Appendix A
Aerodynamic Coefficients

A.1 GENERAL

(1) This section presents the aerodynamic coefficients of the following structures, structural elements and components:

- Buildings (Section A.2)
- Canopy roofs (Section A.3)
- Free-standing boundary walls, fences and signboards (Section A.4)
- Structural elements with rectangular Section (Section A.5)
- Structural elements with sharp edged Section (Section A.6)
- Structural elements with regular polygonal Section (Secion A.7)
- Circular cylinders (Section A.8)
- Spheres (Section A.9)
- Lattice structures and scaffoldings (Section A.10)
- Friction coefficients (Section A.11)
- Effective slenderness and slenderness reduction factor (Section A.12)

A.2 BUILDINGS

A.2.1 General

(1) The external pressure coefficients c_{pe} for buildings and individual parts of buildings depend on the size of the loaded area A. They are given for loaded areas A of $1m^2$ and $10m^2$ in the relevant tables for the appropriate building configurations as $c_{pe.1}$ and $c_{pe.10}$ respectively. For other loaded areas the variation of the values may be obtained from fig. A.1.

Note: The loaded area is the area of the structure, which produces the wind action in the section to be calculated.

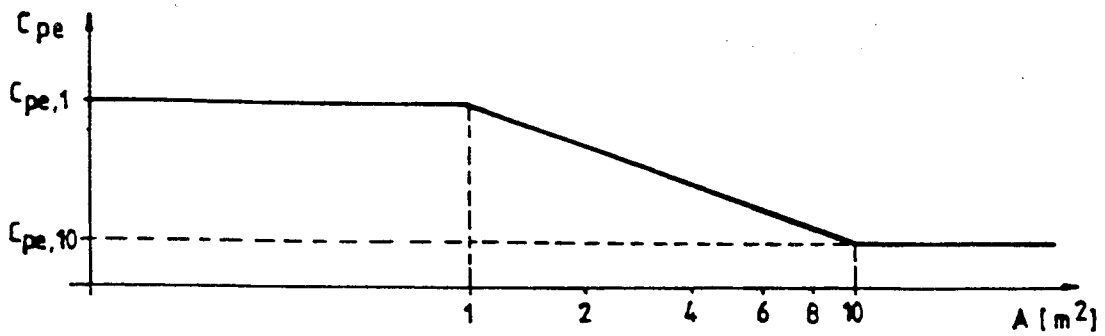

Figure A.1 Variation of External Pressure Coefficient for Buildings with Size of the Loaded Area *A*.

Note: The Figure is based on the following:

$c_{pe} = c_{pe,1}$ $\quad A \leq 1m^2$

$c_{pe} = c_{pe,1} + (c_{pe,10} - c_{pe,1})\log_{10}A$ $\quad 1m^2 < A < 10m^2$

$A \geq 10m^2$ $\quad c_{pe} = c_{pe,10}$

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(1) This section presents the aerodynamic coefficients of the following structures, structural elements and components:

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A.2 BUILDINGS

A.2.1 General

(1) The external pressure coefficients c_{pe} for buildings and individual parts of buildings depend on the size of the loaded area A. They are given for loaded areas A of $1m^2$ and $10m^2$ in the relevant tables for the appropriate building configurations as $c_{pe.1}$ and $c_{pe.10}$ respectively. For other loaded areas the variation of the values may be obtained from fig. A.1.

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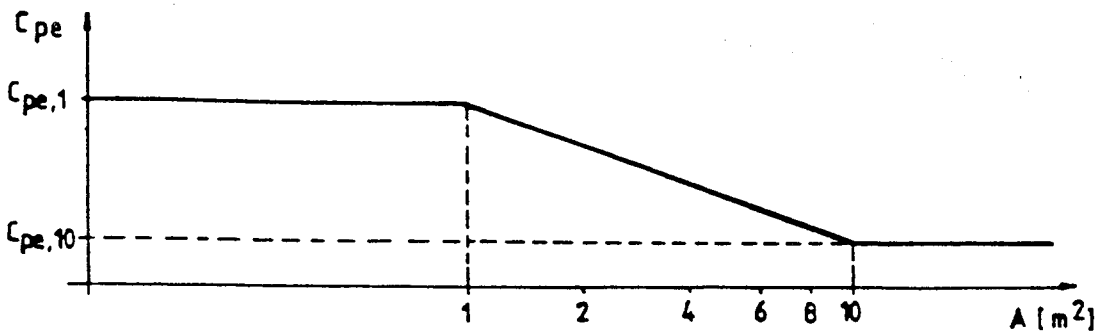


Figure A.1 Variation of External Pressure Coefficient for Buildings with Size of the Loaded Area *A*.

Note: The Figure is based on the following:

$c_{pe} = c_{pe,1}$ $\quad A \leq 1m^2$

$c_{pe} = c_{pe,1} + (c_{pe,10} - c_{pe,1})\log_{10}A$ $\quad 1m^2 < A < 10m^2$

$A \geq 10m^2$ $\quad c_{pe} = c_{pe,10}$

(2) The values $c_{pe,10}$ and $c_{pe,1}$ in Tables A.1 to A.5 are given for orthogonal wind directions 0°, 90°, 180° but represent highest values obtained in a range of wind direction $\theta = \pm 45°$ either side of the relevant orthogonal direction.

(3) These values are only applicable to buildings.

A.2.2 Vertical Walls of Rectangular Plan Buildings

(1) The reference height, z_e, for walls of rectangular plan buildings depends on the aspect ratio h/b and is given in Fig. A.2 for the following three cases.

(a) Buildings, whose height h is less than b, shall be considered to be one part.
(b) Buildings, whose height h is greater than b, but less than $2b$, shall 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.
(c) Buildings, whose height h is greater than $2b$, shall be considered to be in 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 the upper and lower parts, divided into as many horizontal strips with a maximum height of b as desired.

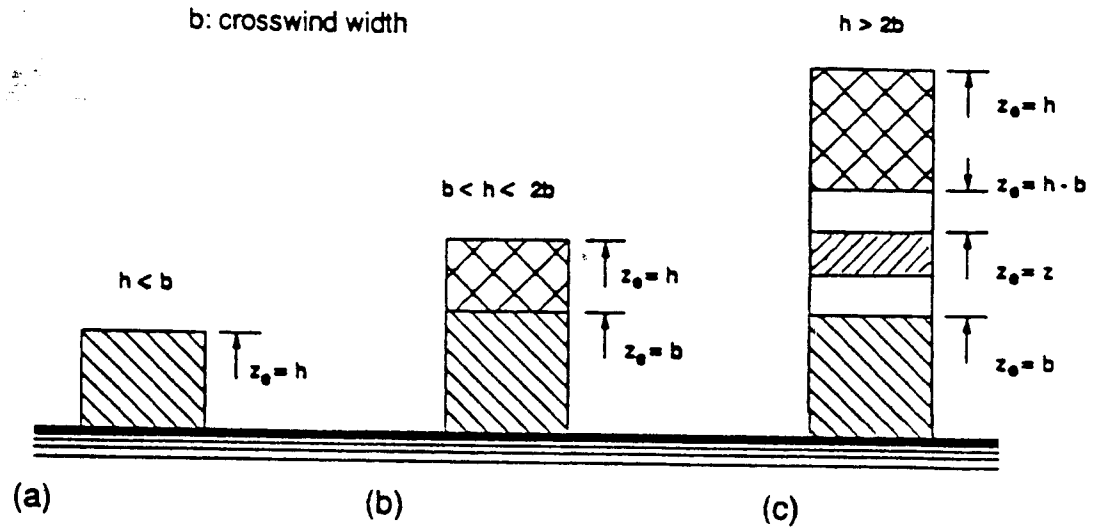


Figure A.2 Reference Height Z_e Depending on h and b.

(2) The external pressure coefficients $c_{pe.10}$ and $c_{pe,1}$ for zone *A, B, C, D,* and E defined in Fig. A.3 are given in Table A.1 depending on the ratio d/h. Intermediate values may be interpolated linearly.

(3) Friction forces should be considered only for long buildings (see Section 3.6.2).

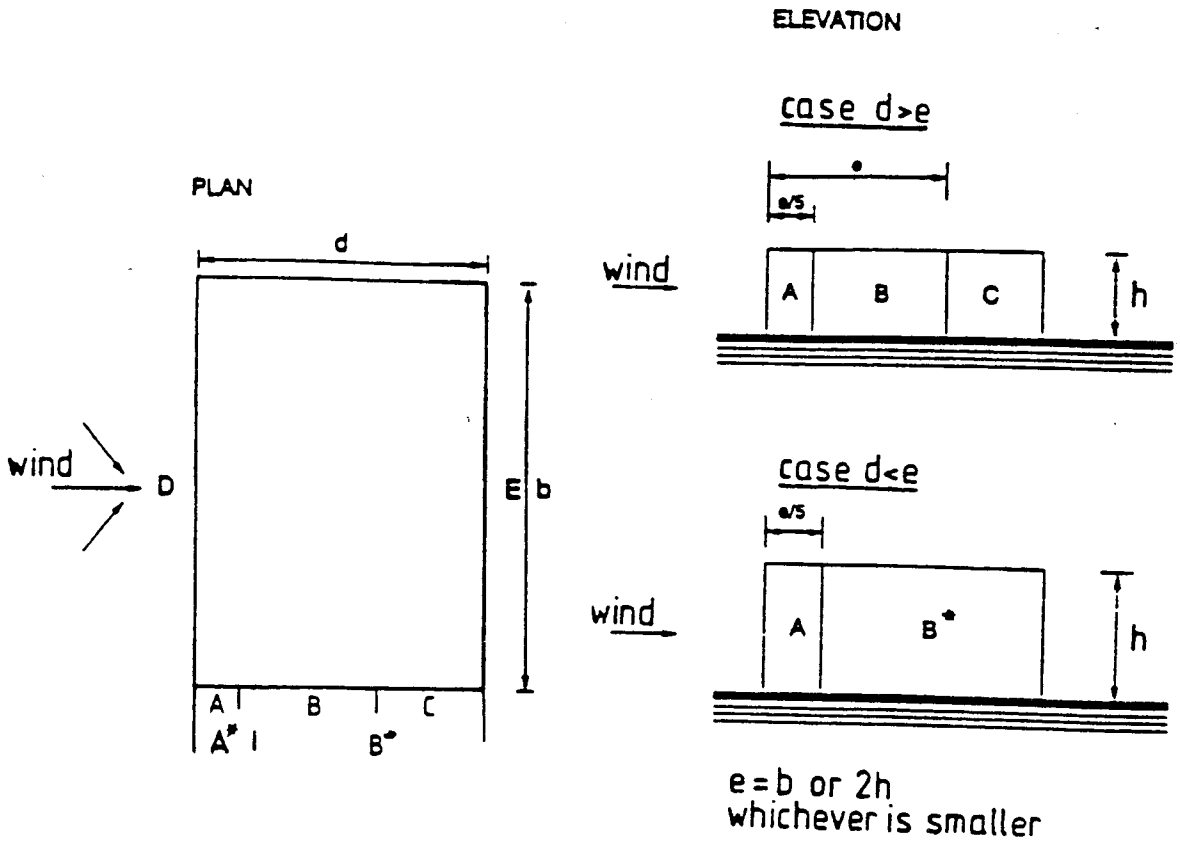


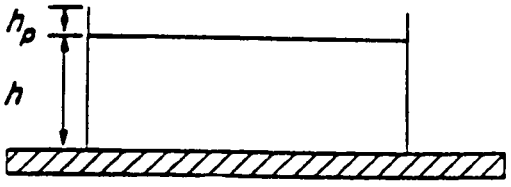
Figure A.3 Key for Vertical Walls

Table A.1 External Pressure Coefficients for Vertical Walls of Rectangular Plan Buildings

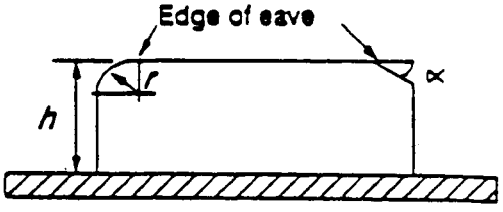
Zone	A		B,B*		C		D		E	
d/h	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
≤1	- 1.0	- 1.3	- 0.8	- 0.1	- 0.5		+0.8	+1.0	- 0.3	
≥4	- 1.0	- 1.3	- 0.8	- 0.1	- 0.5		+0.6	+1.0	- 0.3	

A.2.3 *Flat roofs*

(1) Flat roofs are defined within a slope of ±4°.
(2) The roof should be divided into zones as shown in Fig. A.4
(3) The reference height z_e should be taken as h.
(4) Pressure coefficients for each zone are given in Table A.2.
(5) For long roofs friction forces should be considered (see Section 3.6.2).



Parapets



Curved and mansard eaves

reference height :
$z_e = h$

e = b or 2h
whichever is smaller

b : crosswind dimension

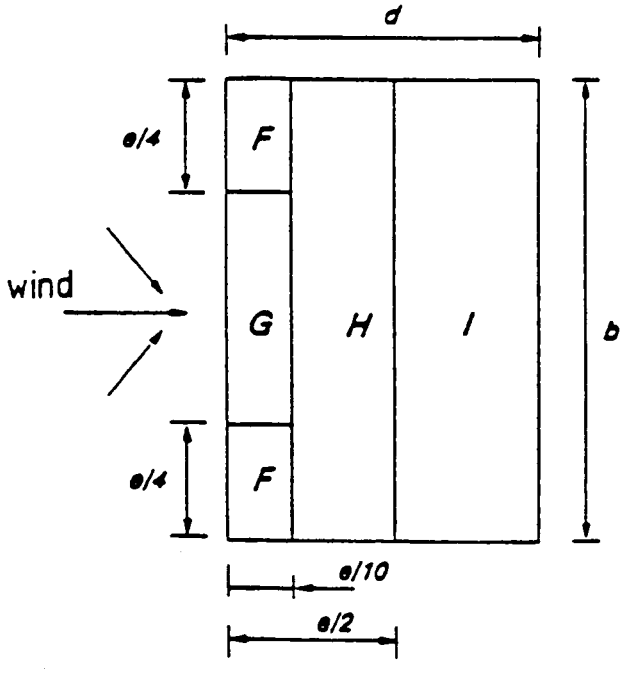


Figure A.4 Key for Flat Roofs

Table A.2 External Pressure Coefficients for flat roofs

		Zone							
		F		G		H			I
		$C_{pe.10}$	$C_{pe.1}$	$C_{pe.10}$	$C_{pe.1}$	$C_{pe.10}$	$C_{pe.1}$	$C_{pe.10}$	$C_{pe.1}$
Sharp eaves		- 1.8	- 2.5	- 1.2	- 2.0	- 0.7	- 1.2	± 0.2	
with parapets	H_p/h = 0.025	- 1.6	- 2.2	- 1.1	- 1.8	- 0.7	- 1.2	± 0.2	
	H_p/h = 0.05	- 1.4	- 2.0	- 0.9	- 1.6	- 0.7	- 1.2	± 0.2	
	H_p/h = 0.10	- 1.2	- 1.8	- 0.8	- 1.4	- 0.7	- 1.2	± 0.2	
Curved eaves	r/h = 0.05	- 1.0	- 1.5	- 1.2	- 1.8	- 0.4		± 0.2	
	r/h = 0.10	- 0.7	- 1.2	- 0.8	- 1.4	- 0.3		± 0.2	
	r/h = 0.20	- 0.5	- 0.8	- 0.5	- 0.8	- 0.3		± 0.2	
mansard eaves	α = 30°	- 1.0	- 1.5	- 1.0	- 1.5	- 0.3		± 0.2	
	α = 45°	- 1.2	- 1.8	- 1.3	- 1.9	- 0.4		± 0.2	
	α = 60°	- 1.3	- 1.9	- 1.3	- 1.9	- 0.5		± 0.2	

Notes: (i) For roofs with parapets or curved eaves, linear interpolation may be used for intermediate values of h_p/h and r/h.

(ii) For roofs with mansard eaves, linear interpolation between α = 30°, α = 45°, α = 60°, may be used. For α > 60° linearly interpolate between the values for α = 60° and the values for flat roofs with sharp eaves.

(iii) In Zone I, where positive and negative values are given, both values shall be considered.

(iv) For the mansard eave itself, the external pressure coefficients are given in Table 3.2.4 "External pressure coefficients for duopitch roofs: wind direction 0" Zone F and G, depending on the pitch angle of the mansard eave.

(V) For the curved eave itself, the external pressure coefficients are given by linear interpolation along the curve, between values on the wall and on the roof.

A.2.4 Monopitch Roofs

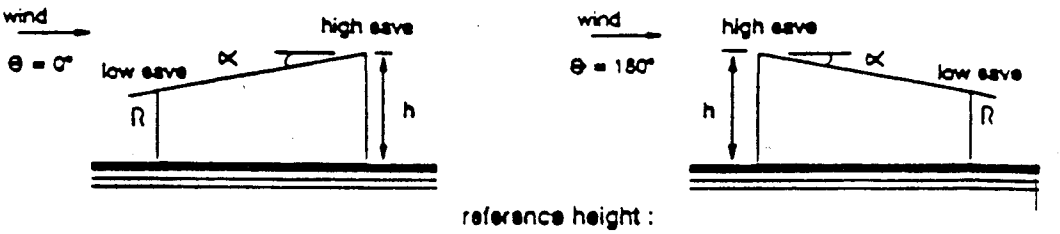
(1) The roof should be divided into zones as shown in Fig. A.5

(2) The reference height z_e should be taken as h.

(3) Pressure coefficients for each zone are given in Table A.3

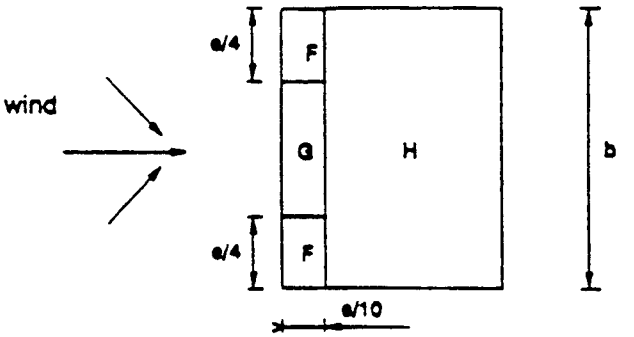
(4) For long roofs friction forces should be considered (see Section 3.6.2).

(5) For elongated roof corners (see Fig. A.5) the zone R is under the same pressure as the corresponding vertical wall. This rule is also applicable for roofs of other types.



(a) general

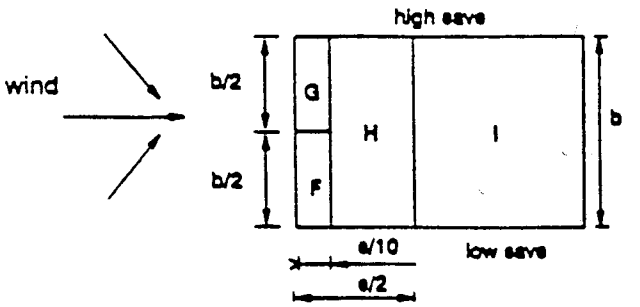
reference height :
$z_e = h$



(b) wind directions θ = 0° and θ = 180°

e = b or 2h
whichever is smaller

b : crosswind dimension



(c) wind direction θ = 90°

Figure A.5 Key for Monopitch Roofs

Table A.3 External Pressure Coefficients for Monopitch Roofs

	Zone for wind direction θ = 0°						Zone for wind direction θ = 180°					
Pitch	F		G		H		F		G		H	
angle a	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$
5°	- 1.7	- 2.5	- 1.2	- 2.0	- 0.6	-1.2	- 2.3	- 2.5	- 1.3	-2.0	-0,8	- 1,2
15°	- 0.9	- 2.0	- 0.8	- 1.5	- 0.3		- 2.5	- 2.8	- 1.3	- 2.0	-0.9	- 1.2
	+ 0.2		+ 0.2		+ 0.2							
30°	- 0.5	- 1,5	- 0.5	- 1,5	- 0.2		- 1.1	- 2.3	- 0.8	- 1.5	- 0.8	
	+ 0.7		+ 0.7		+ 0.4							
45°	+ 0.7		+ 0.7		+ 0.6		- 0.6	- 1.3	- 0.5		- 0.7	
60°	+ 0.7		+ 0.7		+ 0.7		- 0.5	- 1.0	- 0.5		- 0.5	
75°	+ 0.8		+ 0.8		+ 0.8		- 0.5	- 1.0	- 0.5		- 0.5	

	Zone for wind direction θ = 90°							
Pitch	F		G		H		I	
angle a	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$
5°	- 1.6	- 2.2	- 1.8	- 2.0	- 0.6	- 1.2	0.5	
15°	- 1.3	- 2.0	- 1.9	- 2.5	- 0.8	- 1.2	- 0,7	- 1.2
30°	- 1.2	- 2.0	- 1.5	- 2.0	- 1.0	- 1.3	- 0,8	- 1.2
45°	- 1.2	- 2.0	- 1.4	- 2.0	- 1.0	- 1.3	- 0,9	- 1.2
60°	- 1.2	- 2.0	- 1.2	- 2.0	- 1.0	- 1.3	- 0,7	- 1.2
75°	- 1.2	- 2.0	- 1.2	- 2.0	- 1.0	- 1.3	- 0.5	

Note: (i) At θ = 0° the pressure changes rapidly between positive and negative values around a pitch angle of 1 = +15° to + 30°, so both positive and negative values are given.

(ii) Linear interpolation for intermediate pitch angles may be used between values of same sign.

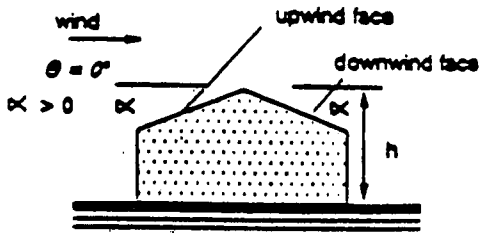
A.2.5 Duopitch Roofs

(1) The roof should be divided into zones as shown in Fig. A.6

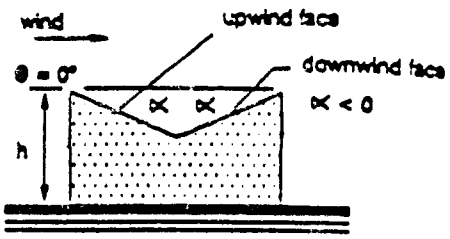
(2) The reference height z_e should be taken as h.

(3) The pressure coefficients for each zone are given in Table A.4

(4) For long roofs friction forces should be considered (see Section 3.6.2)

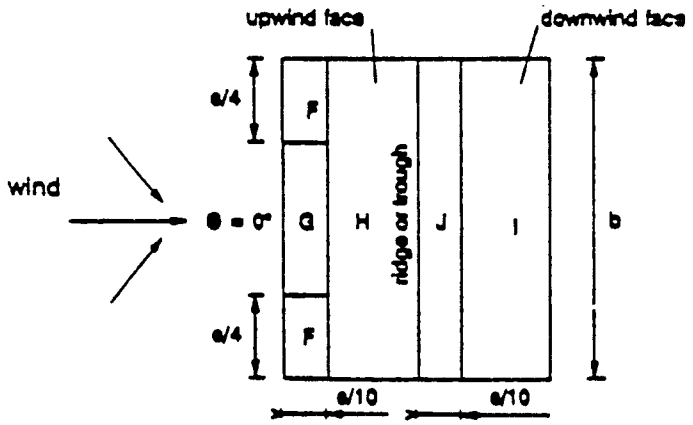


Pitch angle positive



Pitch angle negative

(a) general

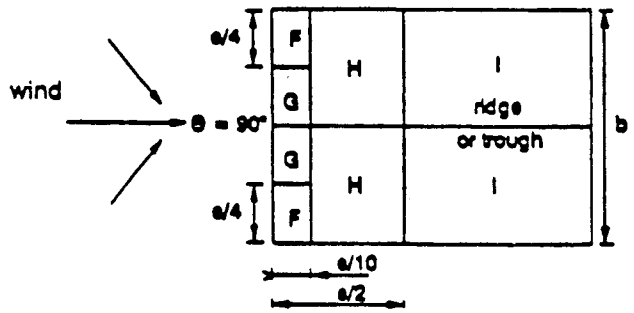


(b) wind direction θ = 0°

reference height :
$z_e = h$

e = b or 2h
whichever is smaller

b : crosswind dimension



(c) wind direction θ = 90°

Figure A.6 Key for Duopitch Roofs

Table A.4 External Pressure Coefficients for Duopitch Roofs

	Zone for wind direction $\theta = 0^\circ$									
Pitch	F		G		H		I		J	
angle α	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$
-45°	- 0.6		- 0.6		- 0.8		- 0.7		- 1.0	- 1.5
-30°	- 1.1	- 2.0	- 0.8	- 1.5	- 0.8		- 0.6		- 0.8	- 1.4
-15°	- 2.5	- 2.8	- 1.3	- 2.0	- 0.9	- 1,2	- 0.5		- 0.7	- 1.2
-5°	- 2.3	- 2.5	- 1.2	- 2.0	- 0.8	- 1,2	- 0.3		- 0.3	
5°	- 1.7	- 2.5	- 1.2	- 2.0	- 0.6	- 1,2	- 0.3		- 0.3	
15°	- 0.9	- 2.0	- 0.8	- 1.5	- 0.3		- 0.4		- 1.0	- 1.5
	+ 0.2		+ 0.2		+ 0.2					
30°	- 0.5	- 1.5	- 0.5	- 1.5	- 0.2		- 0.4		- 0.5	
	+ 0.7		+ 0.7		+ 0.4					
45°	+ 0.7		+ 0.7		+ 0.6		- 0.2		- 0.3	
60°	+ 0.7		+ 0.7		+ 0.7		- 0.2		- 0.3	
75°	+ 0.8		+ 0.8		+ 0.8		- 0.2		- 0.3	

	Zone for wind direction $\theta = 90^\circ$							
	F		G		H		I	
	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$
-45°	-.1.4	- 2.0	- 1.2	- 2.0	- 1.0	- 1.3	- 0.9	-1.2
-30°	- 1.5	- 2.1	- 1.2	- 2.0	- 1.0	- 1.3	- 0.9	-1.2
-15°	- 1.9	- 2.5	- 1.2	- 2.0	- 0.8	- 1.2	- 0.8	-1.2
-5°	- 1.8	- 2.5	- 1.2	- 2.0	- 0.7	- 1.2	- 0.6	-1.2
5°	- 1.6	- 2.2	- 1.3	- 2.0	- 0.7	- 1.2	- 0.5	
15°	- 1.3	- 2.0	- 1.3	- 2.0	- 0.6	- 1.2	- 0.5	
30°	- 1.1	- 1.5	- 1.4	- 2.0	- 0.8	- 1.2	- 0.5	
45°	- 1.1	- 1.5	- 1.4	- 2.0	- 0.9	- 1.2	- 0.5	
60°	- 1.1	- 1.5	- 1.2	- 2.0	- 0.8	- 1.0	- 0.5	
75°	- 1.1	- 1.5	- 1.2	- 2.0	- 0.8	- 1.0	- 0.5	

Notes: (i) At $\theta = 0^\circ$ the pressure changes rapidly between positive and negative values on the windward face around a pitch angle of 1 = +15° to + 30°, so both positive and negative values are given.

(ii) Linear 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 $\alpha = -5^\circ$, but use the data for flat roofs in Section A.6.

A.2.6 Hipped Roofs

(1) The roof should be divided into zones as shown in Fig. A.7.

(2) The reference height z_e should be taken as h.

(3) The pressure coefficients are given in Table A.5.

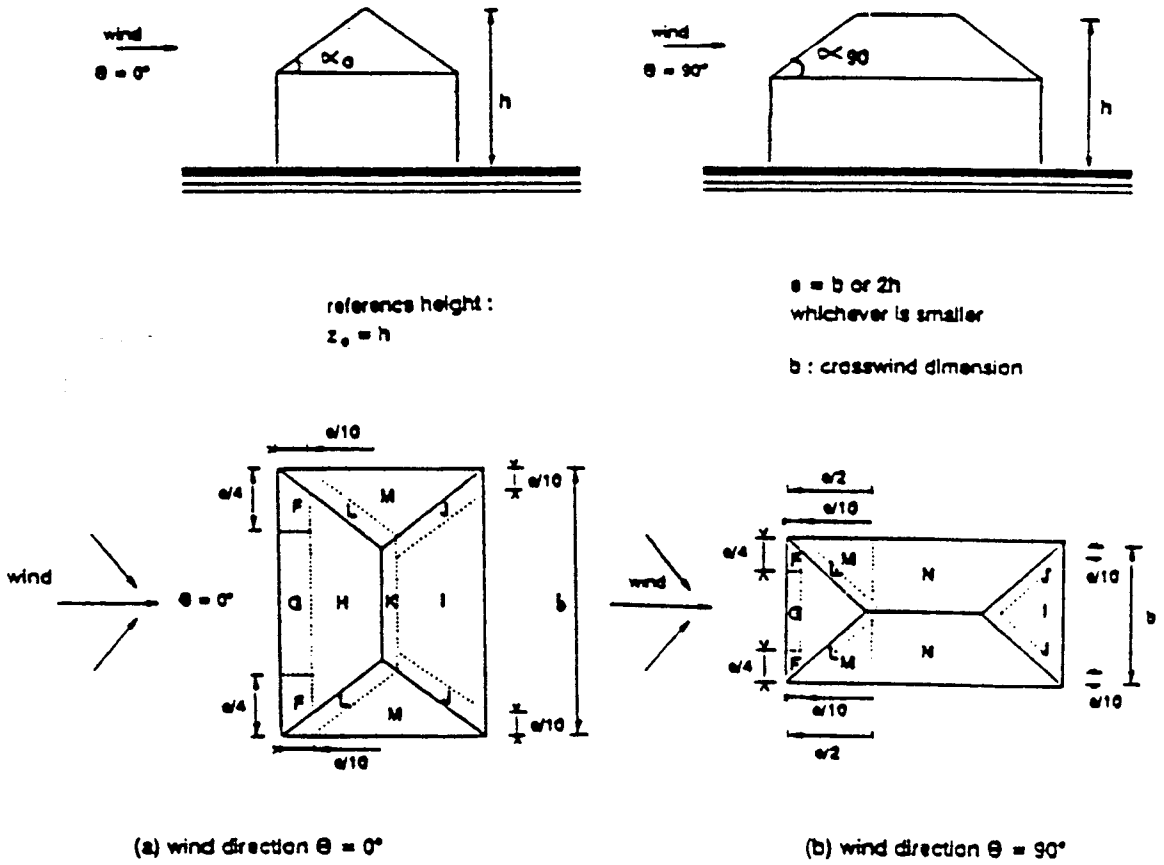


Figure A.7 Key for Hipped Roofs

A.2.7 Multispan Roofs

(1) Pressure coefficients for each span of multispan roofs should be derived from Section A.2.4 for monopitch roofs modified for their position according to Fig. A.8.

(2) The reference height z_e should be taken as h.

(3) For long roofs friction forces should be considered (see Section 3.6.2).

Table A.5 External Pressure Coefficients for Hipped Roofs of Buildings

Pitch angle	Zone for wind direction $\theta = 90°$																	
α_o = for $\theta = 0$			*G*		*H*		*I*		*J*		*K*		*L*		*M*		*N*	
α_{90} for $\theta = 90°$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$	$C_{pe,10}$	$C_{pe,1}$
5°	-1.7	-2.5	-1.2	-2.0	-0.6	-1.2	-0.3		-0.6		0.6		-1.2	-2.0	-0.6	-1.2	-0.4	
+ 15°	-0.9	-2.0	-0.8	1.5	-0.3		-0.5		-1.0	-1.5	-1.2	-2.0	-1.4	-2.0	-0.6	1.2	-0.3	
	+0.2		+0.2		+0.2													
+ 30°	+0.5	-1.5	-0.5	-1.5	-0.2		-0.4		-0.7	-1.2	-0.5		-1.4	-2.0	-0.8	-1.2	-0.2	
	+0.5		+0.7		+0.4													
+ 45°	+0.7		+0.7		+0.6		-0.3		0.6		-0.3		-1.3	-2.0	-0.8	-1.2	-0.2	
+ 60°	+0.7		+0.7		+0.7		-0.3		-0.6		-0.3		-1.2	-2.0	-0.4		-0.2	
+ 75°	+0.8		+0.8		+0.8		-0.3		-0.6		-0.3		-1.2	-2.0	-0.4		-0.2	

Notes: (i) At $\theta = 0°$ the pressure changes rapidly between positive and negative values on the windward face at pitch angle of 1 = 15° to +30°, so both positive and negative values are given.

(ii) Linear interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. (do not interpolate between $\alpha = +5°$ and $\alpha = -5°$, but use the data for flat roofs in A.3.

(iii) The pitch angle of the windward face always will govern the pressure coefficients.

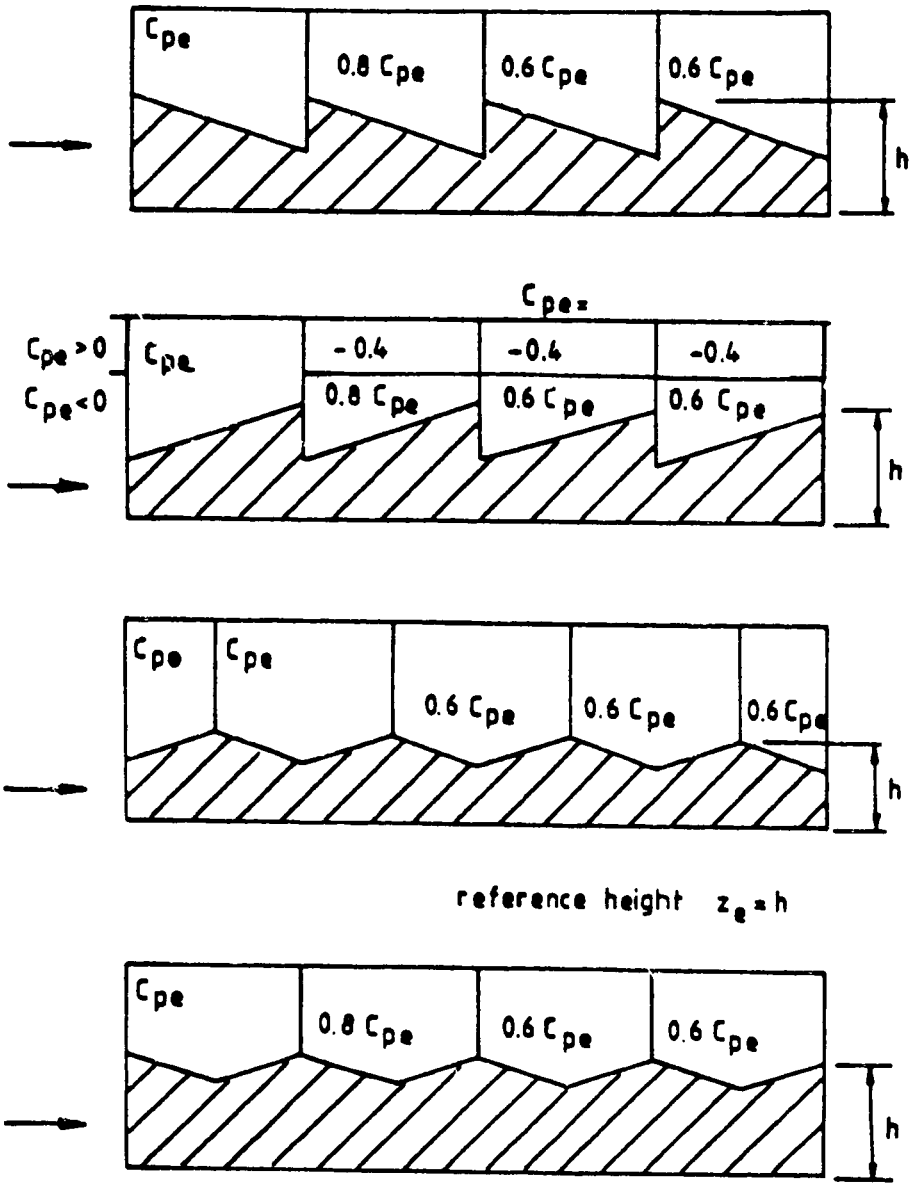


Figure A.8 Key to Multispan Roofs

A.2.8 Vaulted Roofs and Domes

(1) This section applies to circular cylindrical roofs and domes.

(2) The roof should be divided into zones as shown in Figs. A.9 and A.10.

(3) The reference height should be taken as:

$$z_e = h + f/2 \qquad \text{(A.1)}$$

(4) The pressure coefficients are given in Fig. A.9 and Fig. A.10.

(5) Pressure coefficients for the walls should be taken from A.2.2.