there will be horizontal loads on the canopy due to the wind pressure on any fascia at the eaves or on any gable between eaves and ridge on duopitch canopies. Fascia loads should be calculated on the area of the surface facing the wind using a net pressure coefficient of $C_p = 1.3$ on the windward fascia/gable and $C_p = 0.6$ on the leeward fascia/gable acting in the direction of the wind.

2.5.9.2 Canopies attached to buildings

Pressures on canopies attached to buildings depend on the shape and size of the building, the location of the canopy and on the surrounding buildings. Advice is given in reference [6].

2.5.9.3 Grandstands and open-sided buildings

Buildings with permanent walls and one or more open sides should be treated as conventional buildings, with external pressure coefficients determined from 2.4 and 2.5 and the internal pressure coefficients determined from 2.6.3.

2.5.10 Friction induced loads on roofs

2.5.10.1 Roofs of buildings

Frictional forces should be considered on long roofs away from the upwind edges. The resulting frictional drag coefficient should be assumed to act over zone D on flat roofs (see figure 16) for all wind directions; and over zone D for monopitch or duopitch roofs (see figures 19 and 20 and zone J for hipped roofs in figure 21) only when the wind is parallel to the ridge. Values of frictional drag coefficient should be obtained from table 6 and the resulting frictional forces combined with the normal pressure forces as described in 2.1.3.8.

2.5.10.2 Free-standing canopy roofs

Frictional forces should be assumed to act over the whole of the top and bottom surfaces of an empty canopy or the whole of the top surface only for a fully blocked canopy. Values of frictional drag coefficient should be obtained from table 6 and the resulting frictional forces combined with the normal forces as described in 2.1.3.8.

NOTE. If there are fascias at the eaves or verges (see 2.5.9.1.5) only the greater of the fascia or friction forces need to be taken into account.

2.6 Internal pressure coefficients

2.6.1 Enclosed buildings

2.6.1.1 In enclosed buildings, containing external doors and windows which may be kept closed, and where any internal doors are generally open or are at least three times more permeable than the external doors and windows, the internal pressure can be taken as uniform; appropriate internal pressure coefficients are given in table 16. The relevant diagonal dimension a for the internal pressure may be taken as

$$a = 10 \times \sqrt[3]{\text{internal volume of storey}} \quad (13)$$

Table 16. Internal pressure coefficients C_{pi} for enclosed buildings

Type of walls	C_{pi}
Two opposite walls equally permeable; other faces impermeable	
– Wind normal to permeable face	+0.2
– Wind normal to impermeable face	–0.3
Four walls equally permeable; roof impermeable	–0.3

2.6.1.2 Where an enclosed building is subdivided into rooms with internal doors which are not at least three times more permeable than the external doors, the internal pressure may differ between rooms. This will result in net wind loads on internal walls. A method for calculating the internal pressures in multi-room buildings is given in reference [6]. For external walls, provided there are no dominant openings, the internal pressure coefficient C_{pi} should be taken as either -0.3 or $+0.2$, whichever gives the larger net pressure coefficient across the wall. The maximum net pressure coefficient C_p across internal walls should be taken as 0.5 . The relevant diagonal dimension a for the internal pressure may be taken as

$$a = 10 \times \sqrt[3]{\text{internal volume of room}} \quad (14)$$

2.6.1.3 Where an external opening, such as a door, would be dominant when open but is considered to be closed in the ultimate limit state, the condition with door open should be considered as a serviceability limit state, and the loads assessed using the appropriate partial load factors for serviceability.

2.6.2 Buildings with dominant openings

An opening will be dominant, and control the internal pressure coefficients, when its area is equal to, or greater than, twice the sum of the openings in other faces which contribute porosity to the internal volume containing the opening.²⁾

²⁾ Two or more openings in the same face will contribute to one effective dominant opening equal to the combined area and a diagonal dimension a equal to that of the largest opening.

Internal pressure coefficients C_{pi} are given in table 17 as a fraction of the average external pressure C_{pe} at the dominant opening obtained from 2.4 or 2.5 as appropriate. The relevant diagonal dimension a depends on the size of the dominant opening relative to the internal volume and may be taken as the greater of

$$a = \text{diagonal dimension of dominant opening; or} \\ a = 0.2 \times \sqrt[3]{\text{internal volume}} \quad (15)$$

where the internal volume is the volume of the storey or room containing the dominant opening.

Table 17. Internal pressure coefficients C_{pi} for buildings with dominant openings	
Ratio of dominant opening area to sum of remaining openings and distributed porosities	C_{pi}
2	$0.75 \times C_{pe}$
3	$0.9 \times C_{pe}$

2.6.3 Open-sided buildings

2.6.3.1 Internal pressure coefficients C_{pi} for open-sided buildings are given in table 18 according to the form of the building. The relevant diagonal dimension a for use with these coefficients is the diagonal dimension of the open face. In table 18 a wind direction of $\theta = 0^\circ$ corresponds to wind normal and blowing into the open face, or the longer face in the case of two open faces, and normal to the wall in the case of three open faces.

2.6.3.2 For buildings with two opposite open faces, wind skewed at about $\theta = 45^\circ$ to the axis of the building increases the overall side force. This load case should be allowed for by using a net pressure coefficient of 2.2, divided equally between each side wall. More details are given in reference [6].

2.6.4 Open-topped cylinders

The internal pressure coefficient for an open-topped vertical cylinder, such as a tank, silo or stack, is given in table 19.

Table 18. Internal pressure coefficients C_{pi} for open-sided buildings				
Wind direction θ	One open face		Two adjacent open faces ¹⁾	Three adjacent open faces ²⁾
	Shorter	Longer		
0°	+0.85	+0.68	+0.77	+0.60
90°	-0.60	-0.40	+0.77, -0.38	0
180°	-0.16	-0.16	-0.30	-0.39

¹⁾ Two values are given for $\theta = 90^\circ$. The positive value applies when the wind is blowing into the short open face.
²⁾ Apply values to underside of roof only. For the single wall, use pressure coefficients for walls given in table 5.

Table 19. Internal pressure coefficients C_{pi} for open-topped vertical cylinders	
Proportion of cylinder	C_{pi}
$H/d \geq 0.3$	-0.8
$H/d < 0.3$	-0.5

2.7 Pressure coefficients for elements

2.7.1 General

This section deals with the pressure coefficients of elements of small crosswind breadth, typically 200 mm, attached to buildings. For sharp-edged shapes the pressure coefficients remain approximately constant over the whole range of wind speeds likely to be encountered. However, for circular sections the pressure coefficients vary with wind speed and diameter. For circular elements whose diameter is greater than about 200 mm the values in this section are conservative.

2.7.2 Individual sections

2.7.2.1 Net pressure coefficients for long circular and sharp-edged sections, such as rolled steel sections, plate girders, box sections, beams and circular tubes with the long axis normal to the wind are given in table 20. These net pressure coefficients should be taken to act on the projected area normal to the wind.

Element type	C_p
Circular sections	1.2
Sharp-edged sections	2.0

2.7.2.2 For horizontal sections, the reference height H_r should be taken as the height above ground of the axis of the section. Vertical or inclined sections may be taken as being divided into parts of length at least twice the crosswind breadth, $L \geq 2B$, and the reference height H_r should be taken as the height above ground of the top of each part.

2.7.3 Effect of length

The net pressure coefficient for individual sections reduces when length L between free ends is less than 20 diameters. A reduction factor κ to be applied to the net pressure coefficient in these cases is given by figure 25 in terms of the ratio L/B . In the case of sections cantilevered from the ground or another plane surface, such as a roof, the length L should be taken as twice the protruding length. For sections spanning between two planes L should be taken as infinite ($\kappa = 1$).

2.7.4 Lattices and unclad building frames

2.7.4.1 Conservative estimates of the loading on open lattices can be determined by summing the loads on individual members using 2.7.1 to 2.7.3. The length L between free ends should be taken as the length of each element, i.e. the length between nodes of the lattice. When the lattice is dense or shielded, as with multiple lattices frames, the degree of conservatism can be large.

2.7.4.2 Loads on unclad building frames cannot exceed the loads on the fully clad building, except when the building is very long and the wind is skewed about $\theta = 30^\circ$ to the long axis. A simplified method of calculating the wind loads on unclad building frames which accounts properly for the shielding effects is given in reference [7], based on the full method given in reference [6].

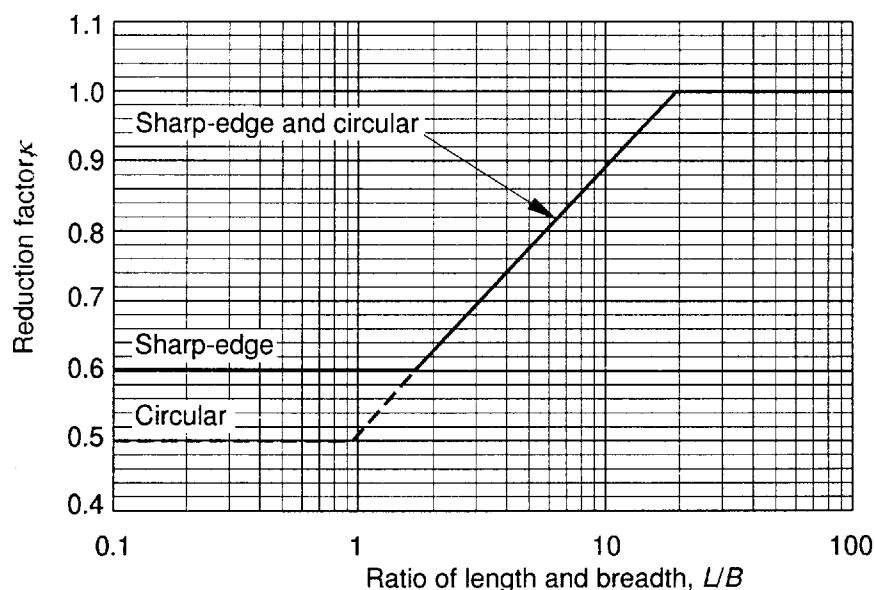


Figure 25. Reduction factor for length of elements

2.8 Free-standing walls, parapets and signboards

2.8.1 Free-standing walls and parapets

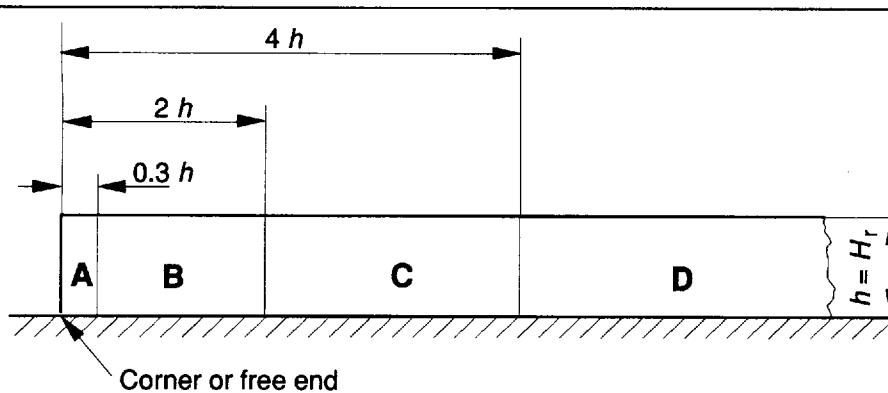
2.8.1.1 Values of net pressure coefficients C_p for free-standing walls and parapets, with or without return corners, are given in table 21 appropriate to the zones shown in figure 26 for two values of solidity. Solidity $\zeta = 1$ refers to solid walls, while $\zeta = 0.8$ refers to walls which are 80 % solid and 20 % open.

2.8.1.2 The high values near the free end or return corners of solid walls (zones A and B) occur when the wind is blowing at $\theta = 45^\circ$ onto that end. Moderate porosity in this region, i.e. solidity $\zeta = 0.8$, reduces these high loads to the values in zone D.

2.8.1.3 Interpolation for solidity may be used in the range $0.8 < \zeta < 1$. For porous walls and fences with solidity less than 0.8, coefficients should be derived as for plane lattice frames (see 2.7.4).

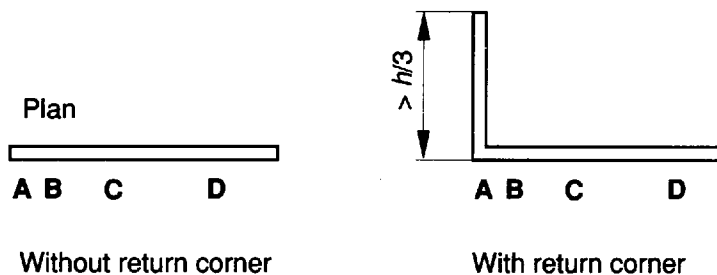
Table 21. Net pressure coefficients C_p for free-standing walls and parapets

Solidity	Walls	Zones			
		A	B	C	D
$\zeta = 1$	Without return corners	3.4	2.1	1.7	1.2
	With return corners	2.1	1.8	1.4	1.2
$\zeta = 0.8$	All	1.2	1.2	1.2	1.2



a) Key to zones

NOTE. For the definition of h and H_r for parapets see figure 17a



b) Key to return corners

Figure 26. Key for free-standing walls and parapets

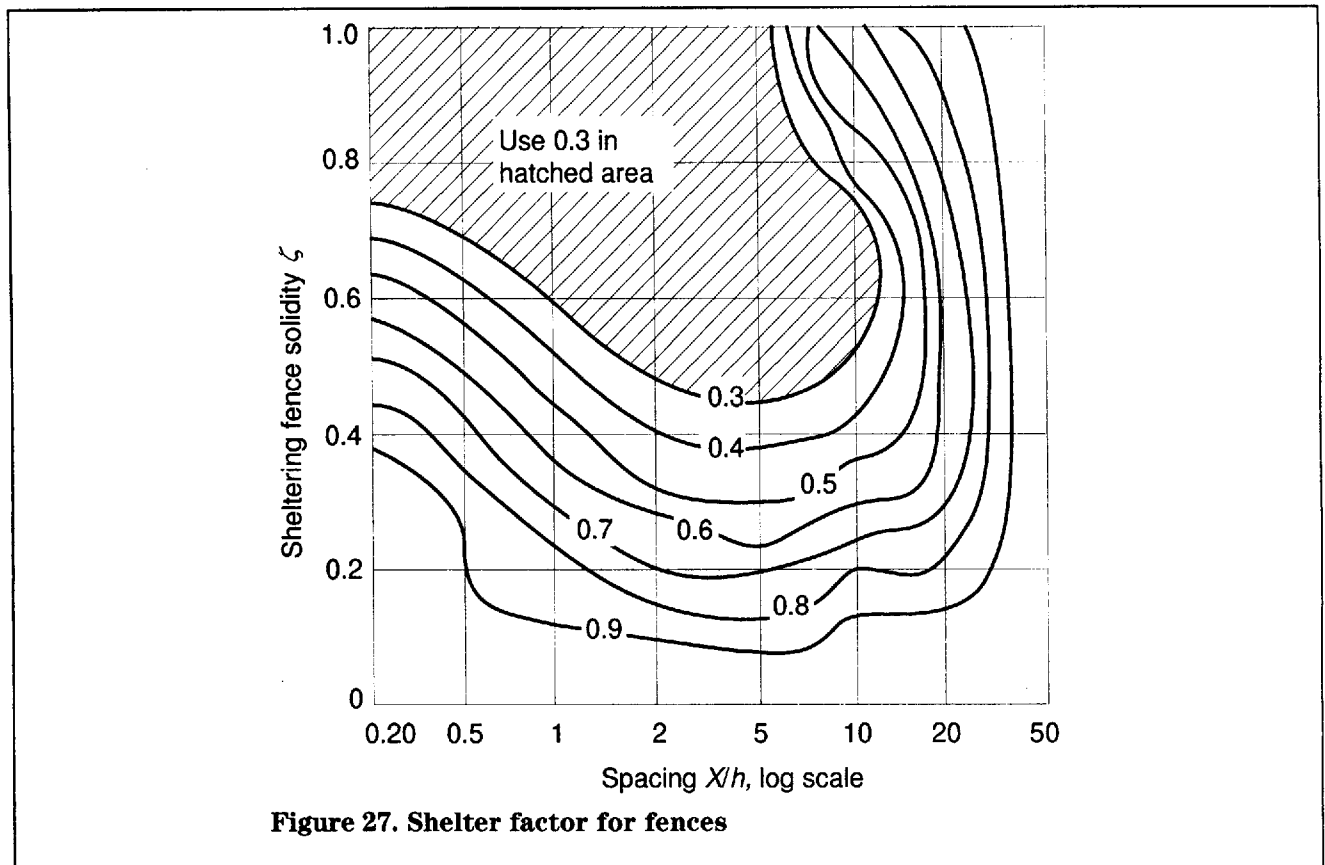


Figure 27. Shelter factor for fences

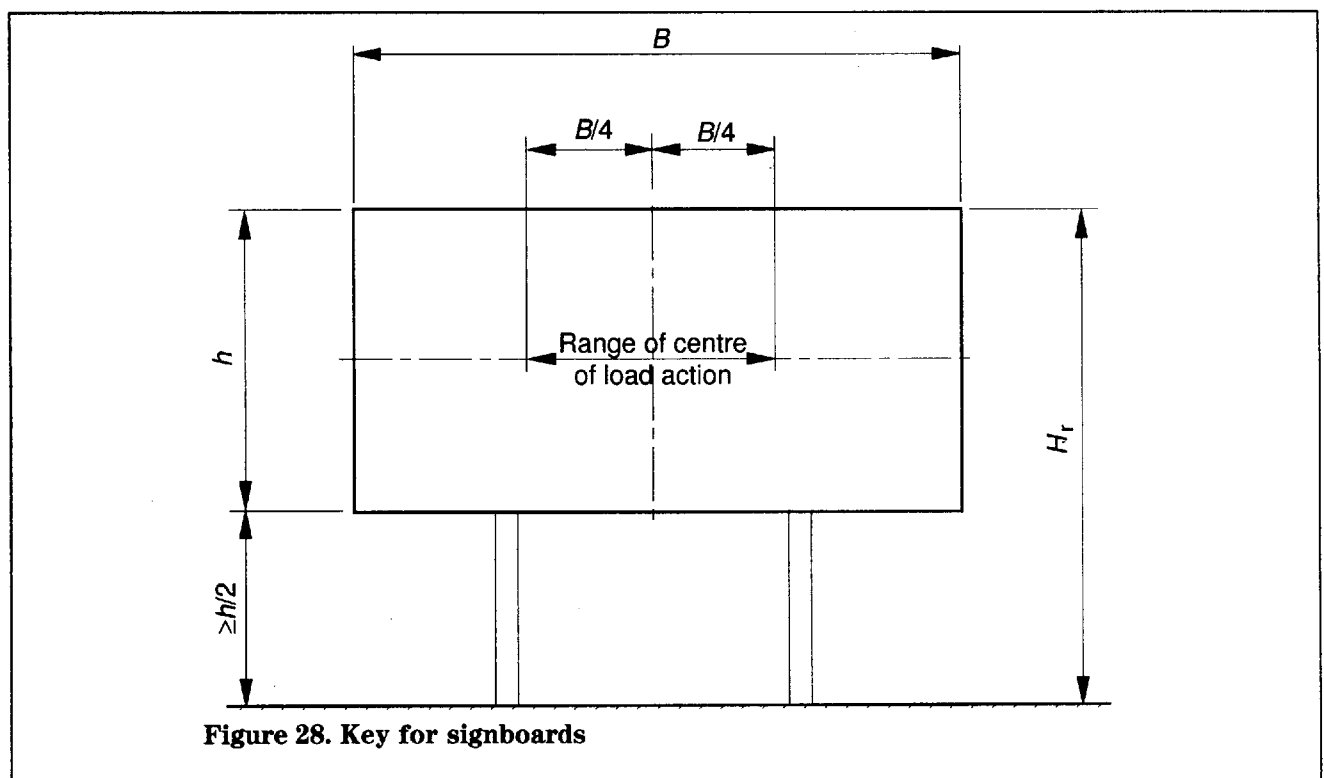


Figure 28. Key for signboards

2.8.1.4 When there are other walls or fences upwind that are equal in height or taller than the wall or fence height h an additional shelter factor can be used with the net pressure coefficients for boundary walls and lattice fences. The degree of the shelter depends on the spacing between the walls or fences and the solidity ζ of the upwind (sheltering) wall or fence. Values of shelter factor to reduce the net pressure coefficient are plotted in figure 27. Shelter remains significant up to spacings of 20 wall heights. At very close spacings the net pressure coefficient on the downwind (sheltered) wall can be zero or can reverse in sign. A minimum limit to the shelter factor of 0.3 has been set to cover this case safely.

2.8.2 Signboards

The net pressure coefficient C_p for signboards, separated from the ground by at least half their height as defined in figure 28, should be taken as $C_p = 1.8$. If the gap is less than half the height of the board, then it should be treated as a free-standing wall in accordance with 2.7.5. The normal force should be taken to act at the height of the centre of the board, but the horizontal position should be taken to vary between $\pm 0.25B$ from the centre of the board.

Section 3. Directional method

3.1 Directional wind loads

3.1.1 Wind direction

3.1.1.1 The directional wind load method requires knowledge of the wind direction in two forms:

- in degrees east of north, represented by φ , used to determine wind speeds and dynamic pressure;
- in degrees relative to normal to each building face (or around the periphery of a circular-plan building), represented by θ , used to determine the pressure coefficients.

NOTE. In practice, it is usually most convenient to relate both φ and the various values of θ for each face, $\theta_1, \theta_2, \theta_3$, etc, to a standard value of θ , corresponding to a principal axis or reference face of the building. This is illustrated in figure 29 for the case of a rectangular-plan building.

3.1.2 Dynamic pressure

3.1.2.1 The value of the dynamic pressure q (in Pa) of the directional method is given by

$$q = 0.613V_e^2 \quad (16)$$

where

V_e is the effective wind speed (in m/s) from 3.2.3.1.

3.1.2.2 The reference value of dynamic pressure for deriving pressure on external surfaces is denoted by q_e and the reference value for deriving internal pressures by q_i .

3.1.2.3 Values of dynamic pressure for various values of wind speed are given in table 2.

3.1.3 Wind load

3.1.3.1 Directional surface pressures

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

$$p_e = q_e C_{pe} \quad (17)$$

where

q_e is the dynamic pressure (3.1.2.2) from the effective wind speed in wind direction φ for the external surface defined in 3.1.2;

C_{pe} is the external pressure coefficient for the building surface in wind direction θ given in 3.3.

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

$$p_i = q_i C_{pi} \quad (18)$$

where

q_i is the dynamic pressure (3.1.2.2) from the effective wind speed in wind direction φ for the internal surface defined in 3.1.2;

C_{pi} is the internal pressure coefficient for the building in wind direction θ given in 3.3.5.

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

- For enclosed buildings

$$p = p_e - p_i \quad (19)$$

where

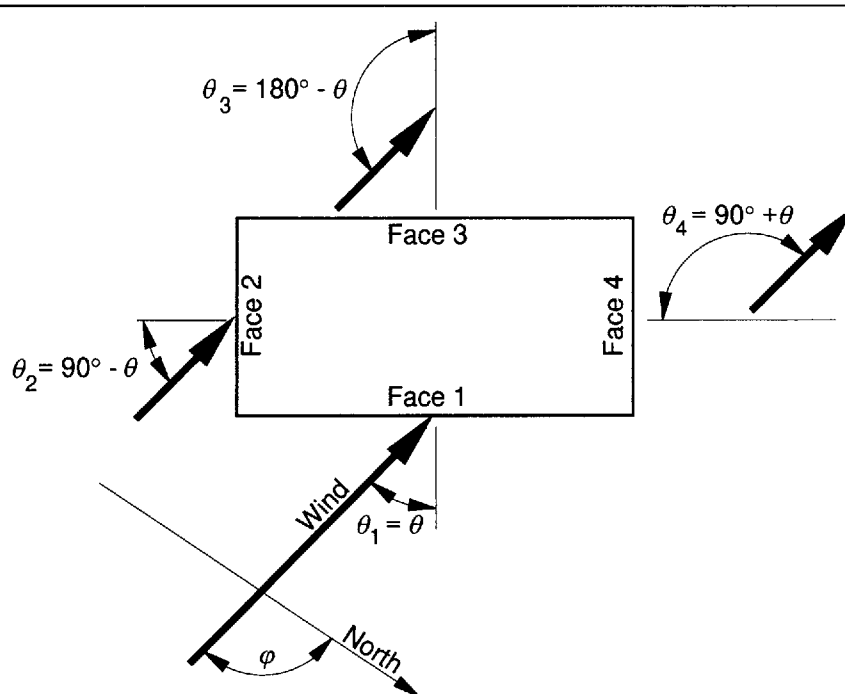


Figure 29. Wind directions for a rectangular-plan building

p_e is the external pressure given in 3.1.3.1.1;
 p_i is the internal pressure given in 3.1.3.1.2.

b) For canopies or building elements

$$p = q_e C_p \quad (20)$$

where

q_e is the dynamic pressure from the effective wind speed for the canopy surface or element defined in 3.1.2;

C_p is the net pressure coefficient for the element given in 2.7.

3.1.3.2 Directional surface loads

The net wind load P on a building surface or element is given by

$$P = pA \quad (21)$$

where

p is the net pressure across the surface;

A is the loaded area.

3.1.3.3 Directional overall loads

3.1.3.3.1 The overall load P on a building may be taken as the vectorial sum of the loads on individual surfaces, multiplied by $(1 + C_T)$ to account for mildly dynamic response. However, since peak loads on each face of buildings do not act simultaneously, the resulting summation would be conservative.

3.1.3.3.2 Accordingly, the overall load on a building of arbitrary shape may be represented by the cases shown in figure 30 in which all windward-facing walls or roof faces are categorized as 'front' and all leeward-facing walls or roof faces as 'rear', when the overall load in the wind direction, P , may be taken as

$$P = 0.85 \{ \Sigma(P_{\text{front}} \cos\theta) - \Sigma(P_{\text{rear}} \cos\theta) \} (1 + C_T) \quad (22)$$

where

P_{front} is the horizontal component of net wind load acting on windward-facing walls and roofs;

P_{rear} is the horizontal component of net wind load acting on leeward-facing walls and roofs;

θ is the angle of the wind from normal to the wall or to the roof in the horizontal plane;

C_T is the dynamic augmentation factor from 1.6.1.

NOTE 1. The factor 0.85 accounts for the non-simultaneous action of wind pressures.

NOTE 2. The horizontal component of the net wind load for each loaded area is resolved into the wind direction by multiplying with the appropriate value of $\cos\theta$ before being summed.

For buildings with flat roofs, or where the contribution to the horizontal loads from the roof is insignificant, the overall load in the wind direction P may be taken, without significant loss of accuracy, as

$$P = 0.85 q_e \{ \Sigma(C_{p_e, \text{front}} A \cos^2\theta) - \Sigma(C_{p_e, \text{rear}} A \cos\theta) \} (1 + C_T) \quad (23)$$

where

$C_{p_e, \text{front}}$ is the pressure coefficient for windward walls in the standard method from table 5;

$C_{p_e, \text{rear}}$ is the pressure coefficient for leeward walls in the standard method from table 5;

NOTE 3. Equation 23 implies that the positive pressure acting on each windward-facing wall reduces with wind angle normal to the wall in proportion to $\cos\theta$, whereas the negative pressure acting on leeward-facing walls is taken as constant with wind angle. Face loads are then resolved vectorially to give the overall load in the wind direction. Walls aligned exactly parallel to the wind give no resolved component in the wind direction. In the case of rectangular buildings, the procedure gives the exact result of the orthogonal cases in 2.1.3.6 of the standard method at the wind directions $\theta = 0^\circ$ and $\theta = 90^\circ$ and very close to the combination of orthogonal loads case in 2.1.3.6 of the standard method at the wind direction $\theta = 45^\circ$. q_e is based on the appropriate diagonal dimensions as defined in figure 5. For polygonal buildings this may be conservatively based on the concept of the smallest enclosing rectangle.

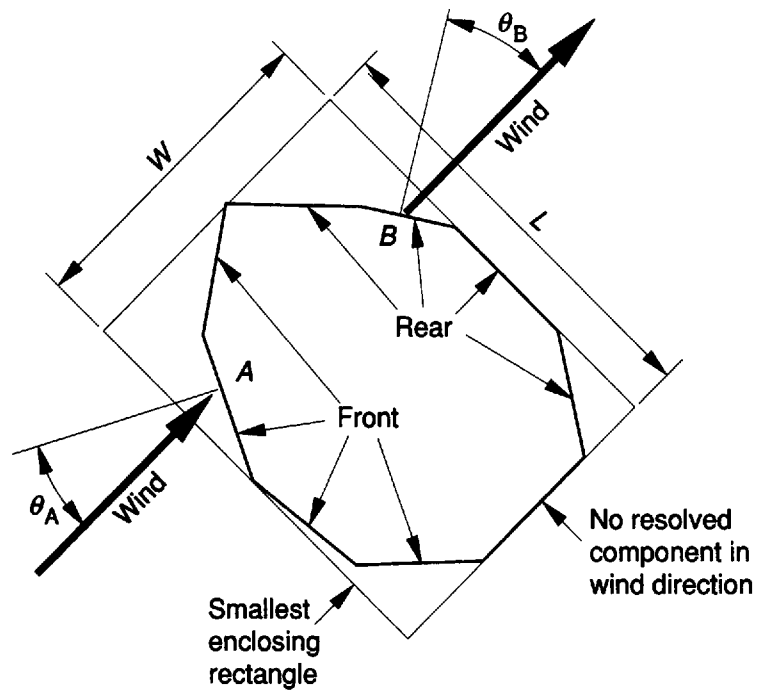
3.1.3.3.3 In the case of re-entrant corners and recessed bays, (see 3.3.1.5 and 3.3.1.6), the boundary of the 'wedge' should be taken as a solid surface normal to the flow ($\cos^2\theta = 1$) as indicated in figure 30b.

3.1.3.4 Directional frictional drag component

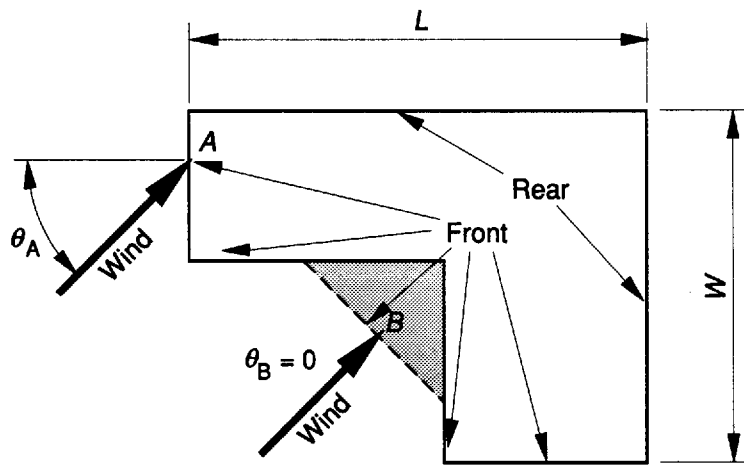
It is recommended in 3.3.1.9, 3.3.2.8, 3.3.3.9 and 3.3.4.3 that frictional forces on long walls and roofs are determined in addition to the forces generated by normal pressures. When determining overall forces on the building, the contribution of frictional forces should be taken to act in the wind direction and added to the normal pressure load given by P .

3.1.3.5 Directional cladding loads

3.1.3.5.1 A simplification of the full directional method which leads to fewer calculations may be used to determine directional cladding loads. The basis of the simplification is to calculate all external surface pressures corresponding to a nominal diagonal dimension $a = 5$ m, and then to adjust these pressures for the actual diagonal size of cladding element using the size effect factor of the standard method C_a given in figure 4.



a) General case for arbitrary-shaped building



b) Building with re-entrant corner (see figure 33)

Figure 30. Key to overall load P

3.1.3.5.2 For this method the expression for the directional external surface pressure p_e given by **3.1.4.1.1** becomes

$$p_e = q_s C_{pe} C_a \quad (24)$$

where

q_s is directly equivalent to the dynamic pressure of the standard method but is determined from the equivalent effective wind speed V_e of the directional method for a gust peak factor (see **3.2.3.3**) of $g_t = 3.44$, corresponding to the nominal diagonal dimension $a = 5$ m.

The expression for the directional internal surface pressure p_i given in **3.1.3.1.2** remains unchanged.

3.2 Directional wind speeds

3.2.1 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.

3.2.2 Site wind speed

The site wind speed V_s should be calculated from equation 8, following the procedure given in **2.2.2**, except for the determination of the altitude factor S_a .

NOTE. In the directional method, topographic effects are determined separately from altitude effects.

When topography is not to be considered, the altitude factor S_a should be determined from

$$S_a = 1 + 0.001 \Delta_S \quad (25)$$

where

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

When topography is to be considered, the altitude factor S_a should be determined from

$$S_a = 1 + 0.001 \Delta_T \quad (26)$$

where

Δ_T is the altitude of the base of the topography (in metres above mean sea level).

3.2.3 Effective wind speed

3.2.3.1 The effective wind speed V_e for each wind direction for a building on a particular site should be determined from

$$V_e = V_s \times S_b \quad (27)$$

where

V_s is the site wind speed for each wind direction given by **3.2.2**;

S_b is the terrain and building factor appropriate to the wind direction being considered, determined from **3.2.3.2.2** for sites in country terrain and from **3.2.3.2.3** for sites in town terrain.

The effective wind speed should be calculated at the effective height H_e , determined from the reference height H_r in accordance with **1.7.3**. Reference heights H_r are defined with the pressure coefficient data for each form of building.

For buildings whose height H is greater than the crosswind breadth B in the wind direction being considered, some reduction in lateral loads may be obtained by dividing the building into a number of parts in accordance with **2.2.3**.

3.2.3.2 Terrain and building factor

3.2.3.2.1 General

The terrain and building factor S_b should be used to modify the site wind speed to take account of the effective height H_e of the building or part, the dimensions of the building, the local topography and the terrain upwind of the site. It also modifies the hourly mean site wind speed to an effective gust wind speed.

The terrain and building factor S_b should be determined from **3.2.3.2.2** for sites in country terrain and from **3.2.3.2.3** for sites in town terrain, taking the following into account:

- the effective height H_e determined in accordance with **1.7.3** from the reference height H_r defined for the form of the building or part (see **2.2.3.2**);
- the distance of the site from the sea in the wind direction being considered;
- for sites in town terrain, the distance of the site from the edge of the town in the wind direction being considered;
- the largest diagonal a of the area over which load sharing takes place as defined in figure 5.

Load effects, e.g. 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.

3.2.3.2.2 Sites in country terrain

In country terrain S_b should be determined from

$$S_b = S_c [1 + (g_t \times S_t) + S_h] \quad (28)$$

where

- S_c is the fetch factor obtained from table 22;
- S_t is the turbulence factor obtained from table 22;
- g_t is the gust peak factor (see **3.2.3.3**);
- S_h is the topographic increment (see **3.2.3.4**).

Table 22. Factors S_c and S_t								
Effective height H_e m	Factor	Upwind distance from sea to site km						
		≤ 0.1	0.3	1.0	3.0	10	30	≥ 100
≤ 2	S_c	0.873	0.840	0.812	0.792	0.774	0.761	0.723
	S_t	0.203	0.215	0.215	0.215	0.215	0.215	0.215
5	S_c	1.06	1.02	0.990	0.966	0.944	0.928	0.882
	S_t	0.161	0.179	0.192	0.192	0.192	0.192	0.192
10	S_c	1.21	1.17	1.13	1.10	1.07	1.06	1.00
	S_t	0.137	0.154	0.169	0.175	0.178	0.178	0.178
15	S_c	1.28	1.25	1.21	1.18	1.15	1.13	1.08
	S_t	0.131	0.141	0.156	0.167	0.171	0.171	0.171
20	S_c	1.32	1.31	1.27	1.23	1.21	1.19	1.13
	S_t	0.127	0.132	0.145	0.157	0.163	0.164	0.166
30	S_c	1.39	1.39	1.35	1.31	1.28	1.26	1.20
	S_t	0.120	0.122	0.132	0.145	0.155	0.159	0.159
50	S_c	1.47	1.47	1.46	1.42	1.39	1.36	1.30
	S_t	0.112	0.113	0.117	0.125	0.135	0.145	0.149
100	S_c	1.59	1.59	1.59	1.57	1.54	1.51	1.43
	S_t	0.097	0.100	0.100	0.100	0.110	0.120	0.132
200	S_c	1.74	1.74	1.74	1.73	1.70	1.67	1.59
	S_t	0.075	0.075	0.075	0.078	0.083	0.093	0.111
300	S_c	1.84	1.84	1.84	1.83	1.82	1.78	1.70
	S_t	0.065	0.065	0.065	0.067	0.068	0.080	0.092

NOTE 1. Interpolation may be used.
NOTE 2. The figures in this table have been derived from reference [8].

3.2.3.2.3 Sites in town terrain

In town terrain S_b should be determined from

$$S_b = S_c T_c (1 + (g_t \times S_t \times T_t) + S_h) \quad (29)$$

where

- S_c is the fetch factor obtained from table 22;
- T_c is the fetch adjustment factor obtained from table 23;
- S_t is the turbulence factor obtained from table 22;
- T_t is the turbulence adjustment factor obtained from table 23;
- g_t is the gust peak factor (see 3.2.3.3);
- S_h is the topographic increment (see 3.2.3.4).

3.2.3.3 Gust peak factor

3.2.3.3.1 The gust peak factor g_t used in the calculation of the terrain and building factor S_b allows for the influence of the dimensions of the building on the maximum gust speed. The dimension of the building which determines the value of the gust peak factor is the length of the diagonal a of the loaded area over which load sharing takes place (see figure 5). Separate values should be used depending upon whether wind loads are being calculated for the whole building, portions of the building or individual components.

3.2.3.3.2 For external pressures on whole buildings and portions of buildings, the values of g_t should be obtained from table 24 using the effective height H_e of the top of the building and the diagonal of the loaded area, a .

Table 23. Adjustment factors T_c and T_t for sites in town terrain

Effective height H_e m	Factor	Upwind distance from edge of town to site km					
		0.1	0.3	1.0	3.0	10	≥ 30
≤ 2	T_c	0.695	0.653	0.619	0.596	0.576	0.562
	T_t	1.92	1.93	1.93	1.93	1.93	1.93
5	T_c	0.846	0.795	0.754	0.725	0.701	0.684
	T_t	1.41	1.60	1.63	1.63	1.63	1.63
10	T_c	0.929	0.873	0.828	0.796	0.770	0.751
	T_t	1.16	1.34	1.50	1.52	1.52	1.52
15	T_c	0.969	0.911	0.863	0.831	0.803	0.783
	T_t	1.04	1.22	1.38	1.47	1.47	1.47
20	T_c	0.984	0.935	0.886	0.853	0.824	0.804
	T_t	1.00	1.17	1.35	1.44	1.45	1.45
30	T_c	0.984	0.965	0.915	0.880	0.851	0.830
	T_t	1.00	1.06	1.21	1.33	1.43	1.43
50	T_c	0.984	0.984	0.947	0.912	0.881	0.859
	T_t	1.00	1.00	1.12	1.24	1.38	1.42
100	T_c	0.984	0.984	0.984	0.948	0.917	0.894
	T_t	1.00	1.00	1.00	1.14	1.28	1.38
200	T_c	0.984	0.984	0.984	0.980	0.947	0.924
	T_t	1.00	1.00	1.00	1.07	1.19	1.31
300	T_c	0.984	0.984	0.984	0.984	0.964	0.940
	T_t	1.00	1.00	1.00	1.04	1.14	1.24

NOTE 1. Interpolation may be used.

NOTE 2. For sites in towns less than 0.1 km from the edge in the upwind direction the site should be assumed to be in open country terrain (see 3.2.3.2.2).

NOTE 3. The figures in this table have been derived from reference [8].

Effective height H_e m	Diagonal dimension a m						
	< 5	10	20	40	100	200	300
≤10	3.44	3.19	2.90	2.62	2.23	1.97	1.77
20	3.44	3.24	2.98	2.69	2.27	2.04	1.83
50	3.44	3.30	3.02	2.75	2.36	2.10	1.89
100	3.44	3.33	3.07	2.79	2.40	2.14	1.95
200	3.44	3.40	3.13	2.84	2.47	2.18	2.01
300	3.44	3.44	3.17	2.86	2.49	2.21	2.04

NOTE. Interpolation may be used.

3.2.3.3.3 When assessing the loads on individual structural components, cladding units and their fixings a value of $g_t = 3.44$ should be taken, unless there is adequate load sharing capacity to justify the use of a lower value (i.e. a diagonal length a greater than 5 m) in which case table 24 should be used to obtain the appropriate value for the gust peak factor g_t . This value of $g_t = 3.44$ should also be taken when using the provisions of 3.1.3.5.2 or 3.4.2 in conjunction with the size effect factor C_a of the standard method.

3.2.3.3.4 For internal pressures, the values of g_t should be obtained from table 24 using the effective height H_e of the top of the building or part of the building containing the relevant storey, and the diagonal of the loaded area a is determined from the volume of the building, storey or room as defined in 2.6.

NOTE. The derivation of the gust peak factor is described in annex F, which also includes mathematical equations to derive g_t . Note that the size effect factor of the standard method C_a , given in figure 4, was determined from $g_t = 3.44$ by the method given in 3.2.3.2 and 3.2.3.3 for a number of typical site exposures.

3.2.3.4 Topographic increment

3.2.3.4.1 The topographic increment S_h should be used to modify the terrain and building factor to allow for local topographical features such as hills, valleys, cliffs, escarpments or ridges which can significantly affect the wind speed in their vicinity. Values of S_h should be derived for each wind direction considered and used in conjunction with the corresponding direction factor S_d .

3.2.3.4.2 Where the average slope of the ground does not exceed 0.05 within a kilometre radius of the site the terrain should be taken as level and the topographic increment S_h should be taken as zero. When the topography is defined as not significant by the simple criteria in figure 7, the terrain may be taken as level and the topographic increment S_h may be taken as zero.

3.2.3.4.3 Depending on whether the topographic increment S_h is used, care should be taken to ensure that the altitude factor S_a , used to determine the site wind speed V_s , is derived from the appropriate definition of altitude Δ_S or Δ_T in 3.2.2.

3.2.3.4.4 In the vicinity of local topographic features the topographic increment S_h is a function of the upwind slope and the position of the site relative to the summit or crest. It should be noted that S_h will vary with height above ground level, from maximum near to the ground reducing to zero at higher levels, and with position from the crest, from maximum near the crest reducing to zero distant from the crest.

3.2.3.4.5 Values of topographic increment are confined to the range $0 < S_h < 0.6$ and apply only to the simple topographic features defined in figure 8. In situations of multiple hills or ridges, this procedure is appropriate when applied to the single hill or ridge on which the site is situated.

3.2.3.4.6 In certain steep-sided enclosed valleys wind speeds may be less than in level terrain. Before any reduction in wind speeds is considered specialist advice should be sought. For sites in complex topography specialist advice should be sought (see references [5] to [8]) or a maximum value of $S_h = 0.6$ used.

NOTE. Values of S_h may be derived from model-scale or full-scale measurements or from numerical simulations.

3.2.3.4.7 In undulating terrain it is often not possible to decide whether the local topography of the site is significant in terms of wind flow. In such cases the average level of the terrain upwind of the site for a distance of 2 km should be taken as the base level from which to assess the height Z and the upwind slope ψ_U of the feature.

3.2.3.4.8 Values of the topographic increment S_h should be obtained from table 25 using the appropriate values for the upwind slope ψ_U , the effective length L_e and the factor s which should be determined from figure 9 for hills and ridges or figure 10 for cliffs and escarpments.

Table 25. Values of L_e and S_h

Slope ($\psi = Z/L_U$)	Shallow ($0.05 < \psi_U < 0.3$)	Steep ($\psi_U > 0.3$)
Effective length	$L_e = L_U$	$L_e = Z/0.3$
Topographic increment	$S_h = 2.0\psi_U s$	$S_h = 0.6s$

3.2.3.4.9 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 both figures 9 and 10 and the smaller value used.

3.2.3.4.10 At some distance from a topographic feature the effect of local topography is replaced by the general effect of altitude. In many cases, it will not be clear whether topography or altitude dominates. As each is assessed differently by the directional method, it is necessary to calculate the effective wind speed V_e twice, as follows, and to take the larger value of V_e obtained:

- with topography, using S_a for the terrain base altitude and the appropriate value of S_h ; and
- without topography, using S_a for the site altitude and $S_h = 0$.

This procedure is recommended to determine the limit of topographic influence downwind of a cliff or escarpment.

3.2.3.4.11 Where the downwind slope of a hill or ridge is greater than $\psi_D = 0.3$ there will be large regions of reduced acceleration or even shelter and it is not possible to give precise design rules for these circumstances. Values of s from figure 9 should be used as upper bound values.

3.3 Directional pressure coefficients

3.3.1 External pressure coefficients C_{pe} for walls of buildings

3.3.1.1 Vertical walls of rectangular-plan buildings

3.3.1.1.1 Pressure coefficients for walls of rectangular-plan buildings are given in table 26 for the zones as defined in figure 31. Zones A and B should be defined, measuring their width from the upwind edge of the wall. If zones A and B do not occupy the whole of the wall, zone D should be defined from the downwind edge of the wall. If zone D does not occupy the remainder of the face, zone C is then defined as the remainder of the face between zones B and D.

3.3.1.1.2 The wind direction θ is defined as the angle of the wind from normal to the wall being considered (see 3.1.1). The reference height H_r is the height above ground of the top of the wall, including any parapet, or the top of the part if the building has been divided into parts in accordance with 2.2.3. The crosswind breadth B and inwind depth D are defined in figure 2. The scaling length b for defining the zones is given by $b = B$ or $b = 2H$, whichever is the smaller.

3.3.1.1.3 Where walls of two buildings face each other and the gap between them is less than b and greater than $b/4$ some funnelling of the flow will occur between the buildings. The maximum effect occurs at a spacing of $b/2$ and is maintained over a range of wind angles $\pm 45^\circ$ from normal to the axis of the gap. In this circumstance, the following apply.

- a) Over the range of wind angle $-45^\circ < \theta < +45^\circ$ the windward-facing wall is sheltered by the leeward-facing wall of the other building. The positive pressures in table 26 apply where the wall is directly exposed to the wind but give conservative values for the whole wall.
- b) Over the ranges of wind angle $-135^\circ < \theta < -45^\circ$ and $+45^\circ < \theta < +135^\circ$ funnelling occurs. Values for zone A at $\theta = \pm 90^\circ$ should be multiplied by 1.2. Values for zones B at $\theta = \pm 90^\circ$ should be multiplied by 1.1 and applied to all parts of zones B to D which face the other building over these ranges of wind angle. These 'funnelling factors' give the maximum effect which corresponds to a gap width of $b/2$ and interpolation is permitted in the range of gap widths from $b/4$ to b (see 2.4.1.4).
- c) Over the ranges of wind angle $-180^\circ < \theta < -135^\circ$ and $+135^\circ < \theta < +180^\circ$ the values of pressure coefficient remain the same as given in table 26.

3.3.1.2 Vertical walls of polygonal-plan buildings

3.3.1.2.1 The pressure coefficients given in table 26 should also be used for the vertical walls of polygonal-plan buildings. In such cases there may be any number of faces (greater than or equal to 3). The wind direction, principal dimensions and scaling length remain as defined in 3.3.1.1.2.

NOTE. Instead of calculating the crosswind breadth B and inwind depth D for the complex building plan, these dimensions may be determined from the smallest rectangle or circle which encloses the plan shape of the building.

3.3.1.2.2 Provided the length of the adjacent upwind face is greater than $b/5$ the peak suction coefficients for zone A given in table 26 can be reduced by multiplying them by the reduction factor appropriate to the adjacent corner angle β given in table 27.

NOTE. A rectangular corner $\beta = 90^\circ$ gives the highest local suction in zone A.

Wind direction θ	$D/H \leq 1$				$D/H \geq 4$			
	A	B	C	D	A	B	C	D
0°	+0.70	+0.83	+0.86	+0.83	+0.50	+0.59	+0.61	+0.59
±15°	+0.77	+0.88	+0.80	+0.68	+0.55	+0.62	+0.57	+0.49
±30°	+0.80	+0.80	+0.71	+0.49	+0.57	+0.57	+0.51	+0.35
±45°	+0.79	+0.69	+0.54	+0.34	+0.56	+0.49	+0.38	+0.24
±60°	+0.24	+0.51	+0.40	+0.26	±0.20	+0.36	+0.29	±0.20
±75°	-1.10	-0.73	+0.23	+0.08	-1.10	-0.73	+0.23	±0.20
±90°	-1.30	-0.80	-0.42	±0.20	-1.30	-0.80	-0.42	±0.20
±105°	-0.80	-0.73	-0.48	-0.26	-0.80	-0.73	-0.48	-0.26
±120°	-0.63	-0.63	-0.45	-0.29	-0.63	-0.63	-0.45	-0.29
±135°	-0.50	-0.50	-0.40	-0.33	-0.50	-0.50	-0.40	-0.33
±150°	-0.34	-0.34	-0.26	-0.32	-0.34	-0.34	-0.26	-0.32
±165°	-0.30	-0.30	-0.23	-0.28	-0.20	-0.17	-0.15	-0.18
±180°	-0.34	-0.24	-0.24	-0.24	-0.17	-0.15	-0.15	-0.15

NOTE 1. Interpolation may be used between given wind directions and for D/H in the range $1 < D/H < 4$.

NOTE 2. When the result of interpolating between positive and negative values is in the range $-0.2 < C_{pe} < +0.2$, the coefficient should be taken as $C_{pe} = \pm 0.2$ and both possible values used.

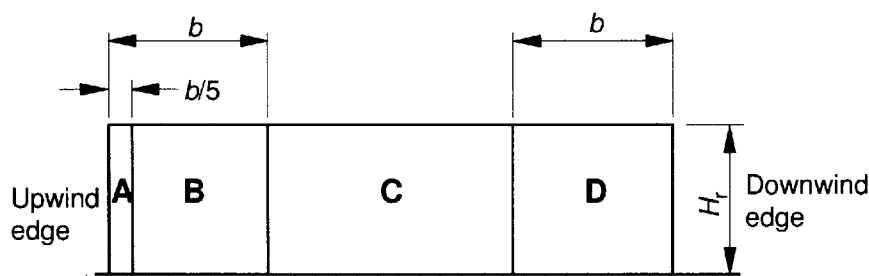


Figure 31. Key for vertical walls of buildings

Corner angle β	Reduction factor
60°	0.7
90°	1.0
120°	0.6
150°	0.2

NOTE. Interpolation is allowed in the range $60^\circ < \beta < 150^\circ$.

3.3.1.2.3 Whenever the value of pressure coefficient for peak suction in zones B and C are more negative than the reduced pressure coefficient in zone A, the reduced zone A values should be applied to these zones also.

3.3.1.3 *Triangular gable walls*

3.3.1.3.1 Pressure coefficients for the triangular gable walls formed by steep duopitch roofs or non-vertical walls (A-frame buildings) in the range $30^\circ \leq \alpha \leq 75^\circ$ are given in table 28 for zones H to K as defined in figure 32. For gable walls formed by duopitch roofs of pitches less than $\alpha = 30^\circ$ or by non-vertical walls of pitches greater than $\alpha = 75^\circ$ (nearly vertical) the general method given in 3.3.1.1 should be used.

3.3.1.3.2 The wind direction θ is defined as the angle of the wind from normal to the wall being considered (see 3.1.1). The reference height H_r is the height of the peak of the gable.

3.3.1.3.3 Where gables of two buildings face each other and the gap between them is less than b some funnelling of the flow will occur between the buildings. The maximum effect occurs at a spacing of $b/2$ and is maintained over a range of wind angles $\pm 45^\circ$ from parallel to the axis of the gap. In this circumstance, the following apply.

- Over the range of wind angle $-45^\circ < \theta < +45^\circ$ the windward-facing gable is sheltered by the leeward-facing gable of the outer building. The positive pressures in table 28 apply where the gable is directly exposed to the wind but give conservative values for the whole gable.
- Over the ranges of wind angle $-135^\circ < \theta < -45^\circ$ and $+45^\circ < \theta < +135^\circ$ funnelling occurs. Values for zone H at $\theta = \pm 90^\circ$ should be multiplied by 1.2. Values for zone I at $\theta = \pm 90^\circ$ should be multiplied by 1.1 and applied to all parts of zones I to K which face the other building over these ranges of wind angle. These funnelling factors give the maximum effect which corresponds to a gap width of $b/2$ and interpolation is permitted in the range of gap widths from $b/4$ to b (see 2.4.1.4).
- Over the ranges of wind angle $-180^\circ < \theta < -135^\circ$ and $+135^\circ < \theta < +180^\circ$ the values of pressure coefficient remain the same as given in table 28.

3.3.1.4 *Non-vertical walls*

3.3.1.4.1 Pressure coefficients for windward-facing non-vertical walls in the range $\theta = \pm 90^\circ$ are given in table 29 for zones A to D defined in figure 31. For all other wind angles, pressures on non-vertical walls should be taken as the same as for vertical walls.

3.3.1.4.2 The wind direction θ is defined as the angle of the wind from normal to the wall being considered (see 3.1.1) and is limited here to the range $\theta = \pm 90^\circ$. The pitch angle α is defined as the angle from horizontal, hence $\alpha = 90^\circ$ for vertical walls. The reference height H_r is the height above ground of the top of the wall.

NOTE. The pressure coefficients for non-vertical walls in table 29 are essentially identical to the pressure coefficients for steep pitched roofs in 3.3.3, allowing for the differences in definition of zones; therefore at large pitch angles ($\alpha > 45^\circ$) the distinction between 'wall' and 'roof' is largely irrelevant. However, steep-pitched surfaces which meet along the top edge to form a ridge, e.g. 'A-frame' buildings, are better interpreted as 'duopitch roofs', falling under the provisions of 3.3.3.

3.3.1.5 *Buildings with re-entrant corners*

3.3.1.5.1 The procedure given in 3.3.1.1 should be used for vertical walls of buildings containing re-entrant corners, such as L, T, X and Y shaped buildings in plan. Items a) to e) define the zones, using figure 33 as reference.

- For the faces of the upwind wing, the crosswind breadth and the height of the wing should be used to determine the scaling parameter b . For all other wings the overall crosswind breadth of the building should be used.

NOTE. Instead of calculating the crosswind breadth B and inwind depth D for the complex building plan, these dimensions may be determined from the smallest rectangle or circle which encloses the plan shape of the upwind wing or of the whole building, respectively.

- For faces with two external corners, zones A, B, C and D are defined in accordance with 3.3.1.1.
- For faces with one upwind (external) corner and one downwind re-entrant corner, zones A, B and C are defined (zone D does not apply).
- For faces with one upwind re-entrant corner and one downwind external corner, zones C and D are defined (zones A and B do not apply).
- In re-entrant corners that face directly into the wind a wedge that extends from the internal corner with the face of the wedge normal to the wind direction is defined. The width of the wedge w should be taken as $w = b$ or $w =$ the width of the wedge limited by an external corner (marked limit of wedge), whichever is the smaller.

3.3.1.5.2 The pressure coefficients for zones defined in 3.3.1.5.1 should be obtained from table 26 appropriate to the wind angle θ measured from normal to each wall.

The pressure coefficients for the zones that lie within the defined wedge should be taken for zone C at $\theta = 0^\circ$ from table 26.

Table 28. External pressure coefficients C_{pe} for vertical gable walls adjacent to non-vertical walls and roofs

Wind direction θ	Pitch of adjacent wall or roof $30^\circ \leq \alpha \leq 75^\circ$							
	$D/H \leq 1$				$D/H \geq 4$			
	H	I	J	K	H	I	J	K
0°	+0.25	+0.80	+0.80	+0.25	+0.18	+0.57	+0.57	+0.18
$\pm 30^\circ$	+0.70	+0.75	+0.50	± 0.2	+0.50	+0.54	+0.36	± 0.20
$\pm 60^\circ$	+0.50	+0.40	± 0.2	-0.25	+0.36	+0.29	± 0.20	± 0.20
$\pm 90^\circ$	-1.10	-0.80	-0.70	-0.60	-1.10	-0.80	-0.70	-0.60
$\pm 120^\circ$	-1.30	-0.75	-0.60	-0.50	-1.30	-0.75	-0.60	-0.50
$\pm 150^\circ$	-0.30	-0.25	-0.25	-0.25	-0.21	-0.18	-0.18	-0.18
$\pm 180^\circ$	-0.25	-0.25	-0.25	-0.25	-0.18	-0.18	-0.18	-0.18

NOTE 1. Interpolation may be used between given wind directions and for D/H in the range $1 < D/H < 4$.

NOTE 2. When the result of interpolating between positive and negative values is in the range $-0.2 < C_{pe} < +0.2$, the coefficient should be taken as $C_{pe} = \pm 0.2$ and both possible values used.

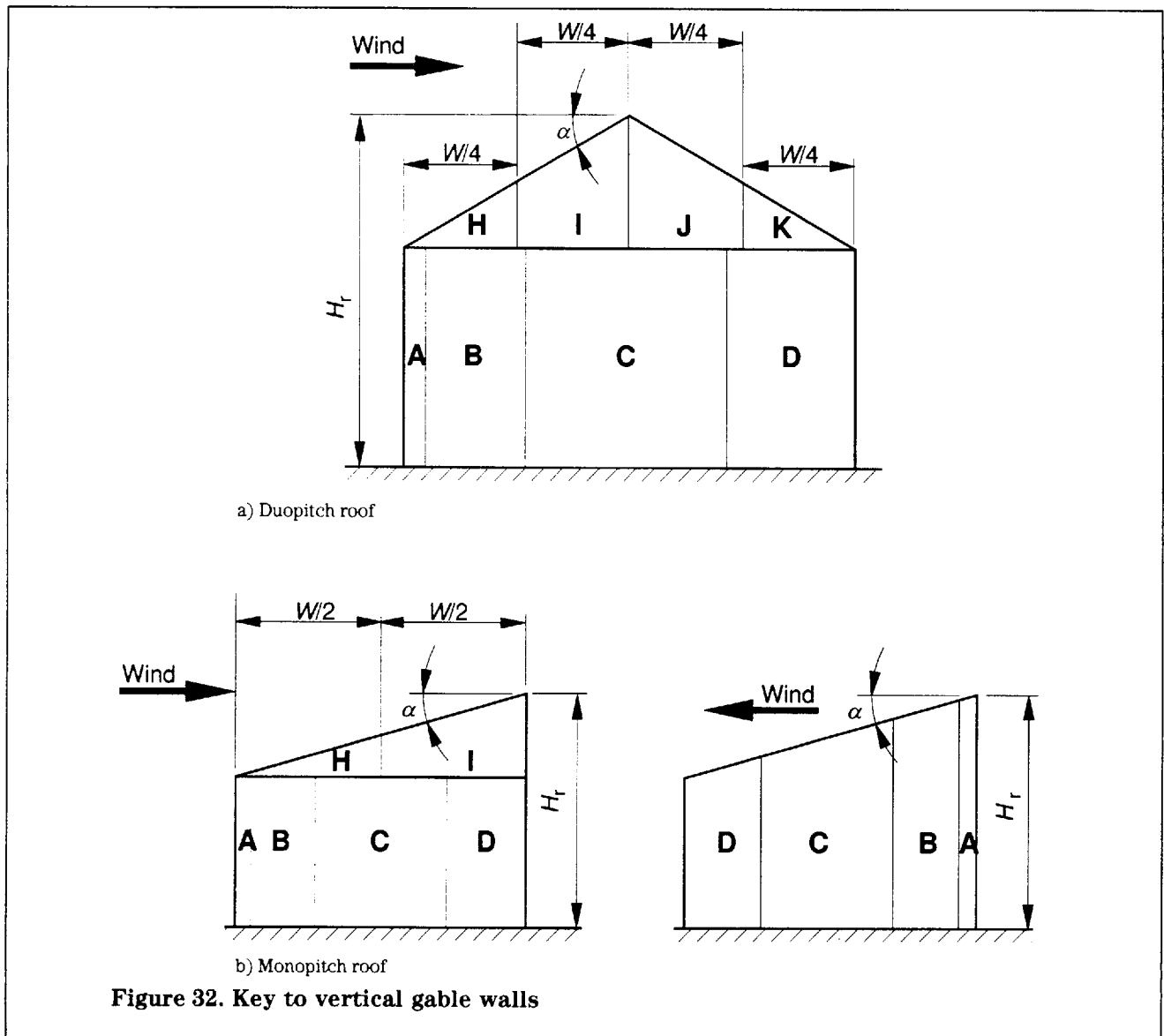


Table 29. External pressure coefficients C_{pe} for windward-facing non-vertical walls

Wind direction θ	Wall (or roof) pitch $\alpha = 30^\circ$				Wall (or roof) pitch $\alpha = 45^\circ$				Wall (or roof) pitch $\alpha = 60^\circ$				Wall (or roof) pitch $\alpha = 75^\circ$			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	0°	+0.31	+0.46	+0.51	+0.46	+0.68	+0.68	+0.68	+0.68	+0.50	+0.57	+0.80	+0.57	+0.58	+0.81	+0.81
$\pm 30^\circ$	+0.42	+0.42	+0.39	+0.20	+0.65	+0.63	+0.54	+0.44	+0.77	+0.59	+0.62	+0.39	+0.85	+0.83	+0.73	+0.55
$\pm 60^\circ$	-0.88	± 0.20	± 0.20	± 0.20	+0.20	+0.38	+0.30	+0.22	+0.59	+0.37	+0.35	+0.20	+0.78	+0.55	+0.41	+0.32
$\pm 90^\circ$	-1.26	-0.55	± 0.20	± 0.20	-1.27	-0.57	± 0.20	± 0.20	-1.21	-0.44	± 0.20	± 0.20	-1.21	-0.43	± 0.20	± 0.20

NOTE 1. Interpolation between given wind directions may be used.

NOTE 2. For pitches between $\alpha = 75^\circ$ and $\alpha = 90^\circ$ (vertical) interpolation may be used using table 26 for which $\alpha = 90^\circ$.NOTE 3. When the result of interpolating between positive and negative values is in the range $-0.2 < C_{pe} < +0.2$, the coefficient should be taken as $C_{pe} = \pm 0.2$ and both possible values used.

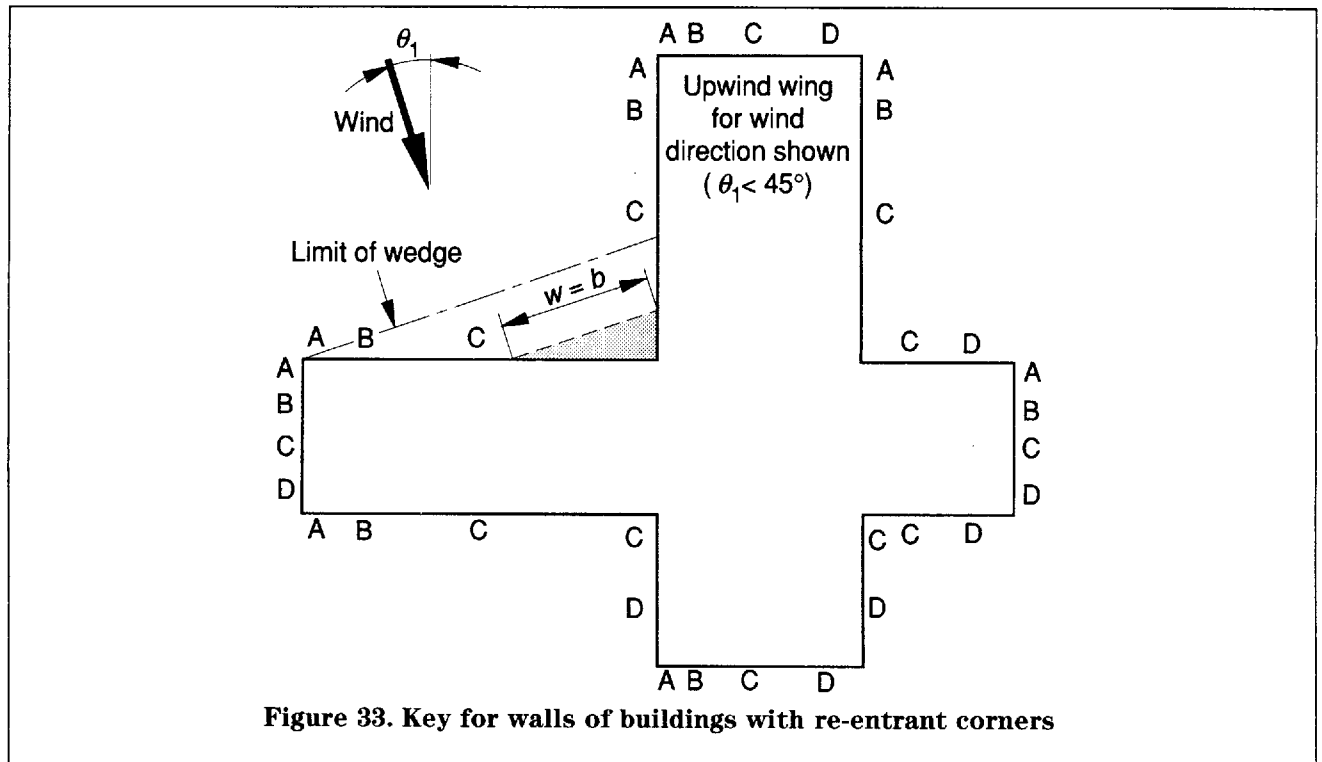


Figure 33. Key for walls of buildings with re-entrant corners

3.3.1.6 Buildings with recessed bays

3.3.1.6.1 Buildings where there are recessed openings, such as porches and balconies or between the wings of a building, should be treated as follows, using figure 34 as reference.

- a) The parameter b should be determined in accordance with 3.3.1.1.2

NOTE. Instead of calculating the crosswind breadth B and inwind depth D for the complex building plan, these dimensions may be determined from the smallest rectangle or circle which enclosed the relevant plan shape defined in items b) or c).

b) If $G < b/2$ the recess is categorized as narrow. The wall in which the recess should be assessed as if the recess did not exist, as shown in figure 34a. The pressure coefficient corresponding to the position of the recess should be applied to all the walls inside the recess. For peak cladding loads at the mouth of the narrow recess, additional local zones A at the external edge of the walls of the recess should be defined as indicated in figure 34a. The relevant plan-shape for calculating b is that of the whole building.

c) If $G > b/2$ the recess is categorized as wide. The procedure in 3.3.1.5 for buildings with re-entrant corners should be applied as indicated in figure 34b. The relevant plan-shape for calculating b is that of any upwind wing, or of the whole building, respectively.

3.3.1.6.2 Where the recessed bay is limited in height by a floor or a soffit, the pressure in the recess should be taken to act on the floor and soffit in addition to the walls.

3.3.1.7 Buildings with internal wells

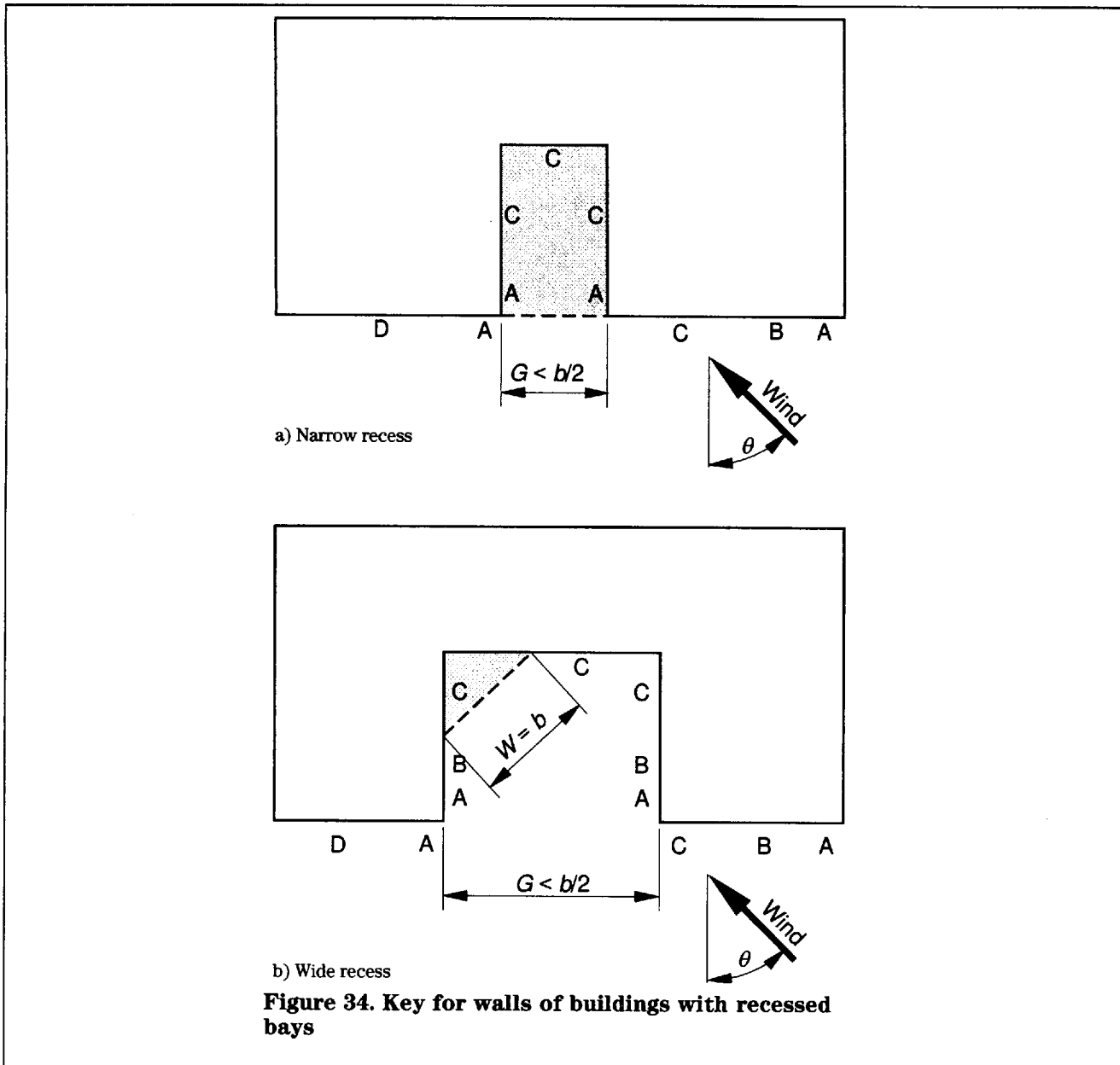
3.3.1.7.1 For buildings with internal wells, the pressure coefficient for the external walls are unaffected by the well and should be derived as if the well did not exist.

3.3.1.7.2 Pressure within the well is dominated by flow over the roof and should be derived as follows.

- a) When the gap across the well G is smaller than $b/2$ the pressure in the well is taken as uniform and equal to the pressure on the roof containing the well.
- b) When $G > b/2$ the procedure for re-entrant corners in 3.3.1.5 should be used.

3.3.1.8 Irregular faces and inset walls

To determine pressure coefficients for the irregular faces of buildings with re-entrant corners in elevation (i.e. walls formed by more than one rectangle) the procedure given for the standard method in 2.4 should be used with directional pressure coefficients obtained from table 26 appropriate to the wind angle θ from normal to each face.



3.3.1.9 Friction induced loads on walls

Friction forces should be determined for long walls with $D > b$ when the wind is parallel to the wall. The frictional drag coefficient should be assumed to act over all zone C and D of such walls, with values as given in table 6. The resulting frictional forces should be applied in accordance with 3.1.3.4.

3.3.2 External pressure coefficients for flat roofs of buildings

3.3.2.1 Choice of method

3.3.2.1.1 A general method for determining the wind pressures on flat, or nearly flat roofs of buildings with any arbitrary plan shape is given in the following section. This general method also accounts for the variations in high local suction around the periphery of the roof caused by various common forms of eaves detail.

3.3.2.1.2 A simpler method, restricted to rectangular-plan buildings only, is given in 3.3.3.3, assuming the flat roof to be a monopitch roof with zero pitch angle. The general method should be used for all roofs of pitch less than $\alpha = 5^\circ$ on non-rectangular plan buildings.

3.3.2.2 General method

3.3.2.2.1 The roof should be subdivided into sections by lines drawn in the wind direction through each upwind-facing corner.

Zones of pressure coefficient are defined for each section from the upwind corner as given in figure 35. The shape of the roof in figure 35 represents a typical arbitrary roof plan.

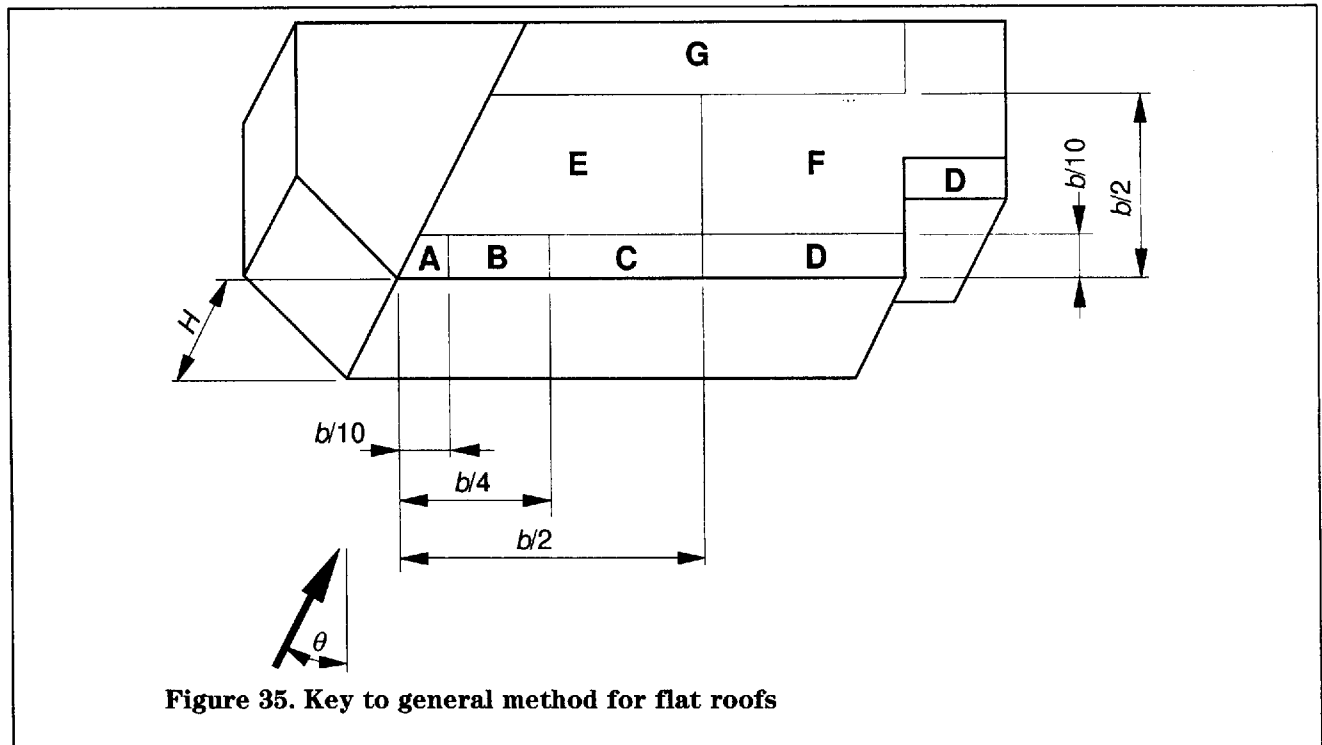


Figure 35. Key to general method for flat roofs

3.3.2.2.2 The wind direction θ is defined as the angle of the wind from normal to the eaves of the section of roof being considered, as defined in figure 35. The reference height H_r is the height above ground of the top of the roof. The crosswind breadth B and inwind depth D are defined in figure 2.

NOTE. Instead of calculating the crosswind breadth B and inwind depth D for the complex building plan at every wind angle, these dimensions may be determined from the smallest rectangle or circle which encloses the plan shape of the building.

The scaling length b for defining the zones is given by $b = B$ or $b = 2H_r$, whichever is the smaller.

3.3.2.2.3 Application of the zones as defined in figure 35 should be repeated for every section of the roof until pressure coefficients for all zones over the whole roof have been defined. Figure 36a shows the completed assignment for the arbitrary shape and wind direction used in figure 35. Figure 36b shows the zones for the same shaped roof but a different wind direction. The examples in figure 36 cover most conditions likely to be encountered.

3.3.2.3 Flat roofs with sharp eaves

External pressure coefficients for each zone of flat roofs with sharp eaves are given in table 30. Sharp eaves represent the most onerous loading condition (highest suction). Pressure coefficients for other common types of eaves are given in 3.3.2.4 to 3.3.2.6.

3.3.2.4 Flat roofs with parapets

3.3.2.4.1 A parapet along any eaves or edge will reduce the pressure coefficients in zones A to D immediately adjacent to that eaves but the pressures in zones E, F and G will be unaffected. The external pressure coefficients given in table 30 for zones A to D for flat roofs with sharp eaves should be multiplied by the appropriate reduction factors given in table 31, dependent on the height of the parapet h , as defined for the standard method in figure 17, and the eaves height H or crosswind width B .

NOTE. The reference height H_r is the height above ground of the top of the parapet.

3.3.2.4.2 Loading of the parapet walls should be determined from 2.7.5.1 for free-standing parapets and from 2.7.5.4 for downwind parapets.

3.3.2.5 Flat roofs with curved eaves

For flat roofs with curved eaves, as defined for the standard method in figure 17, the zones start from the edge of the flat part of the roof. External pressure coefficients for each zone are given in table 32 dependent on the ratio of the corner radius r of the eaves to the scaling length b .

3.3.2.6 Flat roofs with mansard eaves

For flat roofs with mansard eaves, as defined for the standard method in figure 17, the zones start from the edge of the flat part of the roof. External pressure coefficients for each zone are given in table 33 dependent on the pitch of the mansard eaves a .

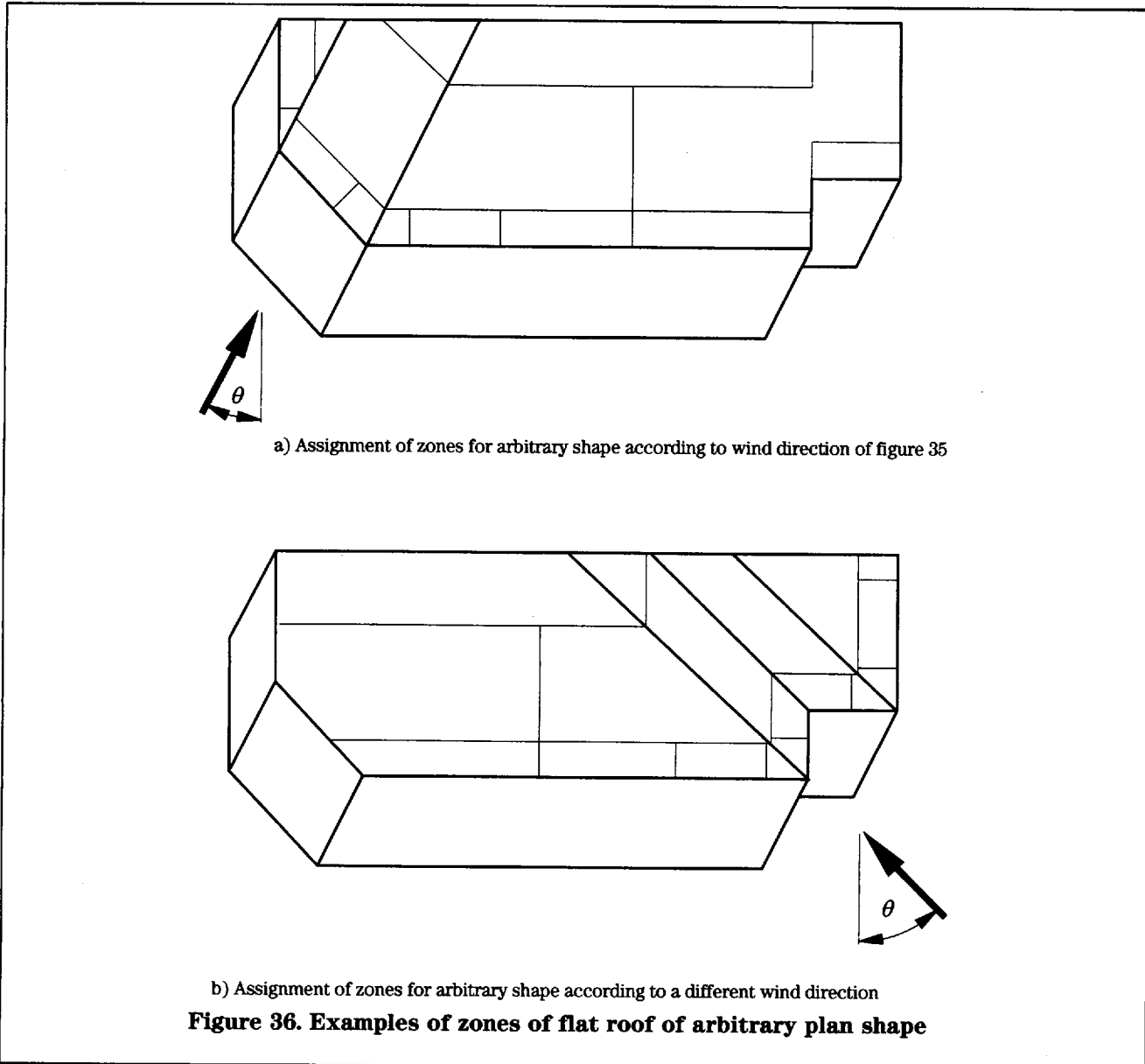


Table 30. External pressure coefficients C_{pe} for flat roofs with sharp eaves

Local wind direction θ	Zone						
	A	B	C	D	E	F	G
0°	-1.47	-1.25	-1.15	-1.15	-0.69	-0.71	± 0.20
$\pm 15^\circ$	-1.68	-1.47	-1.24	-1.14	-0.61	-0.70	± 0.20
$\pm 30^\circ$	-2.00	-1.70	-1.38	-1.03	-0.66	-0.67	± 0.20
$\pm 45^\circ$	-1.90	-1.49	-1.18	-0.86	-0.59	-0.54	± 0.20
$\pm 60^\circ$	-1.70	-1.24	-1.10	-0.64	-0.61	-0.42	± 0.20
$\pm 75^\circ$	-1.45	-0.85	-0.69	-0.35	-0.61	-0.21	± 0.20
$\pm 90^\circ$	-1.43	-0.75	-0.52	-0.24	-0.62	± 0.20	± 0.20

NOTE 1. Interpolation may be used.

NOTE 2. Where both positive and negative values are given both values should be considered.

Local wind direction θ	Parapet height ratio h/b			
	0	0.05	0.10	≥ 0.20
0°	1.00	0.76	0.67	0.56
±30°	1.00	0.90	0.88	0.70
±60°	1.00	1.00	0.97	0.74
±90°	1.00	0.84	0.60	0.60

NOTE. Interpolation may be used

Eaves radius ratio r/b	Local wind direction θ	Zone						
		A	B	C	D	E	F	G
0.05	0°	-0.81	-1.00	-1.15	-1.26	-0.39	±0.20	±0.20
	±15°	-0.79	-1.06	-1.16	-1.09	-0.37	-0.22	±0.20
	±30°	-0.66	-0.97	-1.07	-1.06	-0.35	-0.29	±0.20
	±45°	-0.61	-0.80	-0.92	-0.35	-0.35	-0.35	±0.20
	±60°	-0.66	-0.64	-0.69	-0.62	-0.35	-0.38	±0.20
	±75°	-0.79	-0.48	-0.53	-0.48	-0.37	-0.40	±0.20
	±90°	-0.81	-0.48	-0.39	-0.29	-0.39	-0.43	±0.20
0.10	0°	-0.77	-0.73	-0.79	-0.79	-0.30	-0.21	±0.20
	±15°	-0.64	-0.65	-0.70	-0.69	-0.29	-0.22	±0.20
	±30°	-0.56	-0.60	-0.62	-0.63	-0.29	-0.25	±0.20
	±45°	-0.49	-0.51	-0.56	-0.58	-0.28	-0.28	±0.20
	±60°	-0.56	-0.40	-0.43	-0.46	-0.29	-0.30	±0.20
	±75°	-0.64	-0.39	-0.36	-0.36	-0.29	-0.30	±0.20
	±90°	-0.77	-0.43	-0.37	-0.37	-0.30	-0.30	±0.20
0.20	0°	-0.51	-0.54	-0.54	-0.56	-0.30	-0.21	±0.20
	±15°	-0.46	-0.49	-0.52	-0.53	-0.28	-0.22	±0.20
	±30°	-0.40	-0.43	-0.47	-0.51	-0.26	-0.25	±0.20
	±45°	-0.38	-0.41	-0.43	-0.43	-0.26	-0.27	±0.20
	±60°	-0.40	-0.38	-0.40	-0.38	-0.26	-0.29	±0.20
	±75°	-0.46	-0.35	-0.31	-0.28	-0.28	-0.29	±0.20
	±90°	-0.51	-0.40	-0.36	-0.23	-0.30	-0.30	±0.20

NOTE 1. Interpolation may be used
NOTE 2. Where both positive and negative values are given both values should be considered.

Table 33. External pressure coefficients C_{pe} for flat roofs with mansard eaves

Mansard pitch angle α	Local wind direction θ	Zone						
		A	B	C	D	E	F	G
30°	0°	-0.93	-0.98	-0.98	-0.98	-0.27	± 0.20	±0.20
	±15°	-0.76	-0.85	-0.91	-0.94	-0.22	± 0.20	±0.20
	±30°	-0.66	-0.73	-0.75	-0.88	-0.20	± 0.20	±0.20
	±45°	-0.60	-0.59	-0.63	-0.66	-0.21	± 0.25	±0.20
	±60°	-0.66	-0.40	-0.42	-0.36	-0.20	-0.30	±0.20
	±75°	-0.76	-0.34	-0.30	-0.23	-0.22	-0.30	±0.20
	±90°	-0.93	-0.39	-0.30	-0.22	-0.27	-0.26	±0.20
45°	0°	-1.19	-1.24	-1.29	-1.34	-0.44	± 0.20	±0.20
	±15°	-1.10	-1.22	-1.22	-1.24	-0.39	± 0.20	±0.20
	±30°	-0.98	-1.06	-1.05	-1.05	-0.35	± 0.24	±0.20
	±45°	-0.87	-0.89	-0.88	-0.80	-0.35	± 0.36	±0.20
	±60°	-0.98	-0.62	-0.64	-0.34	-0.35	-0.46	±0.20
	±75°	-1.10	-0.50	-0.45	-0.24	-0.39	-0.48	±0.20
	±90°	-1.10	-0.56	-0.41	-0.21	-0.44	-0.46	±0.20
60°	0°	-1.27	-1.27	-1.27	-1.23	-0.59	± 0.20	±0.20
	±15°	-1.37	-1.25	-1.27	-1.17	-0.54	± 0.20	±0.20
	±30°	-1.32	-1.22	-1.08	-1.02	-0.49	-0.26	±0.20
	±45°	-1.21	-1.11	-0.97	-0.77	-0.45	-0.45	±0.20
	±60°	-1.32	-0.81	-0.73	-0.35	-0.49	-0.60	±0.20
	±75°	-1.37	-0.70	-0.54	-0.23	-0.54	-0.66	±0.20
	±90°	-1.27	-0.69	-0.48	-0.21	-0.59	-0.66	±0.20

NOTE 1. Interpolation between $\alpha = 30^\circ$ and $\alpha = 60^\circ$ may be used.NOTE 2. For $\alpha > 60^\circ$ interpolate between the values for $\alpha = 60^\circ$ in table 33 and the values given in table 30.

NOTE 3. Where both positive and negative values are given, both values should be considered.

3.3.2.7 Flat roofs with inset storeys

For flat roofs with inset storeys, pressure coefficients for both the upper and lower roof should be derived as follows.

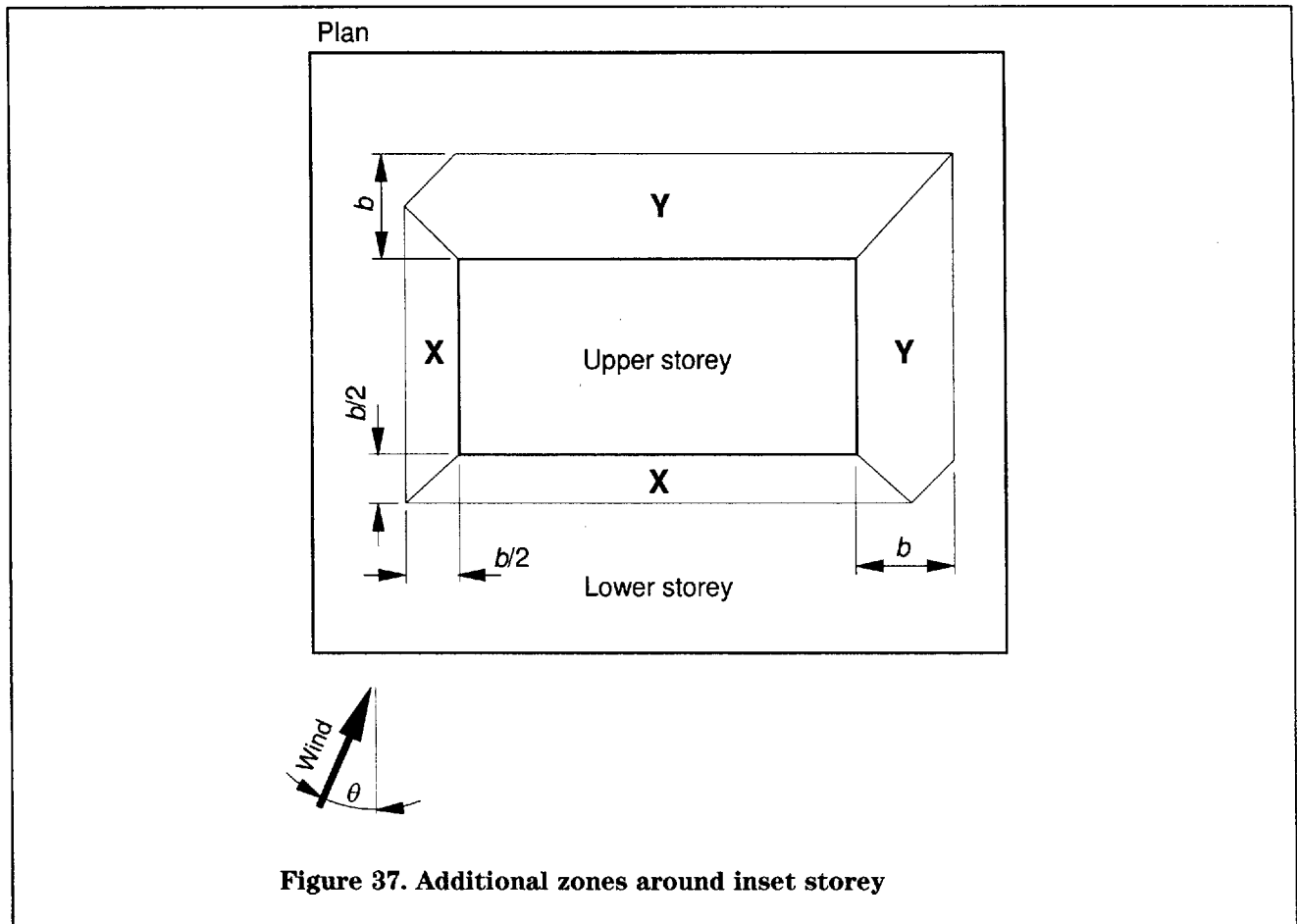
- For the upper roof 3.3.2.3 to 3.3.2.6, depending on the form of the eaves, should be used, taking the reference height H_r as the actual height to the upper eaves but taking H as the height of the inset storey (from the upper eaves to the lower roof level) for determining the scaling length b .
- For the lower roof 3.3.2.3 to 3.3.2.6, depending on the form of the eaves, should be used, where $H_r = H$, the actual height of the lower storey, ignoring the effect of the inset storeys. In addition, two further zones, X and Y, around the base of the inset storeys are defined in figure 37, where the scaling parameter b is based on the dimensions of the upper, inset storey.
- In zones X and Y the pressures shall be taken as the pressure appropriate to the wall zones A to D on each adjacent inset storey wall from 3.3.1.

3.3.2.8 Friction induced loads on flat roofs

Friction forces should be determined for long flat roofs with $D > b/2$ in all wind directions. The frictional drag coefficient should be assumed to act over all of zone G of such roofs, with values as given in table 6. The resulting frictional forces should be applied in accordance with 3.1.3.4.

3.3.3 External pressure coefficients for pitched roofs of buildings**3.3.3.1 General**

The pressure coefficients for windward-facing steep pitched roofs ($\alpha > 45^\circ$) given in this section are essentially identical to the pressure coefficients for windward-facing non-vertical walls in 3.3.1.4 and table 29, allowing for the differences in definition of zones. Therefore at large pitch angles ($\alpha > 45^\circ$) the distinction between wall and roof is largely irrelevant. Steep-pitched surfaces attached to the top of vertical walls are better interpreted as pitched roofs, falling under the provisions of 3.3.3. Steep-pitched surfaces springing directly from the ground which meet along the top edge to form a ridge, e.g. A-frame buildings, are also better interpreted as duopitch roofs, falling under the provisions of 3.3.3.



3.3.3.2 Scaling length and reference height

3.3.3.2.1 Two values are needed for the scaling length b : $b_L = L$ or $b_L = 2H$, whichever is the smaller, and $b_W = W$ or $b_W = 2H$, whichever is the smaller.

3.3.3.2.2 The reference height H_r is the height above ground of the highest point on the roof, the high eaves in the case of monopitch and troughed duopitched roofs, and the ridge in the case of ridged duopitch and hipped roofs.

3.3.3.3 Monopitch roofs

3.3.3.3.1 External pressure coefficients C_{pe} for monopitch roofs are given in table 34 for zones A to J defined in figure 38. These zones are defined from the upwind corner.

NOTE. The pitch angle α is taken as positive when the low eaves is upwind and negative when the high eaves is upwind.

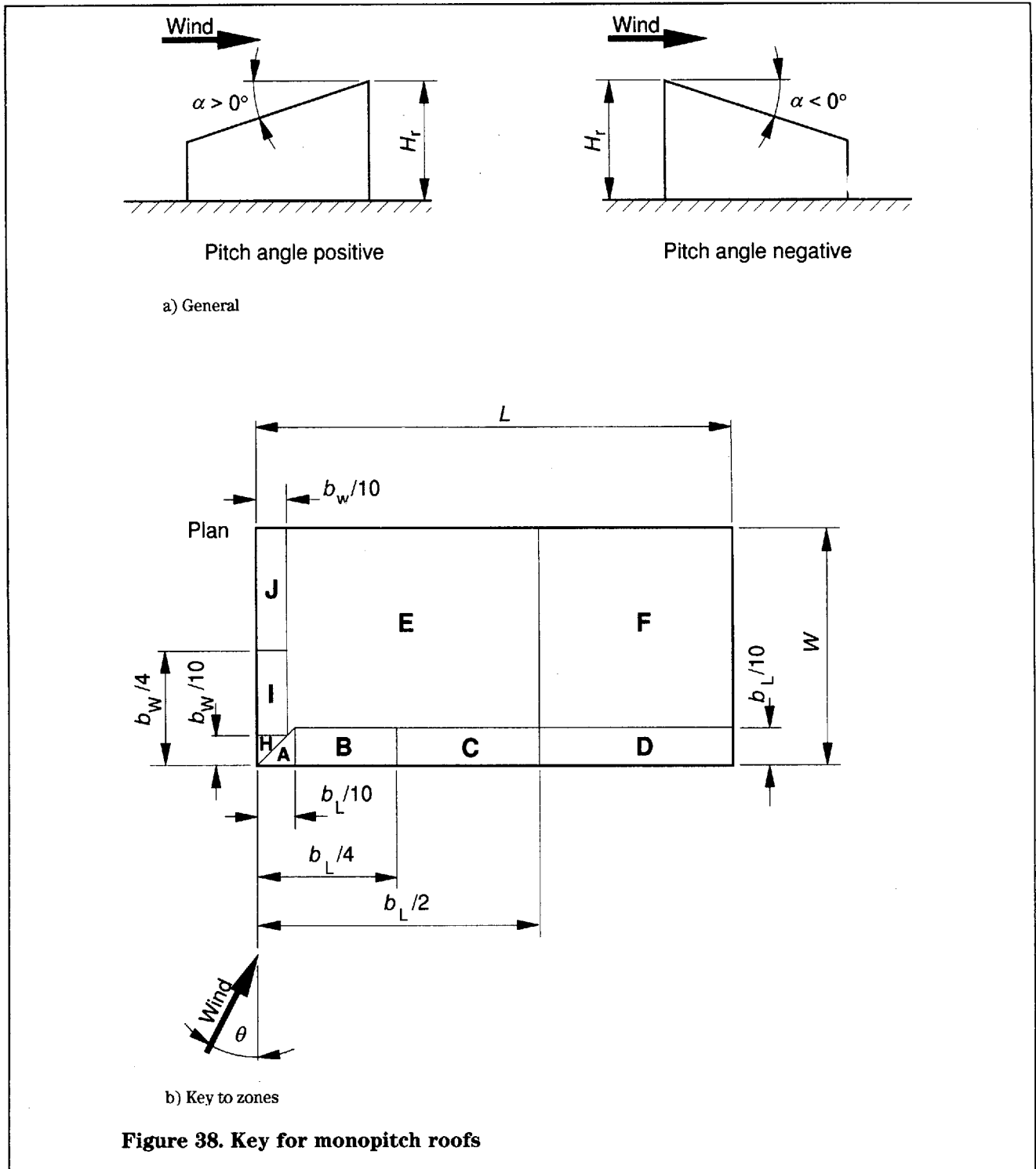
3.3.3.3.2 When all wind directions are considered, symmetry leads to four possible patterns of zones for each form of roof, as shown in figure 39a. Wind normal to either the eaves ($\theta = 0^\circ$) or the verge ($\theta = 90^\circ$) provides special cases where either of two patterns in figure 39a could apply. Because of the fluctuations of wind direction found in practice and in order to give the expected range of asymmetric loading, both patterns should be considered. In the special case $\theta = 0^\circ$ the two load cases have symmetrically identical values, whereas in the special case $\theta = 90^\circ$ the two load cases differ: one with the pitch angle positive and the edge zones along the low eaves; the other with the pitch angle negative and the edge zones along the high eaves.

Table 34. External pressure coefficients C_{pe} for pitched roof zones A to J

Pitch angle α	Local wind direction θ	Zone								
		A	B	C	D	E	F	H	I	J
-45°	0°	-0.61	-0.58	-0.56	-0.41	-0.76	-0.78	-0.62	-0.79	-0.94
	±30°	-0.53	-0.50	-0.49	-0.55	-0.55	-0.81	-0.52	-0.58	-0.58
	±60°	-1.11	-1.29	-1.36	-0.96	-0.97	-0.91	-1.05	-0.97	-1.17
	±90°	-1.25	-0.81	-0.62	-0.42	-0.77	±0.20	-1.48	-1.05	-0.97
-30°	0°	-0.76	-0.68	-0.60	-0.50	-0.76	-0.63	-0.76	-0.85	-0.90
	±30°	-1.13	-1.02	-0.89	-0.79	-0.84	-0.76	-1.17	-0.87	-0.73
	±60°	-2.06	-2.33	-2.17	-1.22	-1.03	-0.80	-1.69	-1.18	-1.21
	±90°	-1.28	-0.94	-0.70	-0.37	-0.70	±0.20	-1.54	-1.10	-1.01
-15°	0°	-1.08	-1.05	-0.97	-0.92	-0.88	-0.82	-1.10	-0.96	-0.83
	±30°	-2.64	-2.37	-1.71	-1.00	-0.93	-0.85	-2.75	-1.66	-1.11
	±60°	-2.25	-2.15	-1.85	-1.02	-0.76	-0.72	-2.44	-1.60	-1.07
	±90°	-1.22	-0.79	-0.58	-0.31	-0.60	-0.20	-1.51	-1.15	-1.10
-5°	0°	-1.49	-1.13	-1.19	-1.12	-0.83	-0.82	-1.47	-0.91	-0.67
	±30°	-2.36	-2.21	-1.63	-1.04	-0.82	-0.77	-2.24	-1.30	-0.91
	±60°	-1.85	-1.57	-1.28	-0.77	-0.65	-0.54	-2.10	-1.67	-1.09
	±90°	-1.30	-0.79	-0.58	-0.27	-0.59	-0.20	-1.65	-1.15	-1.10
0°	0°	-1.47	-1.25	-1.15	-1.15	-0.69	-0.71	-1.43	-0.75	-0.52
	±30°	-2.00	-1.70	-1.38	-1.03	-0.66	-0.67	-1.70	-1.24	-1.10
	±60°	-1.70	-1.24	-1.10	-0.64	-0.61	-0.42	-2.00	-1.70	-1.38
	±90°	-1.43	-0.75	-0.52	-0.24	-0.62	±0.20	-1.47	-1.25	-1.15
+5°	0°	-1.39	-1.24	-1.11	-1.19	-0.56	-0.59	-1.39	-0.69	-0.43
	±30°	-1.78	-1.64	-1.34	-1.09	-0.62	-0.60	-1.75	-1.02	-0.76
	±60°	-1.67	-1.33	-1.12	-0.71	-0.64	-0.42	-2.05	-1.51	-1.05
	±90°	-1.21	-0.83	-0.55	-0.25	-0.61	±0.20	-1.48	-1.15	-1.10
+15°	0°	-0.91	-0.83	-0.78	-0.81	-0.21	-0.31	-0.90	-0.36	-0.30
	±30°	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20
		-0.84	-0.88	-0.82	-0.83	-0.21	-0.37	-0.63	-0.35	-0.32
	±60°	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20
-1.27		-0.86	-0.70	-0.61	-0.54	-0.33	-1.57	-1.21	-0.93	
±90°	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	+0.20	
+30°	0°	-0.38	-0.50	-0.50	-0.50	-0.20	-0.25	-0.60	-0.30	-0.25
	±30°	+0.50	+0.50	+0.50	+0.50	+0.39	+0.40	+0.20	+0.20	+0.20
		-0.50	-0.50	-0.50	-0.50	-0.20	-0.20	-0.40	-0.30	-0.25
	±60°	+0.75	+0.55	+0.40	+0.45	+0.41	+0.26	+0.55	+0.50	+0.47
-0.14		-0.50	-0.45	-0.40	-0.20	-0.20	-0.81	-0.89	-0.83	
±90°	+0.50	+0.43	+0.30	+0.25	+0.20	+0.20	+0.40	+0.40	+0.33	
+45°	0°	-1.13	-0.94	-0.77	-0.19	-0.60	-0.20	-1.25	-1.15	-1.10
	0°	+0.52	+0.50	+0.50	+0.60	+0.49	+0.70	+0.42	+0.40	+0.35
	±30°	+0.80	+0.78	+0.48	+0.55	+0.45	+0.45	+0.65	+0.60	+0.55
	±60°	+0.60	+0.45	+0.35	+0.30	+0.28	+0.21	+0.50	+0.50	+0.50
±90°	-1.17	-0.76	-0.86	-0.33	-0.55	-0.28	-1.25	-1.15	-1.15	
+60°	0°	+0.57	+0.57	+0.57	+0.80	+0.57	+0.80	+0.50	+0.50	+0.50
	±30°	+0.80	+0.79	+0.59	+0.62	+0.59	+0.62	+0.77	+0.77	+0.77
	±60°	+0.70	+0.47	+0.37	+0.35	+0.37	+0.35	+0.59	+0.59	+0.59
	±90°	-0.44	-0.44	-0.44	±0.20	-0.44	±0.20	-1.21	-1.21	-1.21
+75°	0°	+0.81	+0.81	+0.81	+0.81	+0.81	+0.81	+0.58	+0.58	+0.58
	±30°	+0.83	+0.83	+0.83	+0.73	+0.83	+0.73	+0.85	+0.85	+0.85
	±60°	+0.55	+0.55	+0.55	+0.41	+0.55	+0.41	+0.78	+0.78	+0.78
	±90°	-0.43	-0.43	-0.43	±0.20	-0.43	±0.20	-1.21	-1.21	-1.21

NOTE 1. Interpolation may be between values of the same sign.

NOTE 2. Pressure change rapidly from negative to positive with increasing pitch between $\alpha = 15^\circ$ and $\alpha = 30^\circ$ and values for both signs are given.NOTE 3. When interpolating between $\alpha = 15^\circ$ and $\alpha = 30^\circ$, interpolate between negative values to give load case for upward load and between positive values to give load case for downward load.

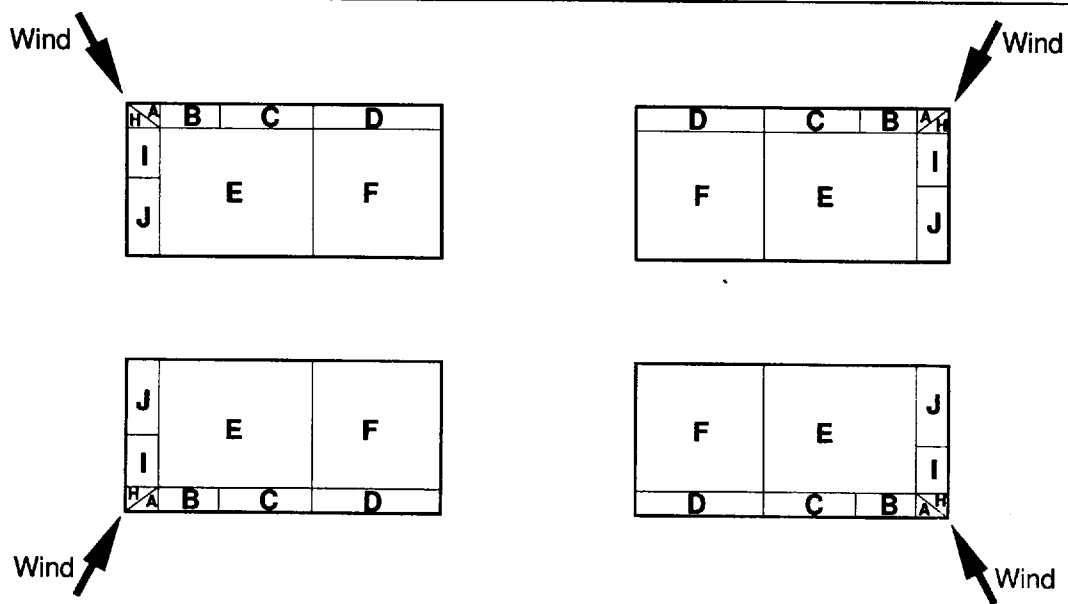


3.3.3.3 Loading of rectangular-plan flat or nearly-flat roofs in the range $-5^\circ < \alpha < 5^\circ$ may be assessed as monopitch roofs as a simpler alternative to the general method for flat roofs in 3.3.2. In this case, when the roof is long in the wind direction, i.e. $D > b/2$, a downwind zone equivalent to zone G in figure 35 may be defined for which $C_{pe} = \pm 0.2$.

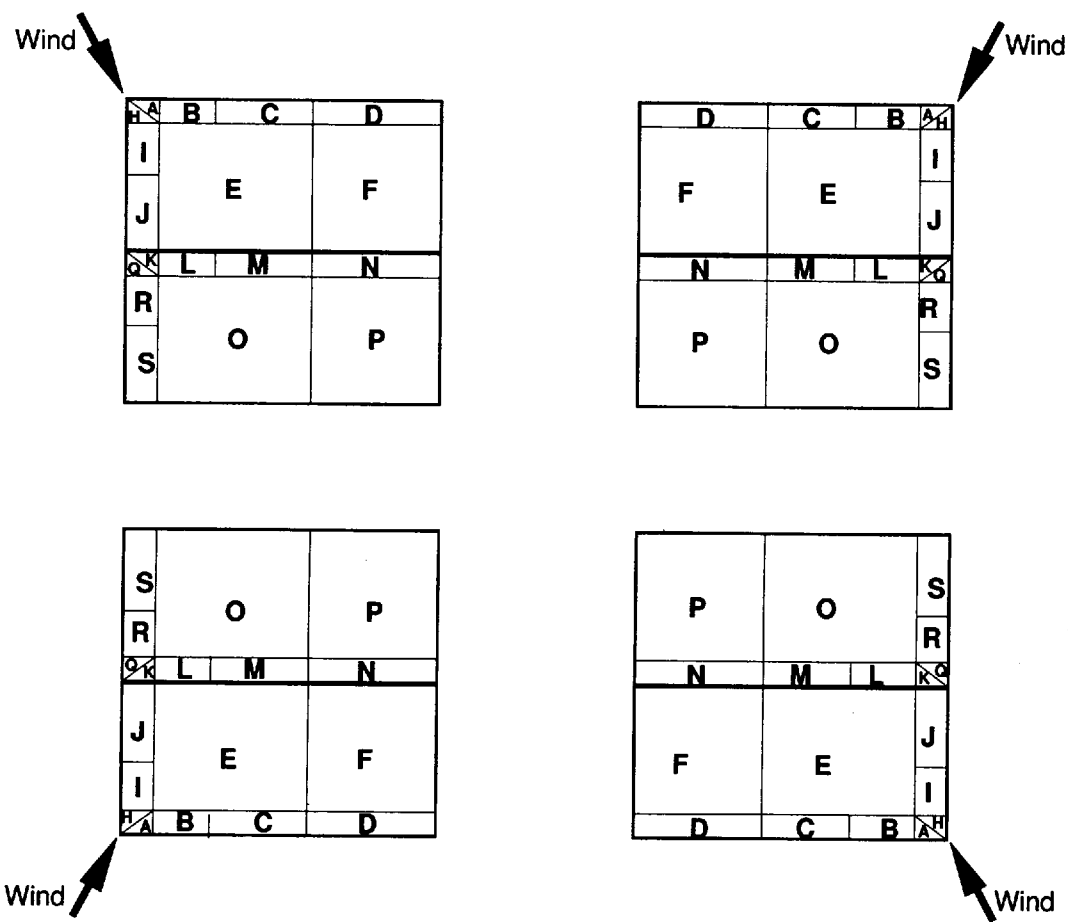
3.3.3.4 Duopitch roofs

3.3.3.4.1 External pressure coefficients C_{pe} for duopitch roofs are given in table 34 for zones A to J and table 35 for zones K to S defined in figure 40. These zones are defined from the upwind corner of each face.

NOTE. The pitch angle α is taken as positive when the roof has a central ridge and negative when the roof has a central trough.



a) Symmetries for monopitch roofs



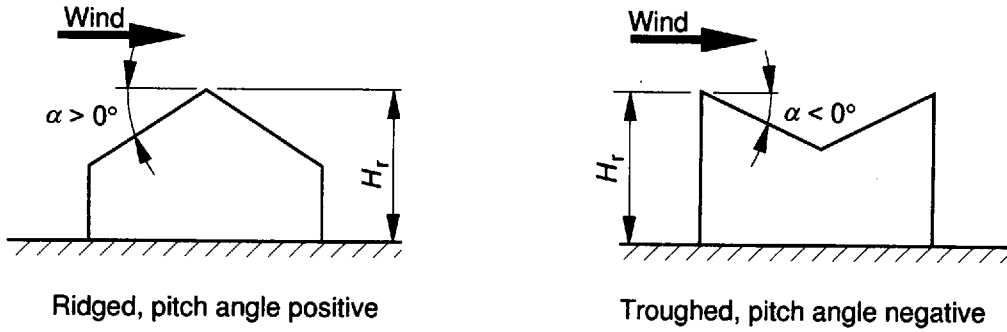
b) Symmetries for duopitch roofs

Figure 39. Symmetries for pitched roofs

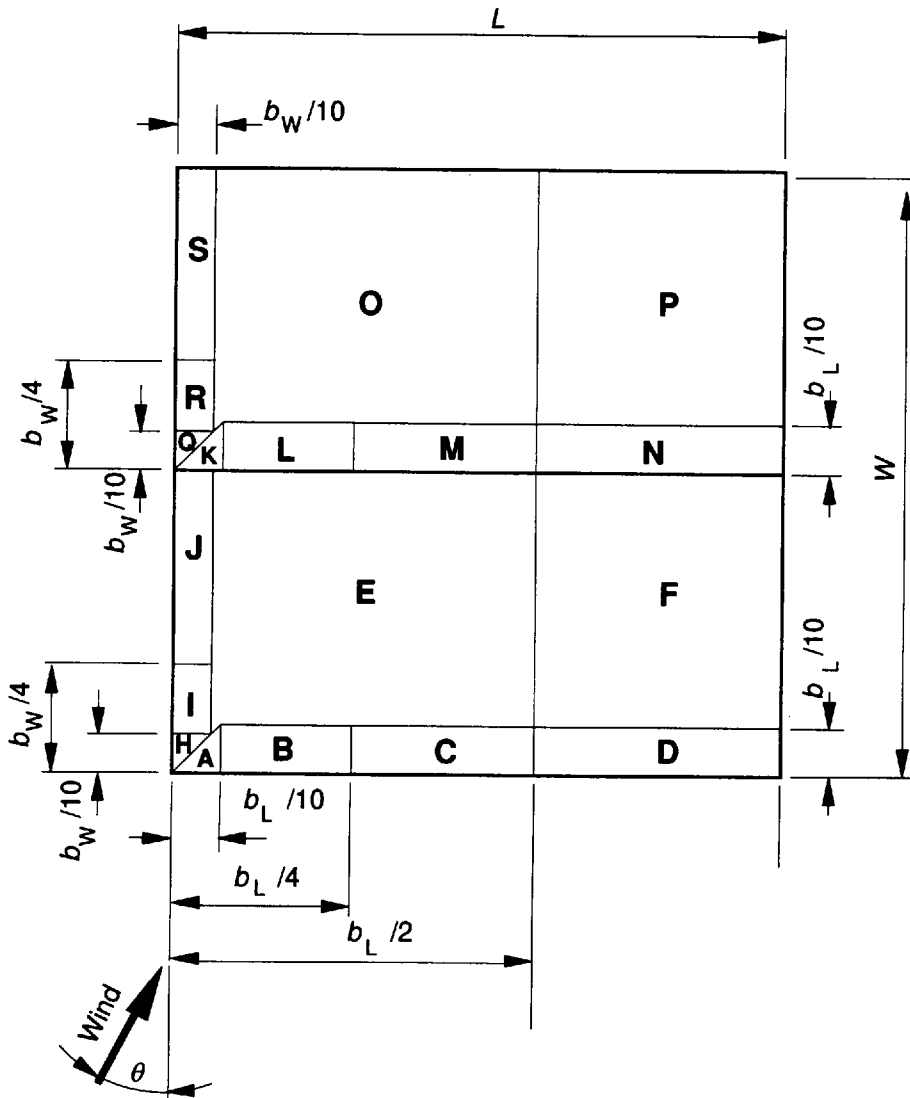
Pitch angle α	Local wind direction θ	Zone								
		K	L	M	N	O	P	Q	R	S
-45°	0°	-0.92	-0.92	-0.92	-0.75	-0.75	-0.75	-0.63	-0.63	-0.63
	±30°	-1.12	-1.12	-1.12	-0.52	±0.20	-0.52	-0.32	-0.32	-0.32
	±60°	-1.04	-1.04	-1.04	-0.24	-0.73	-0.24	-1.05	-1.05	-1.05
	±90°	-1.17	-0.96	-0.86	-0.33	-0.88	-0.28	-1.25	-1.08	-1.36
-30°	0°	-0.78	-0.78	-0.78	-0.66	-0.47	-0.66	-0.40	-0.40	-0.40
	±30°	-0.44	-0.44	-0.44	-0.52	±0.20	-0.52	±0.20	±0.20	±0.20
	±60°	-0.74	-0.74	-0.74	-0.27	-0.62	-0.27	-1.01	-1.01	-1.01
	±90°	-1.13	-0.94	-0.77	-0.19	±0.20	-0.19	-1.25	-1.06	-1.36
-15°	0°	-0.69	-0.69	-0.69	-0.52	-0.26	-0.52	-0.21	-0.21	-0.21
	±30°	±0.20	±0.20	±0.20	±0.20	±0.20	±0.20	-0.55	-0.55	-0.55
	±60°	-0.67	-0.67	-0.67	±0.20	-0.65	±0.20	-1.03	-1.03	-1.03
	±90°	-1.20	-0.84	-0.58	-0.27	-0.64	±0.20	-1.42	-1.10	-1.30
-5°	0°	-0.34	-0.34	-0.34	-0.25	-0.25	-0.25	-0.28	-0.28	-0.28
	±30°	±0.20	±0.20	±0.20	±0.20	-0.26	±0.20	-0.48	-0.48	-0.48
	±60°	-0.69	-0.69	-0.69	±0.20	-0.66	±0.20	-0.88	-0.88	-0.88
	±90°	-1.21	-0.83	-0.55	-0.25	-0.61	±0.20	-1.48	-1.12	-1.30
+5°	0°	-0.32	-0.27	-0.28	-0.28	±0.20	±0.20	-0.36	-0.30	-0.24
	±30°	-0.70	-0.46	-0.30	-0.23	-0.31	±0.20	-0.71	-0.59	-0.46
	±60°	-1.04	-0.90	-0.52	±0.20	-0.56	±0.20	-0.97	-0.83	-0.73
	±90°	-0.90	-0.83	-0.58	±0.20	-0.60	±0.20	-0.89	-0.89	-1.09
+15°	0°	-0.8	-0.81	-0.80	-0.78	-0.39	-0.40	-0.85	-0.55	-0.39
	±30°	-1.32	-1.14	-1.11	-0.88	-0.46	-0.34	-0.47	-1.25	-0.81
	±60°	-1.31	-0.92	-0.72	-0.58	-0.57	-0.23	-1.45	-1.08	-0.75
	±90°	-0.81	-0.74	-0.54	±0.20	-0.58	±0.20	-0.83	-0.77	-0.92
+30°	0°	-0.29	±0.26	-0.25	-0.30	-0.30	-0.30	-0.31	-0.32	-0.33
	±30°	-0.74	-0.63	-0.52	-0.43	-0.39	-0.43	-0.76	-0.51	-0.40
	±60°	-1.04	-1.05	-0.90	-0.64	-0.58	-0.47	-1.02	-0.67	-0.64
	±90°	-0.66	-0.61	-0.49	-0.21	-0.49	±0.20	-0.67	-0.58	-0.69
+45°	0°	-0.21	-0.21	-0.21	-0.20	-0.23	-0.23	-0.21	-0.24	-0.26
	±30°	-0.21	-0.20	-0.20	-0.27	-0.23	-0.26	-0.20	-0.21	-0.22
	±60°	-0.54	-0.54	-0.51	-0.41	-0.44	-0.38	-0.55	-0.47	-0.50
	±90°	-0.55	-0.46	-0.38	-0.20	-0.40	±0.20	-0.60	-0.45	-0.47
+60°	0°	-0.49	-0.49	-0.40	-0.40	-0.30	-0.30	-0.57	-0.57	-0.57
	±30°	-0.63	-0.63	-0.71	-0.69	-0.40	-0.40	-0.67	-0.67	-0.67
	±60°	-1.00	-1.00	-0.60	-0.42	-0.74	-0.63	-0.91	-0.91	-0.91
	±90°	-0.72	-0.72	-0.24	±0.20	-0.60	±0.20	-1.21	-1.21	-1.21
+75°	0°	-0.54	-0.54	-0.43	-0.43	-0.30	-0.30	-0.58	-0.58	-0.58
	±30°	-0.71	-0.71	-0.64	-0.63	-0.40	-0.40	-0.70	-0.70	-0.70
	±60°	-1.13	-1.13	-0.67	-0.31	-1.15	-0.61	-0.97	-0.97	-0.97
	±90°	-0.79	-0.79	-0.42	-0.21	-0.80	±0.20	-1.21	-1.21	-1.21

NOTE 1. Interpolation may be used, except between $\alpha = +5^\circ$ and $\alpha = -5^\circ$.

NOTE 2. When the result of interpolating between positive and negative values is in the range $-0.2 < C_{pe} < +0.2$, the coefficient should be taken as $C_{pe} = +0.2$ and both possible values used.



a) General



b) Key to zones

Figure 40. Key for duopitch roofs

3.3.3.4.2 When all wind directions are considered, symmetry leads to four possible patterns of zones for each form of roof, as shown in figure 39b. Wind normal to either the eaves ($\theta = 0^\circ$) or the verge ($\theta = 90^\circ$) provides special cases where either of two patterns in figure 39b could apply. Because of the fluctuations of wind direction found in practice and in order to give the expected range of asymmetric loading, both patterns should be considered.

3.3.3.4.3 When $\alpha < 10^\circ$ and $W < B$, zones E and F should be considered to extend for a distance $B/2$ downwind from the windward eave, replacing zones L, M and N and part of zones O and P. This load case should be compared with the standard load case defined in figure 40 and the more onerous condition should be used.

3.3.3.5 Hipped roofs

3.3.3.5.1 The provisions in 3.3.3.5.2 to 3.3.3.5.4 apply to conventional hipped roofs on rectangular-plan buildings, where the pitch of the main ridged faces have pitch angle α_1 and the triangular side faces have pitch angle α_2 . Zones of external pressure coefficient are defined in figure 41. Local wind directions θ_1 and θ_2 are defined from normal to the longer and shorter eaves, respectively, where $\theta_2 = 90^\circ - \theta_1$.

3.3.3.5.2 Thus, for the main ridged faces the pitch is α_1 , the wind direction is θ_1 and the zones are A_1 to Y_1 , and for the triangular side faces the pitch is α_2 , the wind direction is θ_2 and the zones are A_2 to Y_2 . The reference height H_r is the height above ground of the ridge.

3.3.3.5.3 External pressure coefficients for zones A to E on the upwind faces are given in table 34. External pressure coefficients for zones O and P on the downwind faces are given in table 35. The size of each of these zones is given in figure 40.

3.3.3.5.4 External pressure coefficients for the additional zones T to W along the hip ridges and for zones X and Y along the main ridge are given in table 36. The width of each of these additional zones in plan is shown in figure 41b. The boundary between each pair of additional zones, T-U, V-W and X-Y, is the mid-point of the respective hip or main ridge.

3.3.3.6 Mixed gables and hipped roofs

Roofs with a standard gable at one end and a hip at the other are a frequent occurrence. In such cases, the governing criterion is the form of the upwind corner for the wind direction being considered.

3.3.3.7 Effect of parapets on pitched roofs

3.3.3.7.1 The effects of parapets should be taken into account to determine external pressure coefficients on pitched roofs. Owing to the way that parapets around roofs change the positive pressures expected on upwind pitches with large positive pitch angles to suction, neglecting their effect is not always conservative. Pressures on the parapet walls should be determined using the procedure in 2.7.5.1 for free-standing parapets and from 2.7.5.4 for downwind parapets.

3.3.3.7.2 Monopitch roofs

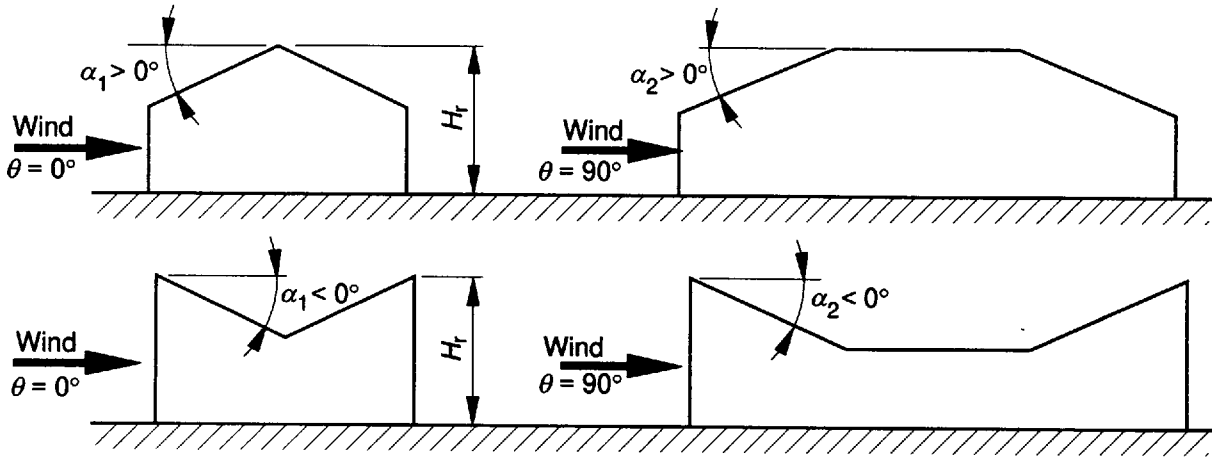
a) *Low eaves with parapet upwind.* For the part of the roof below the top of the parapet, external pressure coefficients should be determined in accordance with 3.3.2.4, i.e. the roof should be treated as a flat roof with parapets, irrespective of actual roof pitch. For any part of the roof that is above the top of the parapet, i.e. if the top of the parapet is below the level of the high eaves, external pressure coefficients should be determined in accordance with 3.3.3.3 as if the parapet did not exist.

b) *High eaves upwind.* External pressure coefficients should be determined in accordance with 3.3.3.3. The reduction factors of table 31 should be used for upwind eaves and verge zones A to D and H to J, with the parapet height h determined at the upwind corner of each respective zone. Thus, for parapets level with the high eaves the parapet height should be taken as $h = 0$ for zones A to D and H, so that the reduction factor is less than unity only for zones I and J.

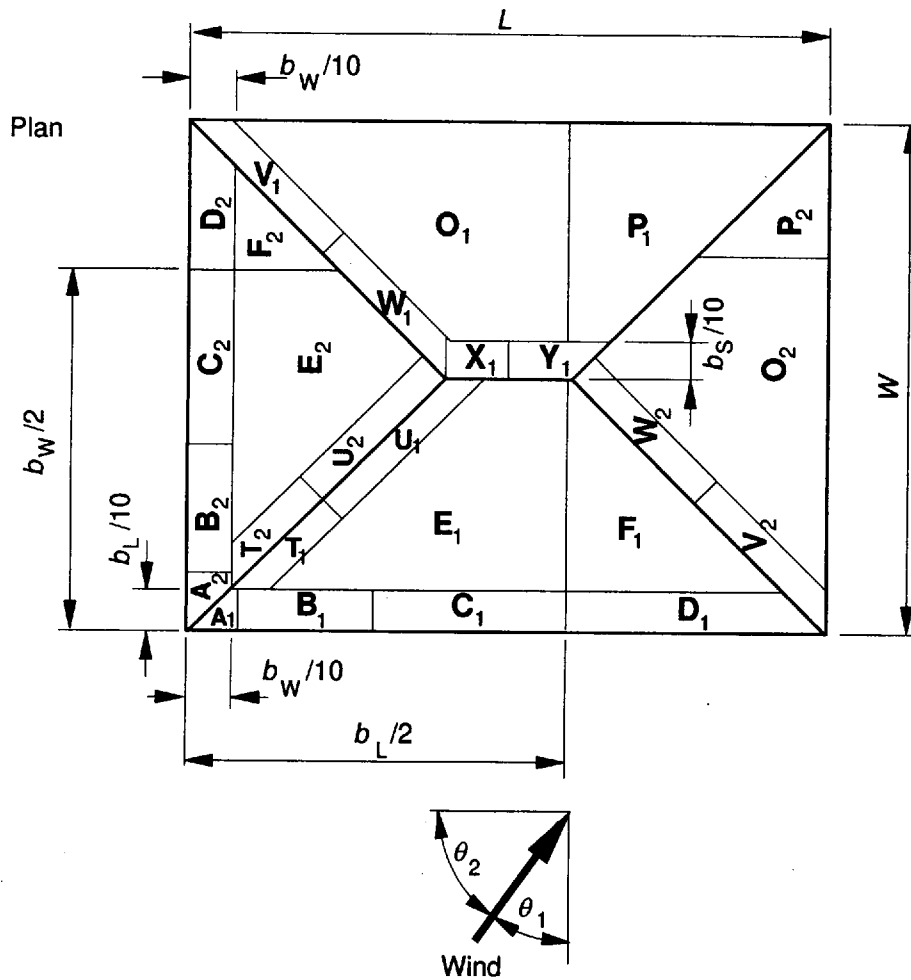
3.3.3.7.3 Duopitch roofs

a) *Upwind face.* For the part of the roof below the top of the parapet, external pressure coefficients should be determined in accordance with 3.3.2.4, i.e. the roof should be treated as a flat roof with parapets, irrespective of actual roof pitch. For any part of the roof that is above the top of the parapet, i.e. if the top of the parapet is below the level of the ridge, external pressure coefficients should be determined in accordance with 3.3.3.4 as if the parapet did not exist.

b) *Downwind face.* External pressure coefficients should be determined in accordance with 3.3.3.4 for the downwind pitch of duopitch roofs. The reduction factors of table 31 should be used only for the verge zones Q to S with the parapet height h determined at the upwind corner of each respective zone.



a) General



b) Key to zones

Figure 41. Key for hipped roofs

Pitch angle α	Local wind direction θ	Additional zones					
		T	U	V	W	X	Y
+5°	0°	-0.56	-0.56	-0.31	-0.45	-0.58	-0.58
	±30°	-0.62	-0.62	-0.60	-0.46	-0.47	-0.54
	±60°	-1.13	-0.63	-0.76	-0.51	-0.38	-0.36
	±90°	-1.19	-0.76	-0.89	-0.50	-0.61	±0.20
+15°	0°	-0.31	-0.31	-0.44	-0.83	-1.17	-1.17
	±30°	-0.37	-0.37	-1.00	-0.99	-1.31	-1.13
	±60°	-0.94	-0.52	-1.43	-0.71	-0.78	-0.80
	±90°	-1.09	-0.77	-0.97	-0.59	-0.64	±0.20
+30°	0°	-0.40	-0.40	-0.53	-0.33	-0.28	-0.28
	±30°	-0.26	-0.26	-0.74	-0.55	-0.51	-0.50
	±60°	-0.99	-0.47	-1.25	-0.82	-0.77	-0.49
	±90°	-1.10	-1.01	-1.40	-0.62	-0.78	±0.20
+45°	0°	-0.74	-0.74	-0.65	-0.24	-0.20	-0.20
	±30°	-0.55	-0.55	-0.52	-0.22	-0.22	-0.28
	±60°	-1.11	-0.33	-0.67	-0.35	-0.32	-0.41
	±90°	-1.22	-0.71	-1.35	-0.43	-0.88	-0.28

NOTE. Interpolation may be used.

3.3.3.7.4 Hipped roofs

a) *Upwind main and hip faces.* For the part of the roof below the top of the parapet, external pressure coefficients should be determined in accordance with 3.3.2.4, i.e. the roof should be treated as a flat roof with parapets, irrespective of actual roof pitch. For any part of the roof that is above the top of the parapet, i.e. if the top of the parapet is below the level of the ridge, external pressure coefficients should be determined in accordance with 3.3.3.5 as if the parapet did not exist.

b) *Downwind main and hip faces.* External pressure coefficients should be determined in accordance with 3.3.3.5 as if the parapet did not exist. The reduction factors of table 31 should not be applied to any zone.

3.3.3.8 Pitched roofs with inset storeys

External pressure coefficients should be determined in accordance with 3.3.2.7, using the appropriate zones for the pitched roofs as derived from 3.3.3.3 to 3.3.3.5.

3.3.3.9 Friction induced loads on pitched roofs

Friction forces should be determined for long pitched roofs when the wind is parallel to the eaves or ridge, i.e. $\theta = 90^\circ$. The frictional drag coefficient should be assumed to act over zones F and P only of such roofs, with the values as given in table 6. The resulting frictional forces should be applied in accordance with 3.1.3.4.

3.3.4 Multipitch and multi-bay roofs

3.3.4.1 Multipitch roofs

3.3.4.1.1 Multipitch roofs are defined as roofs in which each span is made up of pitches of two or more pitch angles, as shown in figure 22 for the standard method. The form in figure 22a is commonly known as a mansard roof.

NOTE. Flat roofs with mansard eaves are dealt with in 3.3.2.6.

3.3.4.1.2 External pressure coefficients for each pitch should be derived in accordance with 3.3.3.4 or 3.3.3.5, according to the form of the verges, but omitting the eaves edge zones along the change in slope where indicated in figure 22.

NOTE. The letters designating the zones in figure 22 which correspond to the standard method should be ignored.

- The eaves edge zones A to D on the bottom edge of all windward faces should be included when the pitch angle of that face is less than that of the pitch below, including the lowest face forming the actual eaves of the windward side, as shown in figure 22a. The eaves zones A to D should be excluded when the pitch angle is greater than that of the pitch below, as shown in figure 22b.
- The ridge zones K to N for gabled roofs or ridge zones X and Y for hipped roofs should be included only on the highest downwind face along the actual ridge, as shown in figures 22a and 22b. Ridge zones on all other downwind faces should be excluded.
- Verge zones H to J on gabled roofs or hip zones U to W on hipped roofs should be included for all faces.

3.3.4.2 Multi-bay roofs

3.3.4.2.1 Multi-bay roofs are defined as roofs made up of a series of monopitch, duopitch, hipped or similar spans as shown in figures 23a to 23c.

3.3.4.2.2 Pressure coefficients on the first span, i.e. the upwind pitch of multi-bay monopitch roofs and the upwind pair of pitches of duopitch roofs, may be taken to be the same as for single span roof. However, these pressures are reduced in value for the downwind spans.

3.3.4.2.3 Account may be taken of this reduction by following the procedure in 2.5.5 of the standard method, but using the key in figure 42 to define regions of shelter at any given wind direction.

NOTE. When the wind direction is normal to the eaves, i.e. $\theta = 0^\circ$, figure 42 becomes identical to the standard method case of figure 23d. When the wind is normal to the gables, i.e. $\theta = 90^\circ$, there are no regions of shelter.

3.3.4.3 Friction induced loads on multipitch and multi-bay roofs

Friction forces should be determined for long pitched roofs when the wind is parallel to the eaves or ridge, i.e. $\theta = 90^\circ$. The frictional drag coefficient should be assumed to act over only zones F and P of such roofs, with values as given in table 6. The resulting frictional forces should be added to the normal pressure forces in accordance with 3.1.3.4.

3.3.5 Internal pressure coefficients

3.3.5.1 It is recommended that the procedures for internal pressure coefficients given in 2.6 for the standard method are used. When necessary, interpolation should be used between the orthogonal wind directions to obtain values for the other wind directions.

3.3.5.2 Table 18, giving internal pressure coefficients for open-sided buildings, has been expanded in table 37 to give values for 30° increments of wind direction.

NOTE. If more accurate values are required, internal pressures in enclosed buildings or buildings with dominant openings may also be determined from the distribution of external pressures by calculating the balance of internal flows (see reference [6]).

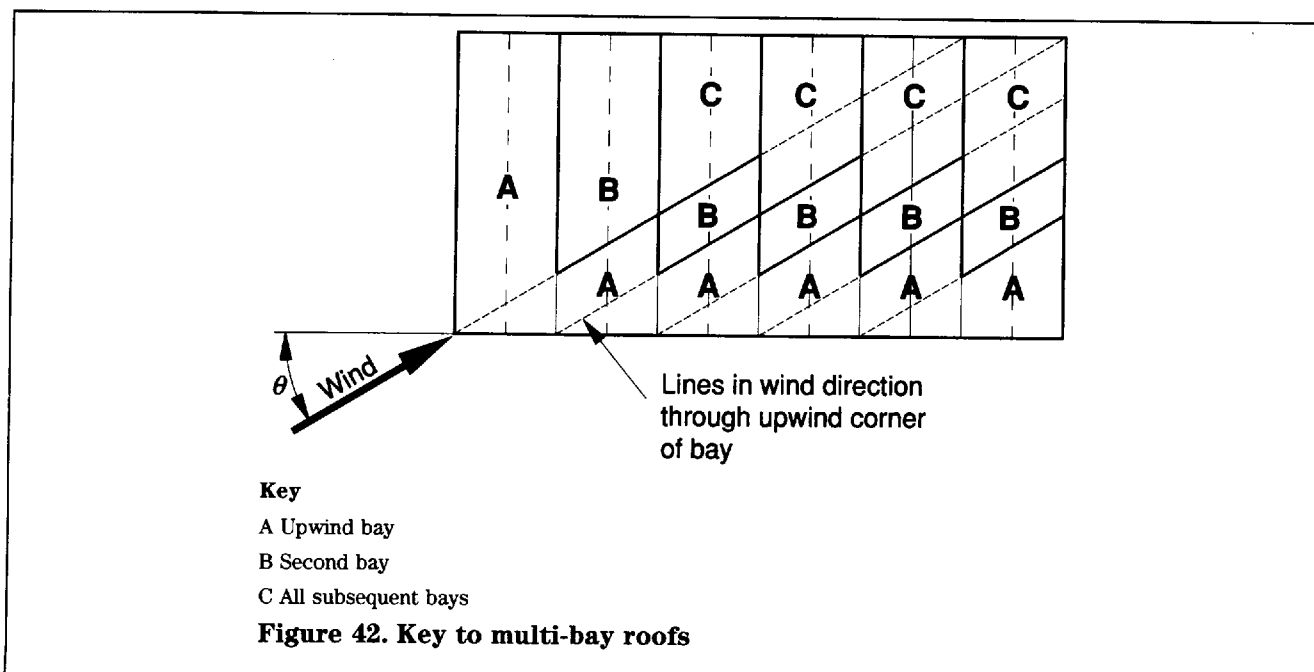


Table 37. Internal pressure coefficients C_{pi} for open-sided buildings

Wind direction θ	One open face				Two or more adjacent open faces	
	Shorter	Longer			Longer and one shorter ¹⁾	Longer and both shorter ²⁾
		Upwind third	Middle third	Downwind third		
$\pm 0^\circ$	+0.85	+0.68	+0.68	+0.68	+0.77	+0.60
$\pm 30^\circ$	+0.71	+0.54	+0.70	+0.80	+0.77	+0.50
$\pm 60^\circ$	+0.32	+0.38	+0.44	+0.54	+0.77	+0.30
$\pm 90^\circ$	-0.60	-0.40	-0.40	-0.40	+0.77, -0.38	0
$\pm 120^\circ$	-0.46	-0.46	-0.46	-0.46	-0.53	-0.63
$\pm 150^\circ$	-0.31	-0.40	-0.40	-0.40	-0.60	-0.49
$\pm 180^\circ$	-0.16	-0.16	-0.16	-0.16	-0.33	-0.39

¹⁾ Two values are given for $\theta = 90^\circ$. The positive value applies when the wind is blowing into the short open face.
²⁾ Apply values to underside of roof only. For the single wall, use pressure coefficients for walls given in table 26.

3.4 Hybrid combinations of standard and directional methods

3.4.1 Standard effective wind speeds with directional pressure coefficients

3.4.1.1 Applicability

Standard effective wind speeds should be combined with directional pressure coefficients in cases where the form of the building is well defined but the exposure of the site is not well defined.

NOTE. Typical examples are relocatable or portable buildings, or mass-produced designs.

3.4.1.2 Application

As the standard effective wind speeds apply to the range $\theta = \pm 45^\circ$ either side of the notional orthogonal wind directions, the appropriate standard effective wind speed to be used with each of the directional pressure coefficients should be selected from this range. This results in a load case for each wind direction for which pressure coefficients are given, usually twelve.

3.4.2 Directional effective wind speeds with standard pressure coefficients

3.4.2.1 Applicability

Directional effective wind speed should be combined with standard pressure coefficients if a more precise estimate of site exposure is required, particularly when there is significant topography or when the site is in a town. In the standard method the method for significant topography (2.2.2.2) was derived assuming the turbulence characteristics for open country terrain and some advantage may be gained by using the actual site characteristics. The standard method for effective wind speeds assumes that the site is 2 km from the edge of a town, with sites closer to the edge treated as being in country terrain and sites further into the town treated as being at 2 km, thus, the potential benefits of shelter from the town exposure are not exploited for any locations except those at exactly 2 km from the edge.

3.4.2.2 Application

3.4.2.2.1 The directional effective wind speeds should be determined in each of the twelve wind directions using the value of gust factor $g_t = 3.44$, for the datum diagonal dimension $a = 5$ m as follows:

- from $\varphi = 0^\circ$ to $\varphi = 330^\circ$ in 30° intervals, aligned from north, for which values of directional factor are given in table 3; or
- from $\theta = 0^\circ$ to $\theta = 330^\circ$ in 30° intervals, aligned with respect to the building axes, interpolating corresponding values of directional factor from table 3; or
- in 30° intervals from normal to the steepest slope of the significant topographic feature, interpolating corresponding values of directional factor from table 3.

Option a) is the simplest to implement when topography is not significant; option b) ensures that estimates will correspond exactly with the building axes; option c) ensures that the most onerous topographic effects are included.

3.4.2.2.2 For each orthogonal load case the largest value in the range $\theta = \pm 45^\circ$ either side of the notional wind direction should be selected from the directional wind speeds. These values may be taken to be equivalent to the standard effective wind speeds and used in the standard method.

Annexes

Annex A (normative)

Necessary provisions for wind tunnel testing

A.1 Static structures

Tests for the determination of wind loads on static structures should not be considered to have been properly conducted unless:

- a) the natural wind has been modelled to account for:
 - 1) the variation of mean wind speed with height above ground appropriate to the terrain of the site; and
 - 2) the intensity and scale of the turbulence appropriate to the terrain of the site at a determined geometric scale;
- b) the building has been modelled at a geometric scale not more than the following multiples of the geometric scale of the simulated natural wind, with appropriate corrections applied to account for any geometric scale discrepancies within this range:
 - 3 for overall loads; and
 - 2 for cladding loads;
- c) the response characteristics of the wind tunnel instrumentation are consistent with the measurements to be made;
- d) the tests enable the peak wind loads with the required annual risk of being exceeded to be predicted.

A.2 Dynamic structures

Tests for the determination of the response of dynamic structures should not be considered to have been properly conducted unless the provisions for static structures in items a) to d) of A.1 are satisfied, together with the additional provision that:

the structural model is represented (physically or mathematically) in mass distribution, stiffness and damping in accordance with the established law of dimensional scaling.

NOTE. Information to enable designers to make a considered judgment of the facilities offered when commissioning wind tunnel tests is available in reference [9]. Advice may also be sought from the Building Research Advisory Service, Building Research Establishment, Garston, Watford, Herts WD2 7JR. Tel: 01923 664664.

Annex B (informative)

Derivation of extreme wind information

B.1 Introduction

The wind data archived by the Meteorological Office are derived from continuously recording anemographs, normally exposed at a height of 10 m above ground in open, level terrain or, in other terrains, at a height equivalent to the standard exposure. Currently, the network numbers about 130 stations and the main archive comprises hourly mean wind speeds and wind directions, together with details of the maximum gust each hour. Many of these stations have past records spanning several decades, although the computer-held ones generally begin in about 1970.

Conventionally, estimation of the extreme wind climate in temperate regions has involved the analysis of a series of annual maximum wind speeds, for example using the method proposed by Gumbel [8]. The main disadvantage of methods using only annual maximum values is that many other useful data within each year are discarded. For the preparation of the basic wind speed map given in figure 6, a superior technique involving the maximum wind speed during every period of windy weather (or storm) was used. This approach greatly increased the amount of data available for analysis and enabled the directional and seasonal characteristics of the UK wind climate to be examined.

A storm was defined as a period of at least 10 consecutive hours with an overall mean wind speed greater than 5 m/s. Such periods were identified for 50 anemograph stations, evenly distributed over the United Kingdom and mostly having standard exposures, using their records during the period 1970 to 1980. At the majority of these stations, the average number of storms each year was about 140. The maximum hourly mean wind speed blowing from each of twelve 30° wind direction sectors (centred on 0°, 30°, 60°, etc.) was calculated for each storm.

Three types of new extreme wind information were needed: an improved map of basic wind speeds V_b ; direction factors S_d ; and seasonal factors S_s .

Analyses of extreme wind speeds are performed in terms of their probability of occurrence. The standard measure of probability is the cumulative distribution function (CDF), conventionally given the symbol P (used elsewhere in this standard for wind load), and corresponding to the annual risk of not being exceeded.

Design to resist extreme winds is based on the annual risk (probability) Q of the hourly mean wind speed being exceeded given by $Q = 1 - P$. The reciprocal of the annual risk is sometimes referred to as the return period and is best interpreted as the mean interval between recurrences when averaged over a very long period. The definition of return period rapidly becomes invalid for periods less than about 10 years. The period between individual recurrences varies considerably from this mean value, so the concept of return period is not very useful and is open to misinterpretation. The concept of annual risk is less open to misinterpretation and should be viewed as the risk of exceeding the design wind speed in each year the building is exposed to the wind.

B.2 Basic wind speed

B.2.1 Storm maxima

The basic wind speed V_b is estimated to have a risk of $Q = 0.02$ of being exceeded in any year. To obtain this speed for each station, all the maximum wind speeds in storms v_s were first abstracted, irrespective of direction. The cumulative distribution function P representing the risk of a particular value not being exceeded was determined by the method of order statistics. In this method, the maxima were sorted into ascending order of value and assigned a rank m where $m = 1$ for the lowest value and $m = N$ for the highest value, then P was estimated for the storm maxima v_s by $P(v_s) = m/(N + 1)$.

B.2.2 Annual maxima

Maxima from different storms can be regarded as statistically independent, so the CDF $P(v)$ of annual maximum wind speeds v was found from $P(v) = P^r(v_s)$, where r is the average annual rate of storms. This CDF of annual maxima was fitted to a Fisher-Tippett Type I (FT1) distribution, defined by

$$P(v) = \exp\{-\exp(-y)\} \quad (\text{B.1})$$

where

$$y = a(v - U);$$

U is the mode;

$1/a$ is the dispersion.

Hence

$$y = -\ln \left[-\ln \left\{ \left(\frac{m}{N+1} \right)^r \right\} \right] \quad (\text{B.2})$$

and a plot of y versus v_s led to estimates of the annual mode and dispersion. The wind speed V associated with a certain annual cumulative risk P of not being exceeded may be found from:

$$V = \left(U + \frac{\ln [1/P]}{a} \right) \quad (\text{B.3})$$

NOTE. Equation B.3 follows from equation B.2 because the approximation $-\ln(1 - P) \approx P$ holds well for small values of P .

B.2.3 Best extreme model

When the maximum wind speed in each storm v_s is replaced by its square v_s^2 and this is multiplied by half the density of air, the dynamic pressure q is obtained. Extreme-value theory predicts that the FT1 distribution should be a better fit to dynamic pressure than to wind speed. The above extreme value analysis method was repeated for each station using q as the variable. It was found that the rate of convergence of storm maxima to the FT1 model was faster for the q model than the v_s model. The wind speed corresponding to the dynamic pressure having a risk of $Q = 0.02$ of being exceeded at least once per year was used to derive the value at each station. Corrections were then made to the individual station estimates to ensure that when all the values were plotted on a map, they represented a height of 10 m above ground in open, level terrain at mean sea level. Isotachs were then drawn to be a best fit to the wind speeds plotted.

Fitting the dynamic pressure q to the FT1 model has been standard practice in most of Europe for many years, whereas the practice in the UK had previously been to fit the wind speed V . The difference between the two models at the design risk $Q = 0.02$ is small, about 4%. At very small risks, for example at $Q = 10^{-4}$ used for nuclear installations, the q model predicts smaller wind speeds than before. Whereas at higher risks, for example for frequent service conditions, the q model predicts higher wind speeds than before. While adoption of the better q model brings the UK into line with European practice, it also implies that previous practice at small risks was overconservative, but that service conditions may have been unconservative. These changes are also reflected in the expression for probability factor S_p in annex D.

B.2.4 Extension to Northern Ireland

There were insufficient anemograph stations to define the isotachs for Northern Ireland, so it was necessary to incorporate additional data from Eire in order to allow interpolation up to the national border. This was done by comparing results from the storms analysis for Northern Ireland with a map, prepared by the Irish Meteorological Service, showing isotachs of gust speeds having an annual risk of being exceeded of $Q = 0.02$.

B.3 Direction factor

The same analysis was performed on the series of maximum wind speeds from each 30° wind direction sector, to yield ratios of the sectorial extreme to the all-direction extreme for wind speed and dynamic pressure. After correction for site exposure, the directional characteristics of extreme winds showed no significant variation with location anywhere in the United Kingdom, with the strongest winds blowing from directions south-west to west. This enabled one set of direction factors to be proposed. The ratios calculated refer to a given risk in each sector. However, due to contributions from other sectors, the overall risk will be greater than the required value. The direction factor S_d has been derived by adjusting sectorial ratios to ensure an evenly distributed overall risk.

B.4 Seasonal factor

The overall storm maxima (irrespective of wind direction) were analysed for each month, using a technique similar to that used for the annual analyses. Given the risk of a value being exceeded by month, the risk in any longer period is the sum of the monthly risks. The seasonal characteristics of strong winds also show no significant variation across the UK so, again, one set of factors could be proposed S_s . The strongest winds usually occur in mid-winter and the least windy period is between June and August.

B.5 Verification of the data

Since this analysis was performed, a further 10 years of data has become available which doubles the data record and includes the severe storms of October 1987 and of January and February 1990. A more recent analysis of the full 21-year records for ten of the original 50 sites showed an improved analysis accuracy but the values were not significantly different from the original analysis. This gives further confidence that the 11-year period of the original analysis was representative.

B.6 Further information

References [8] and [10] to [14] give further information on the derivation of extreme wind information.

Advice can also be obtained from the Meteorological Office at the following addresses.

England and Wales: Meteorological Office, Advisory Service, London Road, Bracknell, Berkshire RG12 2SZ.
Tel: 01344 856856 or 01344 856207

Scotland: Meteorological Office, Saughton House, Broomhouse Drive, Edinburgh EH11 3XQ.
Tel: 0131 244 8362 or 0131 244 8363

Northern Ireland: Meteorological Office, Progressive House, 1 College Square East, Belfast BT1 6BQ.
Tel: 01232 328457

Annex C (informative)

Dynamic augmentation

C.1 Dynamic augmentation factor

C.1.1 General

The dynamic displacement of a structure in its lowest-frequency mode can be related to the corresponding quasi-static displacement by the product of two parameters: the building height factor K_h and the building type factor K_b . The full analysis of the governing relationships leads to equations which are too complex for codification purposes. A numerical evaluation and curve-fitting exercise carried out for practical prismatic buildings, including portal-frame structures, showed that simplifications could be made to the algebraic relationships with only marginal loss of accuracy within a range of mildly dynamic structures.

C.1.2 Full equation

The peak deflection (and hence peak stresses) can be obtained by applying a factor to the static deflection, where this factor is the ratio of the actual peak deflection to the static peak deflection. This ratio is defined here as $(1 + C_r)$ in terms of the dynamic augmentation factor C_r given by

$$C_r = \left(1 - \frac{1}{S_g^2}\right) \times \left[\sqrt{1 + \frac{K_h \cdot K_b}{60}} - 1\right] \quad (\text{C.1})$$

where

S_g is the gust factor appropriate to the size of the structure and terrain and is given by $S_g = 1 + g_t S_t$ for country terrain; and $S_g = 1 + g_t S_t T_t$ for town terrain;

S_t , T_t , g_t are obtained from tables 22, 23 and 24, respectively.

K_h and K_b are parameters depending on the building height and location and on the form of construction of the building (see C.2). Values of K_b are given in table 1.

C.1.3 Range of validity

As long as the dynamic augmentation factor remains in the range $0 \leq C_r \leq 0.25$ the method works well, and this range can be used as the definition of mildly dynamic buildings. With fully dynamic buildings, which give values of $C_r > 0.25$, the method becomes less accurate and generally more conservative. The limits of $C_r < 0.25$ and $H < 300$ m in figure 3 serve to exclude these fully dynamic structures from the provisions of this Part of BS 6399.

C.1.4 Simple equation

Using the curve-fitted expressions for the building height factor K_h and the building type factor K_b enables presentation of the values of C_r to a good approximation by the family of curves presented in figure 3. The equation for this family of curves is

$$C_r = \frac{K_b(H/h_o)^{0.75}}{800 \log(H/h_o)} \quad (\text{C.2})$$

where

h_o is a dimensional constant with value
 $h_o = 0.1$ m.

C.2 Building height factor and building type factor

C.2.1 Derivation of values

The product $K_h \times K_b$ given in equation (C.1) is given with only marginal loss of accuracy by

$$K_h \times K_b = \left\{ K_t \times \left(\frac{20 S_o}{n_o^2 a} \right)^{2/3} \right\} \times \left(\frac{V_s}{24 \xi} \right) \quad (\text{C.3})$$

where

S_o is the terrain and building factor for mean values given in 3.2.3.2, so that

$S_o = S_c (1 + S_h)$ for country terrain; and
 $S_o = S_c T_c (1 + S_h)$ for town terrain (from tables 22 and 23);

n_o is the natural frequency of the fundamental mode of vibration (in Hz);

a is the diagonal size of the building (in m);

ξ is the structural damping of the building as a fraction of critical;

V_s is the site wind speed (in m/s);

K_t is a terrain correction factor such that
 $K_t = 1.33$ at the sea coast; and $K_t = 0.75$ at least 2 km inside town terrain.

NOTE. Intermediate values of K_t could be obtained by interpolation, taking the variation of S_o as a guide.

C.2.2 Default values of parameters

In figure 3 and equation (C.2) standard values of parameters have been assumed to be given by the following.

$$n_o = \frac{60}{\sqrt{aH}} \quad (\text{C.4})$$

$$V_s = 24 \quad (\text{C.5})$$

$$K_h = S_o^{2/3} \times H^{2/3} \times K_t \quad (\text{C.6})$$

$$K_b = \frac{1}{32\xi} \quad (\text{C.7})$$

The building height factor K_h defined by equation (C.6) varies only weakly with change of terrain roughness, so that a simple terrain-independent form given by

$$K_h = (0.8H)^{0.75} \quad (\text{C.8})$$

where H is the building height in metres, can be used without significant loss of accuracy. This simplification is used in figure 3 and equation (C.2).

Values of the building type factor K_b given in table 1, have been derived from data obtained from a large number of completed buildings and other structures.

C.3 More accurate assessment of dynamic augmentation

If the assumptions used to derive the value of dynamic augmentation factor C_r are inappropriate for the particular building, or if a more accurate assessment is required, then the expression for the product $K_h \times K_b$ given by equation (C.3) can be used in conjunction with relevant values of the parameters. In particular, values of V_b , S_o and K_t can be derived for the actual location and exposure of the building, and values of n_o and ξ obtained from measurements or predictions for the structure.

Annex D (normative)**Probability factor and seasonal factor****D.1 Probability factor**

The basic wind speed as defined in clause 2.2.1 has an annual risk of being exceeded of $Q = 0.02$. To vary the basic wind speed for other such annual probabilities the basic wind speed should be multiplied by the probability factor S_p given by

$$S_p = \sqrt{\frac{5 - \ln\{-\ln(1 - Q)\}}{5 - \ln(-\ln 0.98)}} \quad (\text{D.1})$$

where Q is the annual probability required. This expression corresponds to a Fisher-Tippett type 1 (FT1) model for dynamic pressure that has a characteristic product (mode/dispersion ratio) value of 5, which is valid for the UK climate only.

A number of values of S_p for standard values of Q are relevant:

- $S_p = 0.749$ for $Q = 0.632$ (see note 1);
- $S_p = 0.845$ for $Q = 0.227$ (see note 2);
- $S_p = 1.000$ for $Q = 0.02$ (see note 3);
- $S_p = 1.048$ for $Q = 0.0083$ (see note 4);
- $S_p = \sqrt{1.4}$ for $Q = 5.7 \times 10^{-4}$ (see note 5);
- $S_p = 1.263$ for $Q = 10^{-4}$ (see note 6).

NOTE 1. The annual mode, corresponding to the most likely annual maximum value.

NOTE 2. For the serviceability limit, assuming the partial factor for loads for the ultimate limit is $\gamma_f = 1.4$ and for the serviceability limit is $\gamma_f = 1.0$, giving

$$S_p = \sqrt{1/1.4} = 0.845$$

NOTE 3. The standard design value, corresponding to a mean recurrence interval of 50 years.

NOTE 4. The design risk for bridges, corresponding to a mean recurrence interval of 120 years.

NOTE 5. The annual risk corresponding to the standard partial factor for loads, corresponding to a mean recurrence interval of 1754 years. Back-calculated assuming the partial factor load for the ultimate limit is $\gamma_f = 1.4$ and all risk is ascribed to the recurrence of wind.

NOTE 6. The design risk for nuclear installations, corresponding to a mean recurrence interval of 10 000 years.

D.2 Seasonal factor

The seasonal factor S_s may be used for buildings which are expected to be exposed to the wind for specific subannual periods, reducing the basic wind speeds while maintaining the risk Q of being exceeded at a value 0.02 in the stated period. The seasonal factor S_s may also be used in conjunction with the probability factor S_p for other risks Q of being exceeded in the stated period. If values of S_s are used they should be taken from table D.1.

Table D.1 Values of seasonal factor

Months	Subannual periods				Months
	1 month	2 months	4 months	6 months	
Jan	0.98	0.98	0.98	0.87	Jan
Feb	0.83	0.83	0.83	0.83	Feb
Mar	0.82	0.83	0.83	0.83	Mar
Apr	0.75	0.71	0.73	0.76	Apr
May	0.69	0.71	0.73	0.76	May
Jun	0.66	0.71	0.73	0.83	Jun
Jul	0.62	0.71	0.73	0.83	Jul
Aug	0.71	0.85	0.96	0.90	Aug
Sep	0.82	0.85	0.96	0.90	Sep
Oct	0.82	0.89	1.00	1.00	Oct
Nov	0.88	0.95	1.00	1.00	Nov
Dec	0.94	1.00	1.00	1.00	Dec
Jan	0.98	0.98	1.00	1.00	Jan
Feb	0.83	0.86	1.00	1.00	Feb
Mar	0.82	0.86	1.00	1.00	Mar

NOTE. The factor for the 6 month winter period October to March inclusive is 1.0 and for the 6 month summer period April to September inclusive is 0.84.

Annex E (informative)

Terrain categories and effective height

E.1 Terrain categories

E.1.1 General

The roughness of the ground surface controls both the mean wind speed and its turbulent characteristics and is described by an effective aerodynamic roughness length z_0 . Over a smooth surface such as open country the wind speed is higher near the ground than over a rougher surface such as a town. By defining three basic terrain categories wind speeds can be derived for any intermediate category or to account for the influence of differing upwind categories to that of the site. The three basic categories defined in 1.7 are as follows.

a) *Sea*. This applies to the sea, but also to inland lakes which are large enough and close enough to affect the wind speed at the site. Although this standard does not cover offshore structures, it is necessary to define such a category so that the gradual deceleration of the wind speed from the coast inland can be quantified and the wind speed for any land-based site can be determined. The aerodynamic roughness length for sea is taken as $z_0 = 0.003$ m.

b) *Country*. This covers a wide range of terrain, from the flat open level, or nearly level country with no shelter, such as fens, airfields, moorland or farmland with no hedges or walls, to undulating countryside with obstructions such as occasional buildings and windbreaks of trees, hedges and walls. Examples are farmlands and country estates and, in reality, all terrain not otherwise defined as sea or town. The aerodynamic roughness length for country is taken as $z_0 = 0.03$ m.

c) *Town*. This terrain includes suburban regions in which the general level of roof tops is about 5 m above ground level, encompassing all two storey domestic housing, provided that such buildings are at least as dense as normal suburban developments for at least 100 m upwind of the site. Whilst it is not easy to quantify it is expected that the plan area of the buildings is at least 8% of the total area within a 30° sector centred on the wind direction being considered. The aerodynamic roughness length for town is taken as $z_0 = 0.3$ m.

NOTE. The aerodynamic roughness of forests and mature woodland is similar to town terrain ($z_0 = 0.3$ m). It is inadvisable to take advantage of the shelter provided by woodland unless it is permanent (not likely to be clear felled).

E.1.2 Variation of fetch

Fetch refers to the terrain directly upwind of the site. The adjustment of wind speed characteristics as the wind flows from one terrain to another is not instantaneous. At a change from a smoother to a rougher surface the mean wind speed is gradually slowed down near the ground and the turbulence in the wind increases.

This adjustment requires time to work up through the wind profile and at any site downwind of a change in terrain the wind speed is at some intermediate flow between that for the smooth terrain and that for the fully developed rough terrain. The resulting gradual deceleration of the mean speed and increase in turbulence has been accounted for in tables 22 and 23 by defining the site by its distance downwind from the coast and, in addition if it is in a town, by its distance from the edge of the town.

Shelter of a site from a town upwind of the site has not been allowed for, other than if the site is in a town itself. To do so would introduce too much complexity with only a marginal saving in the resulting wind loads. However, [8] and [15] give information on how to take such effects into account.

It is important, if directional effects need to be considered, to take full account of the effects of terrain upwind of the site in conjunction with the direction factor. This becomes even more important if the effects of topography also need to be considered, as the topographic increment S_h can be large.

E.2 Effective height

E.2.1 In rough terrain, such as towns and cities, the wind tends to behave as if the ground level was raised to a height just below the average roof height, leaving an indeterminate region below which is often sheltered. This displacement height H_d is a function of the plan area density and general height of the buildings or obstructions. The effective height, H_e of any building that is higher than its surroundings in such terrain is thus the reference height H_r less the displacement height H_d . Thus $H_e = H_r - H_d$.

E.2.2 The displacement height has been determined by ESDU [16] from available references for urban and woodland terrain. Based on this work the normal practical range of displacement heights has been found to be $0.75H_0 < H_d < 0.90H_0$. A value of $H_d = 0.8H_0$ has been adopted in 1.7.3.

E.2.3 This does not apply where the building to be designed is a similar height or lower than its surroundings. A minimum effective height of $H_e = 0.4H_r$ has been adopted.

E.2.4 The displacement height reduces with separation distance X between buildings particularly across open spaces within, or at the edge of, a built up area, as described in 1.7.3.3 and illustrated in figure E.1.

E.2.5 Accelerated wind speeds occur close to the base of buildings which are significantly taller than the displacement height. 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.

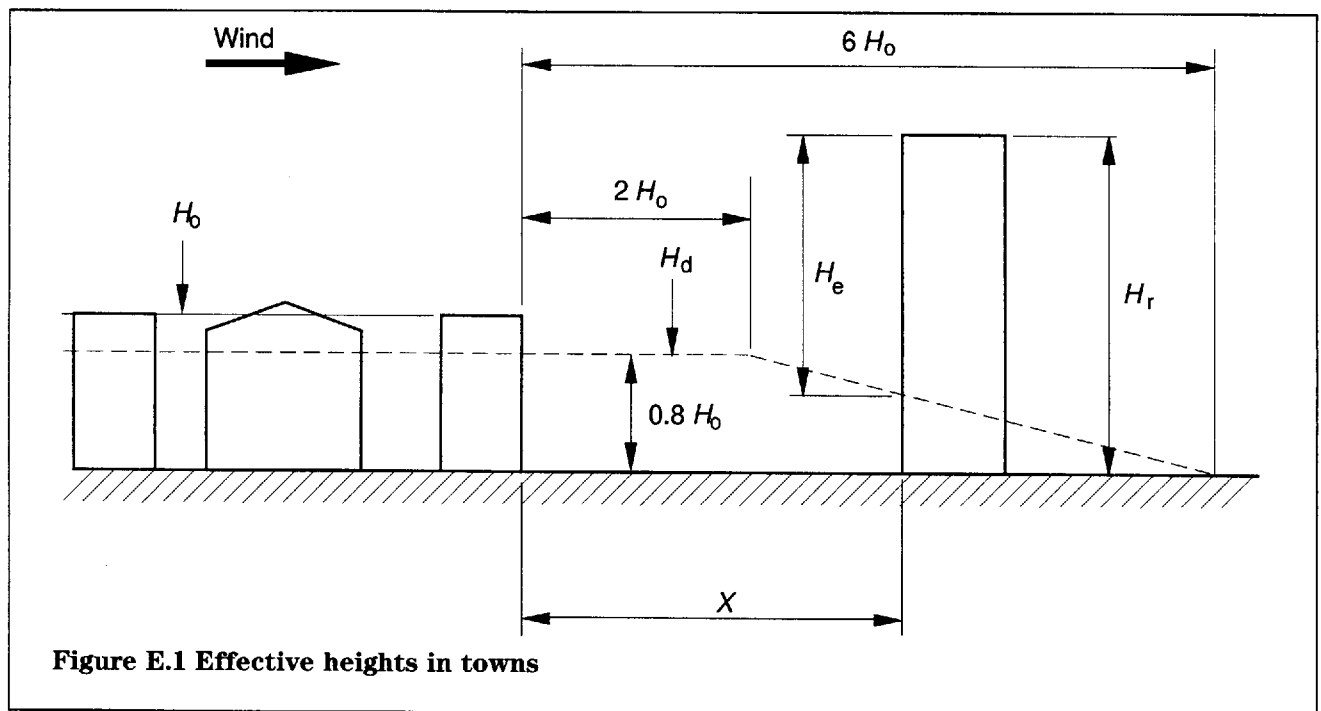


Figure E.1 Effective heights in towns

Annex F (informative)

Gust peak factor

A simplified formula [8] for g_t given by $g_t = 0.42 \ln(3600/t)$, where t is the gust duration time in seconds, has been shown to be within a few percent of more complex formulations as proposed by Greenway [17] and ESDU [18]. For the purposes of these procedures the simplified formula was thus considered adequate. However, the value of the gust factor in terms of the gust period t is not of direct application to design. The problem is rather to determine, for static structures, the appropriate gust speed which will envelop the structure or component to produce the maximum loading thereon.

Fortunately for bluff type structures, such as buildings, which can be designed statically, there is a simple empirical relationship between the period t and the characteristic size of the structure or element a given by

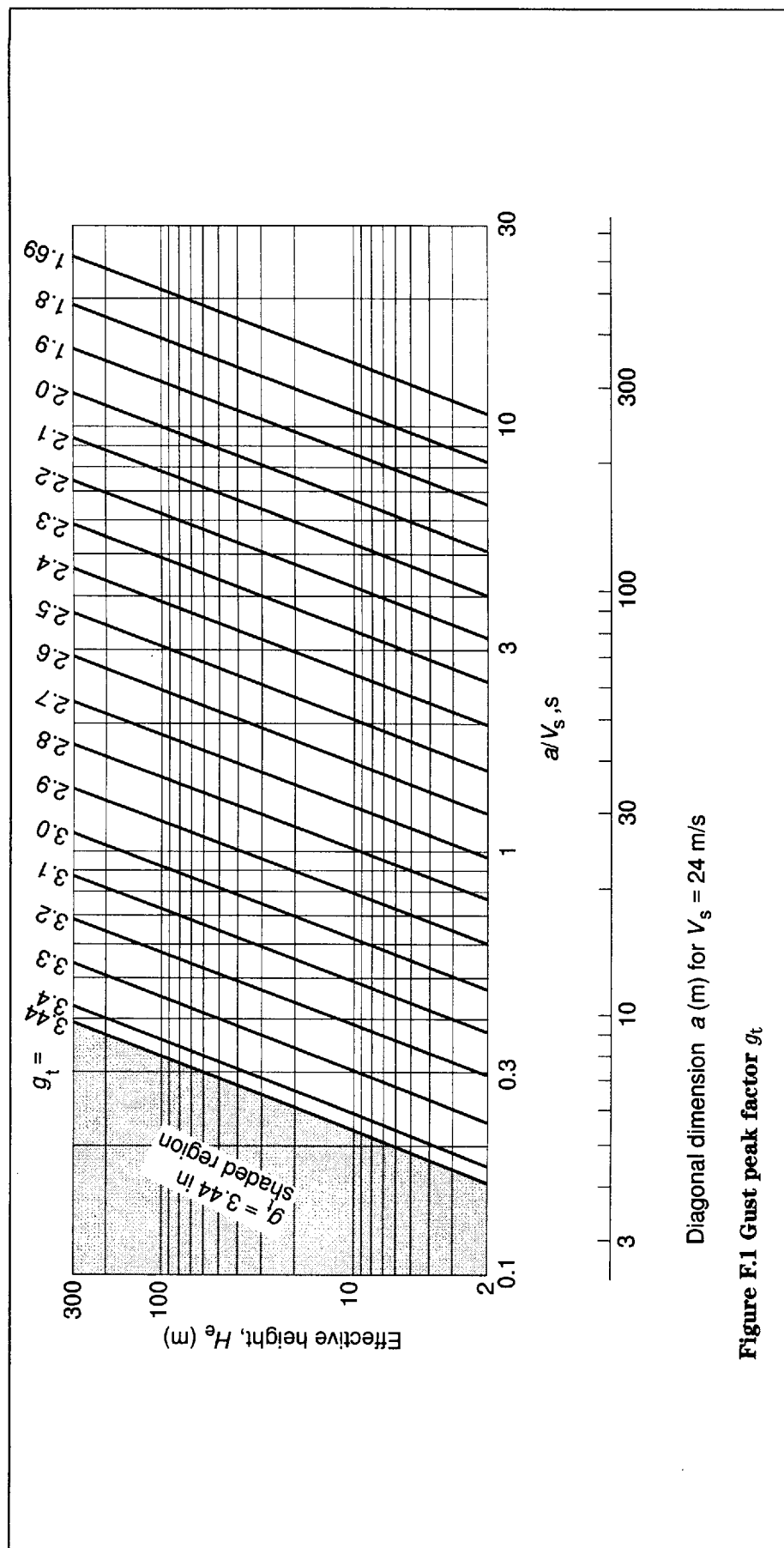
$$t = 4.5a/V_0 \quad (\text{F.1})$$

where

V_0 is the relevant mean wind speed at height H_r given by $V_0 = V_s S_c$ for country terrain; and $V_0 = V_s S_c T_c$ for town terrain.

NOTE. Acceleration of the wind speed by topography does not significantly affect the size of the gusts, so that topographic increment S_h is not included in the equations for V_0 .

By combining these two equations, a graph can be plotted of height against a/V_s for town terrain to give values of the gust peak factor g_t . This is shown in figure F.1. For design purposes it is likely that V_s will lie within the range $20 \text{ m/s} < V_s < 30 \text{ m/s}$ so that for a size of, for example 20 m, a/V_s lies in the range $0.67\text{s} < a/V_s < 1\text{s}$. For a height of 20 m above ground, g_t wind speed would be within $\pm 1.8\%$ over this range of site mean speed. Similar percentage changes would apply for different sizes and heights. Consequently for these purposes the values of g_t adopted have been based on a single value of $V_s = 24 \text{ m/s}$, representative of the whole of the UK. The resulting values of size a are then shown as the abscissa on the graph of figure F.1 which enables g_t to be read directly for given heights and sizes. Factor g_t is given in table 24 for various heights and building sizes.



Diagonal dimension a (m) for $V_s = 24$ m/s

Figure F.1 Gust peak factor g_t

Annex G (normative)**Topographic location factor****G.1 General**

The data for the topographic location factor, s , given in figures 9a) and 9b) and 10a) and 10b) have been plotted from the following empirical equations fitted to measured data.

Equations G.1 to G.10 may be used to compute the value of topographic location factor, s . As the fitted equations are empirical, it is most important that values of the parameters to the equations are restricted to the stated ranges, otherwise invalid values will be generated.

G.2 Figures 9a and 9b, upwind — All topography

For the ranges:

$$-1.5 \leq X/L_U \leq 0 \quad \text{and} \quad 0 \leq H/L_e \leq 2.0$$

take:

$$s = A \times \exp\left(B \times \frac{X}{L_U}\right) \quad \text{G.1}$$

where:

$$A = 0.1552 \left[\frac{H}{L_e}\right]^4 - 0.8575 \left[\frac{H}{L_e}\right]^3 + 1.8133 \left[\frac{H}{L_e}\right]^2 - 1.9115 \left[\frac{H}{L_e}\right] + 1.0124 \quad \text{G.2}$$

and

$$B = 0.3542 \left[\frac{H}{L_e}\right]^2 - 1.0577 \left[\frac{H}{L_e}\right] + 2.6456 \quad \text{G.3}$$

Note: At the crest/summit (where $X = 0$) the value of topographic location factor is equal to the parameter A given by Equation G.2.

when:

$$X/L_U < -1.5 \text{ or } H/L_e > 2.0, \text{ take the value } s = 0 \text{ (} S_h = 0 \text{)}$$

G.3 Figures 9a and 9b, downwind — Hills and ridges

For the ranges:

$$0 \leq X/L_D \leq 2.0 \quad \text{and} \quad 0 \leq H/L_e \leq 2.0$$

take:

$$s = A \times \exp\left(B \times \frac{X}{L_D}\right) \quad \text{G.4}$$

where:

$$A = 0.1552 \left[\frac{H}{L_e}\right]^4 - 0.8575 \left[\frac{H}{L_e}\right]^3 + 1.8133 \left[\frac{H}{L_e}\right]^2 - 1.9115 \left[\frac{H}{L_e}\right] + 1.0124 \quad \text{G.5}$$

and

$$B = -0.3056 \left[\frac{H}{L_e}\right]^2 + 1.0212 \left[\frac{H}{L_e}\right] - 1.7637 \quad \text{G.6}$$

Note: Equations G.2 and G.5 are identical.

when:

$$X/L_D > 2.0 \text{ or } H/L_e > 2.0, \text{ take the value } s = 0 \text{ (} S_h = 0 \text{)}$$

G.4 Figures 10a and 10b, downwind — Cliffs and escarpments

For the ranges:

$$0.1 \leq X/L_e \leq 3.5 \quad \text{and} \quad 0.1 \leq H/L_e \leq 2.0:$$

take:

$$s = A \times \left(\log \left[\frac{X}{L_e}\right]\right)^2 + B \times \log \left[\frac{X}{L_e}\right] + C \quad \text{G.7}$$

where:

$$A = -1.3420 \left(\log \left[\frac{H}{L_e}\right]\right)^3 - 0.8222 \left(\log \left[\frac{H}{L_e}\right]\right)^2 + 0.4609 \log \left[\frac{H}{L_e}\right] - 0.0791 \quad \text{G.8}$$

$$B = -1.0196 \left(\log \left[\frac{H}{L_e}\right]\right)^3 - 0.8910 \left(\log \left[\frac{H}{L_e}\right]\right)^2 + 0.5343 \log \left[\frac{H}{L_e}\right] - 0.1156 \quad \text{G.9}$$

and

$$C = 0.8030 \left(\log \left[\frac{H}{L_e}\right]\right)^3 + 0.4236 \left(\log \left[\frac{H}{L_e}\right]\right)^2 - 0.5738 \log \left[\frac{H}{L_e}\right] + 0.1606 \quad \text{G.10}$$

For the range $0 \leq X/L_e < 0.1$, interpolate between values for $X/L_e = 0$ ($s = A$ in Equation G.2) and $X/L_e = 0.1$.

when: $H/L_e < 0.1$, use the values for $H/L_e = 0.1$.

when: $X/L_D > 3.5$ or $H/L_e > 2.0$, take the value $s = 0$ ($S_h = 0$)

G.5 Tabulated values

Alternatively, values of s may be interpolated directly from tables G.1 to G.4. As tables G.1 to G.4 have been derived directly from the equations, they may be useful in checking the accuracy of implementation of the equations when developing software or spreadsheets.

Table G.1 Topographic location factor, *s*, for hills and ridges, from figure 9a

H/L_e	X/L_U											X/L_D											
	-1.5	-1.4	-1.3	-1.2	-1.1	-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0	0.1	0.2	0.3	0.4	0.5		
0.100	0.018	0.024	0.031	0.040	0.051	0.066	0.085	0.110	0.141	0.182	0.235	0.303	Use table G.2										
0.126	0.018	0.024	0.030	0.039	0.050	0.064	0.083	0.107	0.137	0.176	0.227	0.292	Use table G.2										
0.158	0.018	0.023	0.030	0.038	0.049	0.063	0.080	0.103	0.132	0.169	0.217	0.278	Use table G.2										
0.200	0.018	0.023	0.029	0.037	0.047	0.060	0.077	0.098	0.125	0.160	0.205	0.262	Use table G.2										
0.251	0.017	0.022	0.028	0.035	0.045	0.057	0.073	0.093	0.118	0.150	0.191	0.242	0.308	0.392	0.498	0.634	0.844	1.125	1.585	2.242	3.295		
0.316	0.017	0.021	0.027	0.034	0.043	0.054	0.068	0.086	0.109	0.138	0.174	0.220	0.279	0.353	0.446	0.564	0.720	0.920	1.181	1.525	2.070		
0.398	0.016	0.020	0.025	0.032	0.040	0.050	0.063	0.079	0.099	0.124	0.156	0.196	0.246	0.310	0.389	0.489	0.625	0.800	1.015	1.270	1.625		
0.501	0.015	0.019	0.023	0.029	0.036	0.045	0.057	0.071	0.088	0.110	0.137	0.170	0.213	0.265	0.330	0.412	0.512	0.630	0.770	0.925	1.100		
0.631	0.014	0.017	0.021	0.027	0.033	0.041	0.050	0.062	0.077	0.095	0.117	0.145	0.179	0.221	0.273	0.337	0.420	0.520	0.635	0.765	0.910		
0.794	0.013	0.016	0.019	0.024	0.029	0.036	0.044	0.053	0.065	0.080	0.098	0.120	0.147	0.180	0.221	0.270	0.330	0.400	0.480	0.570	0.670		
1.000	0.012	0.014	0.017	0.021	0.025	0.030	0.037	0.045	0.054	0.066	0.080	0.097	0.118	0.144	0.174	0.212	0.250	0.290	0.340	0.390	0.450		
1.259	0.010	0.011	0.014	0.017	0.020	0.024	0.029	0.035	0.043	0.052	0.062	0.075	0.090	0.109	0.132	0.159	0.190	0.220	0.260	0.300	0.350		
1.585	0.006	0.008	0.009	0.011	0.013	0.016	0.019	0.023	0.028	0.034	0.041	0.049	0.059	0.071	0.086	0.103	0.120	0.140	0.160	0.180	0.200		
1.995	0.004	0.004	0.005	0.006	0.008	0.009	0.011	0.014	0.017	0.020	0.025	0.030	0.037	0.045	0.054	0.066	0.080	0.095	0.110	0.125	0.140		

Table G.2 Topographic location factor, *s*, for hills and ridges, from figure 9b

H/L_e	X/L_U											X/L_D										
	-0.3	-0.28	-0.26	-0.24	-0.22	-0.2	-0.18	-0.16	-0.14	-0.12	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1	
0.010	0.451	0.475	0.501	0.528	0.566	0.587	0.618	0.652	0.687	0.724	0.763	0.805	0.848	0.894	0.942	0.993	0.959	0.926	0.894	0.863	0.834	
0.013	0.449	0.473	0.499	0.526	0.554	0.584	0.616	0.649	0.684	0.721	0.760	0.801	0.844	0.890	0.938	0.989	0.955	0.922	0.890	0.859	0.830	
0.016	0.447	0.471	0.496	0.523	0.551	0.581	0.612	0.645	0.680	0.717	0.755	0.796	0.839	0.884	0.932	0.983	0.949	0.916	0.885	0.854	0.825	
0.020	0.444	0.468	0.493	0.519	0.547	0.577	0.608	0.641	0.675	0.712	0.750	0.790	0.833	0.878	0.925	0.975	0.942	0.909	0.878	0.848	0.819	
0.025	0.440	0.464	0.489	0.515	0.543	0.572	0.603	0.635	0.669	0.705	0.743	0.783	0.825	0.869	0.916	0.966	0.933	0.901	0.870	0.840	0.811	
0.032	0.436	0.459	0.484	0.509	0.537	0.566	0.596	0.628	0.662	0.697	0.734	0.774	0.815	0.859	0.905	0.954	0.921	0.890	0.860	0.830	0.802	
0.040	0.430	0.453	0.477	0.503	0.530	0.558	0.588	0.619	0.652	0.687	0.724	0.763	0.803	0.846	0.891	0.939	0.907	0.877	0.847	0.818	0.790	
0.050	0.423	0.446	0.469	0.494	0.521	0.548	0.577	0.608	0.641	0.675	0.711	0.748	0.788	0.830	0.874	0.921	0.890	0.860	0.831	0.803	0.776	
0.063	0.414	0.436	0.460	0.484	0.509	0.536	0.565	0.595	0.626	0.659	0.694	0.731	0.770	0.811	0.854	0.899	0.869	0.840	0.812	0.784	0.758	
0.079	0.404	0.425	0.448	0.471	0.496	0.522	0.549	0.578	0.609	0.641	0.674	0.710	0.747	0.787	0.828	0.872	0.843	0.815	0.788	0.762	0.736	
0.100	0.391	0.411	0.433	0.455	0.479	0.504	0.531	0.558	0.587	0.618	0.650	0.684	0.720	0.757	0.797	0.839	0.811	0.785	0.759	0.734	0.710	
0.126	0.375	0.395	0.415	0.437	0.459	0.483	0.508	0.534	0.562	0.591	0.621	0.653	0.687	0.722	0.760	0.799	0.773	0.748	0.724	0.701	0.678	
0.158	0.356	0.375	0.394	0.414	0.435	0.457	0.480	0.505	0.531	0.558	0.586	0.616	0.647	0.681	0.715	0.752	0.728	0.705	0.682	0.661	0.640	
0.200	0.334	0.351	0.369	0.387	0.406	0.427	0.448	0.471	0.494	0.519	0.545	0.573	0.601	0.632	0.663	0.697	0.675	0.654	0.634	0.614	0.595	

Table G.1 (continued)

H/L_e	X/L_D																			
	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5
0.100	0.309	0.261	0.221	0.187	0.159	0.134	0.114	0.096	0.082	0.069	0.058	0.049	0.042	0.035	0.030	0.025	0.022	0.018	0.015	0.013
0.126	0.299	0.253	0.215	0.183	0.155	0.132	0.112	0.095	0.080	0.068	0.058	0.049	0.042	0.035	0.030	0.026	0.022	0.018	0.016	0.013
0.158	0.286	0.244	0.207	0.177	0.150	0.128	0.109	0.093	0.079	0.067	0.057	0.049	0.041	0.035	0.030	0.026	0.022	0.019	0.016	0.013
0.200	0.271	0.232	0.198	0.169	0.145	0.124	0.106	0.090	0.077	0.066	0.056	0.048	0.041	0.035	0.030	0.026	0.022	0.019	0.016	0.014
0.251	0.254	0.218	0.187	0.160	0.138	0.118	0.101	0.087	0.075	0.064	0.055	0.047	0.041	0.035	0.030	0.026	0.022	0.019	0.016	0.014
0.316	0.233	0.201	0.174	0.150	0.129	0.112	0.096	0.083	0.072	0.062	0.054	0.046	0.040	0.034	0.030	0.026	0.022	0.019	0.016	0.014
0.398	0.210	0.183	0.159	0.138	0.120	0.104	0.090	0.079	0.068	0.059	0.052	0.045	0.039	0.034	0.029	0.026	0.022	0.019	0.017	0.015
0.501	0.186	0.162	0.142	0.125	0.109	0.095	0.084	0.073	0.064	0.056	0.049	0.043	0.038	0.033	0.029	0.025	0.022	0.019	0.017	0.015
0.631	0.160	0.142	0.125	0.110	0.098	0.086	0.076	0.067	0.059	0.052	0.046	0.041	0.036	0.032	0.028	0.025	0.022	0.019	0.017	0.015
0.794	0.136	0.121	0.108	0.096	0.086	0.077	0.068	0.061	0.054	0.048	0.043	0.039	0.034	0.031	0.027	0.024	0.022	0.019	0.017	0.015
1.000	0.113	0.102	0.092	0.083	0.074	0.067	0.060	0.054	0.049	0.044	0.040	0.036	0.032	0.029	0.026	0.023	0.021	0.019	0.017	0.015
1.259	0.089	0.081	0.074	0.067	0.061	0.055	0.050	0.045	0.041	0.037	0.034	0.031	0.028	0.026	0.023	0.021	0.019	0.017	0.016	0.014
1.585	0.060	0.054	0.050	0.045	0.041	0.038	0.034	0.031	0.029	0.026	0.024	0.022	0.020	0.018	0.017	0.015	0.014	0.013	0.012	0.011
1.995	0.037	0.034	0.031	0.028	0.026	0.023	0.021	0.019	0.018	0.016	0.015	0.013	0.012	0.011	0.010	0.009	0.008	0.008	0.007	0.006

Table G.2 (continued)

H/L_e	X/L_D																			
	0.12	0.14	0.16	0.18	0.2	0.22	0.24	0.26	0.28	0.3	0.32	0.34	0.36	0.38	0.4	0.42	0.44	0.46	0.48	0.5
0.010	0.805	0.777	0.750	0.725	0.700	0.675	0.652	0.630	0.608	0.587	0.567	0.547	0.528	0.510	0.493	0.476	0.459	0.443	0.428	0.413
0.013	0.801	0.774	0.747	0.721	0.697	0.673	0.649	0.627	0.606	0.585	0.565	0.545	0.526	0.508	0.491	0.474	0.458	0.442	0.427	0.412
0.016	0.797	0.769	0.743	0.717	0.693	0.669	0.646	0.624	0.602	0.582	0.562	0.542	0.524	0.506	0.488	0.472	0.455	0.440	0.425	0.410
0.020	0.791	0.764	0.738	0.712	0.688	0.664	0.642	0.620	0.598	0.578	0.558	0.539	0.520	0.503	0.485	0.469	0.453	0.437	0.422	0.408
0.025	0.784	0.757	0.731	0.706	0.682	0.659	0.636	0.614	0.593	0.573	0.554	0.535	0.516	0.499	0.482	0.465	0.449	0.434	0.419	0.405
0.032	0.775	0.748	0.723	0.698	0.675	0.652	0.629	0.608	0.587	0.567	0.548	0.529	0.511	0.494	0.477	0.461	0.445	0.430	0.415	0.401
0.040	0.764	0.738	0.713	0.689	0.665	0.643	0.621	0.600	0.580	0.560	0.541	0.523	0.505	0.488	0.471	0.455	0.440	0.425	0.411	0.397
0.050	0.750	0.725	0.700	0.677	0.654	0.632	0.611	0.590	0.570	0.551	0.532	0.514	0.497	0.480	0.464	0.449	0.433	0.419	0.405	0.391
0.063	0.733	0.708	0.685	0.662	0.640	0.618	0.598	0.578	0.558	0.540	0.522	0.504	0.487	0.471	0.455	0.440	0.425	0.411	0.397	0.384
0.079	0.712	0.688	0.666	0.644	0.622	0.602	0.582	0.562	0.544	0.526	0.508	0.492	0.475	0.460	0.444	0.430	0.415	0.402	0.388	0.375
0.100	0.687	0.664	0.642	0.621	0.601	0.581	0.562	0.544	0.526	0.509	0.492	0.476	0.461	0.445	0.431	0.417	0.403	0.390	0.377	0.365
0.126	0.656	0.635	0.614	0.595	0.575	0.557	0.539	0.522	0.505	0.488	0.473	0.457	0.443	0.428	0.415	0.401	0.388	0.376	0.364	0.352
0.158	0.620	0.600	0.581	0.563	0.545	0.528	0.511	0.495	0.479	0.464	0.449	0.435	0.421	0.408	0.395	0.382	0.370	0.358	0.347	0.336
0.200	0.577	0.559	0.542	0.525	0.509	0.493	0.478	0.463	0.449	0.435	0.421	0.408	0.396	0.383	0.371	0.360	0.349	0.338	0.328	0.317

Table G.3 Topographic location factor, s , for cliffs and escarpments, downwind of crest, from Figure 10a

H/L_e	X/L_e																						
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	
0.100	Use table G.4																						
0.126																							
0.158																							
0.200																							
0.251																							
0.316	0.470	0.435	0.405	0.379	0.355	0.333	0.314	0.295	0.278	0.263	0.248	0.234	0.221	0.208	0.196	0.185							
0.398	0.553	0.519	0.489	0.461	0.435	0.411	0.388	0.367	0.347	0.328	0.310	0.293	0.276	0.260	0.245	0.231							
0.501	0.597	0.564	0.534	0.506	0.480	0.455	0.431	0.409	0.387	0.367	0.347	0.328	0.310	0.293	0.276	0.259							
0.631	0.605	0.575	0.547	0.520	0.494	0.470	0.447	0.424	0.403	0.382	0.362	0.343	0.325	0.307	0.290	0.273							
0.794	0.585	0.558	0.533	0.508	0.484	0.461	0.439	0.418	0.398	0.378	0.359	0.341	0.323	0.306	0.290	0.273							
1.000	0.542	0.519	0.496	0.474	0.453	0.433	0.413	0.394	0.376	0.358	0.341	0.324	0.308	0.293	0.278	0.263							
1.259	0.481	0.462	0.443	0.424	0.407	0.389	0.372	0.356	0.340	0.325	0.311	0.296	0.283	0.269	0.256	0.243							
1.585	0.410	0.394	0.379	0.364	0.349	0.335	0.322	0.308	0.296	0.283	0.271	0.260	0.249	0.238	0.227	0.217							
1.995	0.337	0.342	0.366	0.364	0.355	0.344	0.332	0.320	0.308	0.297	0.286	0.275	0.265	0.255	0.245	0.236	0.227	0.218	0.209	0.201	0.193	0.185	
	0.270	0.266	0.281	0.278	0.271	0.263	0.254	0.246	0.237	0.229	0.221	0.214	0.207	0.200	0.193	0.186	0.180	0.174	0.168	0.162	0.156	0.151	
	0.212	0.197	0.203	0.199	0.194	0.188	0.182	0.177	0.171	0.166	0.161	0.156	0.151	0.146	0.142	0.138	0.134	0.130	0.126	0.122	0.119	0.115	
	0.159	0.138	0.138	0.134	0.130	0.126	0.122	0.118	0.115	0.111	0.108	0.105	0.102	0.099	0.097	0.094	0.092	0.089	0.087	0.085	0.083	0.081	
	0.103	0.091	0.091	0.088	0.085	0.082	0.079	0.077	0.074	0.072	0.069	0.067	0.065	0.063	0.061	0.059	0.057	0.055	0.054	0.052	0.051	0.049	
	0.066	0.060	0.067	0.067	0.065	0.063	0.060	0.057	0.054	0.051	0.048	0.046	0.043	0.040	0.038	0.036	0.033	0.031	0.029	0.027	0.025	0.023	

Table G.4 Topographic location factor, s , for cliffs and escarpments, downwind of crest, from Figure 10b

H/L_e	X/L_e																					
	0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.2	0.22	0.24	0.26	0.28	0.3	0.32	0.34	0.36	0.38	0.4	0.42
0.050	0.921	0.908	0.895	0.882	0.869	0.856	0.818	0.785	0.757	0.732	0.710	0.689	0.670	0.653	0.637	0.622	0.608	0.595	0.582	0.570	0.559	0.549
0.063	0.899	0.890	0.882	0.873	0.865	0.856	0.818	0.785	0.757	0.732	0.710	0.689	0.670	0.653	0.637	0.622	0.608	0.595	0.582	0.570	0.559	0.549
0.079	0.872	0.868	0.865	0.862	0.859	0.856	0.818	0.785	0.757	0.732	0.710	0.689	0.670	0.653	0.637	0.622	0.608	0.595	0.582	0.570	0.559	0.549
0.100	0.839	0.842	0.846	0.849	0.853	0.856	0.818	0.785	0.757	0.732	0.710	0.689	0.670	0.653	0.637	0.622	0.608	0.595	0.582	0.570	0.559	0.549
0.126	0.799	0.805	0.811	0.816	0.822	0.828	0.810	0.793	0.777	0.762	0.748	0.734	0.721	0.709	0.697	0.686	0.675	0.664	0.654	0.644	0.635	0.626
0.158	0.752	0.758	0.765	0.771	0.777	0.784	0.781	0.775	0.768	0.761	0.753	0.744	0.736	0.727	0.719	0.710	0.702	0.694	0.685	0.677	0.669	0.662
0.200	0.697	0.703	0.709	0.715	0.721	0.727	0.733	0.736	0.735	0.733	0.729	0.725	0.719	0.714	0.708	0.702	0.695	0.689	0.682	0.676	0.669	0.663
0.251	0.634	0.639	0.644	0.649	0.654	0.659	0.671	0.678	0.682	0.683	0.682	0.680	0.678	0.674	0.670	0.666	0.661	0.656	0.651	0.646	0.640	0.635
0.316	0.564	0.568	0.572	0.576	0.580	0.584	0.599	0.608	0.613	0.616	0.617	0.616	0.616	0.614	0.611	0.608	0.605	0.601	0.597	0.593	0.588	0.584
0.398	0.489	0.492	0.495	0.498	0.501	0.504	0.519	0.528	0.534	0.538	0.540	0.540	0.540	0.539	0.537	0.535	0.532	0.529	0.526	0.523	0.519	0.516
0.501	0.412	0.414	0.416	0.418	0.420	0.423	0.435	0.444	0.449	0.452	0.454	0.455	0.455	0.454	0.453	0.451	0.449	0.447	0.445	0.442	0.440	0.437

Table G.3 (continued)

H/L_e	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5
0.100	0.174	0.164	0.154	0.144	0.135	0.126	0.118	0.110	0.102	0.094	0.087	0.079	0.072	0.065
0.126	0.217	0.203	0.190	0.177	0.165	0.153	0.141	0.130	0.119	0.108	0.098	0.088	0.078	0.068
0.158	0.244	0.228	0.213	0.199	0.185	0.171	0.158	0.145	0.132	0.120	0.108	0.096	0.084	0.073
0.200	0.257	0.241	0.225	0.210	0.196	0.182	0.168	0.154	0.141	0.128	0.115	0.103	0.091	0.079
0.251	0.258	0.242	0.228	0.213	0.199	0.185	0.172	0.158	0.146	0.133	0.120	0.108	0.096	0.085
0.316	0.249	0.235	0.221	0.208	0.195	0.182	0.170	0.158	0.146	0.134	0.123	0.112	0.101	0.090
0.398	0.231	0.219	0.207	0.196	0.185	0.174	0.163	0.152	0.142	0.132	0.122	0.113	0.103	0.094
0.501	0.207	0.197	0.187	0.178	0.169	0.160	0.151	0.143	0.134	0.126	0.118	0.110	0.102	0.095
0.631	0.178	0.170	0.163	0.156	0.149	0.142	0.135	0.129	0.123	0.116	0.110	0.104	0.098	0.093
0.794	0.145	0.140	0.135	0.130	0.125	0.121	0.116	0.111	0.107	0.103	0.098	0.094	0.090	0.086
1.000	0.112	0.108	0.105	0.102	0.099	0.096	0.093	0.090	0.087	0.085	0.082	0.079	0.077	0.074
1.259	0.079	0.077	0.075	0.073	0.071	0.069	0.068	0.066	0.064	0.063	0.061	0.059	0.058	0.056
1.585	0.048	0.046	0.045	0.043	0.042	0.041	0.040	0.038	0.037	0.036	0.035	0.034	0.033	0.032
1.995	0.021	0.019	0.017	0.015	0.013	0.012	0.010	0.008	0.007	0.005	0.003	0.002	0.000	- 0.001

Table G.4 (continued)

H/L_e	0.44	0.46	0.48	0.5
0.050	0.538	0.529	0.519	0.510
0.063	0.538	0.529	0.519	0.510
0.079	0.538	0.529	0.519	0.510
0.100	0.538	0.529	0.519	0.510
0.126	0.617	0.608	0.600	0.591
0.158	0.654	0.646	0.639	0.632
0.200	0.656	0.650	0.643	0.637
0.251	0.629	0.624	0.618	0.613
0.316	0.579	0.575	0.570	0.565
0.398	0.512	0.508	0.505	0.501
0.501	0.434	0.431	0.428	0.425

List of references (see clause 2)

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