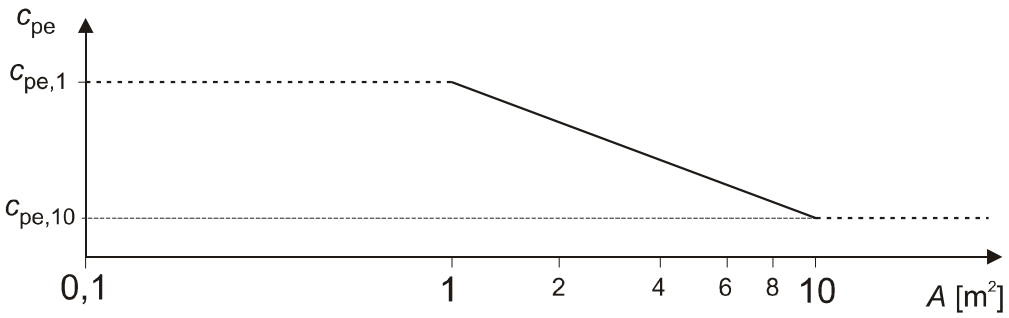
7.2 Pressure coefficients for buildings

7.2.1 General

(1) The external pressure coefficients c_{pe} for buildings and parts of buildings depend on the size of the loaded area A, which is the area of the structure, that produces the wind action in the section to be calculated. The external pressure coefficients are given for loaded areas A of 1 m^2 and 10 m^2 in the tables for the appropriate building configurations as $c_{pe,1}$, for local coefficients, and $c_{pe,10}$, for overall coefficients, respectively.

NOTE 1 Values for $c_{pe,1}$ are intended for the design of small elements and fixings with an area per element of 1 m^2 or less such as cladding elements and roofing elements. Values for $c_{pe,10}$ may be used for the design of the overall load bearing structure of buildings.

NOTE 2 The National Annex may give a procedure for calculating external pressure coefficients for loaded areas above 1 m^2 based on external pressure coefficients $c_{pe,1}$ and $c_{pe,10}$. The recommended procedure for loaded areas up to 10 m^2 is given in Figure 7.2.



The figure is based on the following:
for 1 $m^2 < A < 10$ m^2 $\quad c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10}) \log_{10} A$

Figure 7.2 — Recommended procedure for determining the external pressure coefficient c_{pe} for buildings with a loaded area A between 1 m^2 and 10 m^2

(2) The values $c_{pe,10}$ and $c_{pe,1}$ in Tables 7.2 to 7.5 should be used for the orthogonal wind directions 0°, 90°, 180°. These values represent the most unfavourable values obtained in a range of wind direction $\Theta = \pm 45°$ either side of the relevant orthogonal direction.

(3) For protruding roof corners the pressure on the underside of the roof overhang is equal to the pressure for the zone of the vertical wall directly connected to the protruding roof; the pressure at the top side of the roof overhang is equal to the pressure of the zone, defined for the roof.

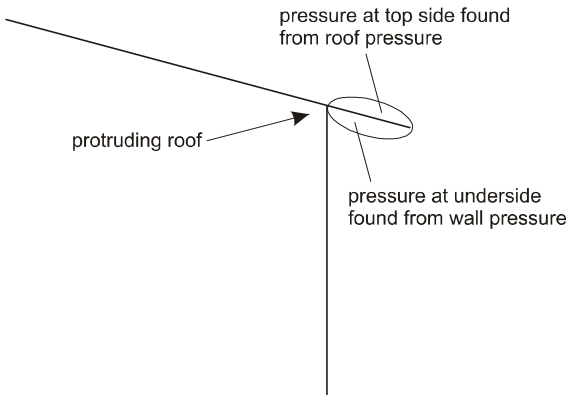


Figure 7.3 — Illustration of relevant pressures for protruding roofs

7.2.2 Vertical walls of rectangular plan buildings

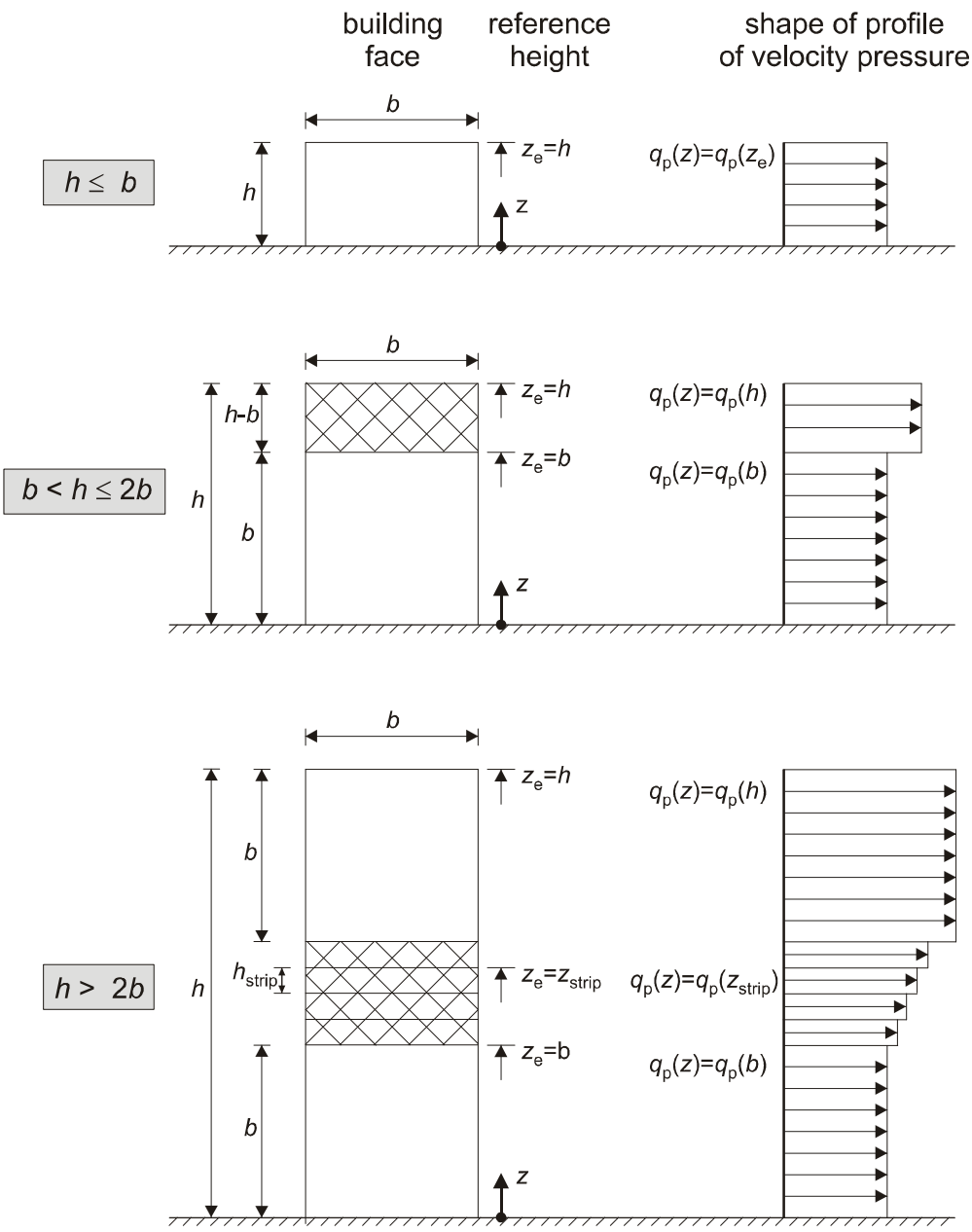
(1) The reference heights, z_e, for windward walls of rectangular plan buildings (zone D, see Figure 7.5) depend on the aspect ratio h/b and are always the upper heights of the different parts of the walls. They are given in Figure 7.4 for the following three cases:

– A building, whose height h is less than b should be considered to be one part.

– A building, whose height h is greater than b, but less than $2b$, may 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 consisting of the remainder.

– A building, whose height h is greater than $2b$ may 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, which may be divided into horizontal strips with a height h_{strip} as shown in Figure 7.4.

NOTE The rules for the velocity pressure distribution for leeward wall and sidewalls (zones A, B, C and E, see Figure 7.5) may be given in the National Annex or be defined for the individual project. The recommended procedure is to take the reference height as the height of the building.



NOTE The velocity pressure should be assumed to be uniform over each horizontal strip considered.

Figure 7.4 — Reference height, z_e, depending on *h* and *b*, and corresponding velocity pressure profile

(2) The external pressure coefficients $c_{pe,10}$ and $c_{pe,1}$ for zone A, B, C, D and E are defined in Figure 7.5.

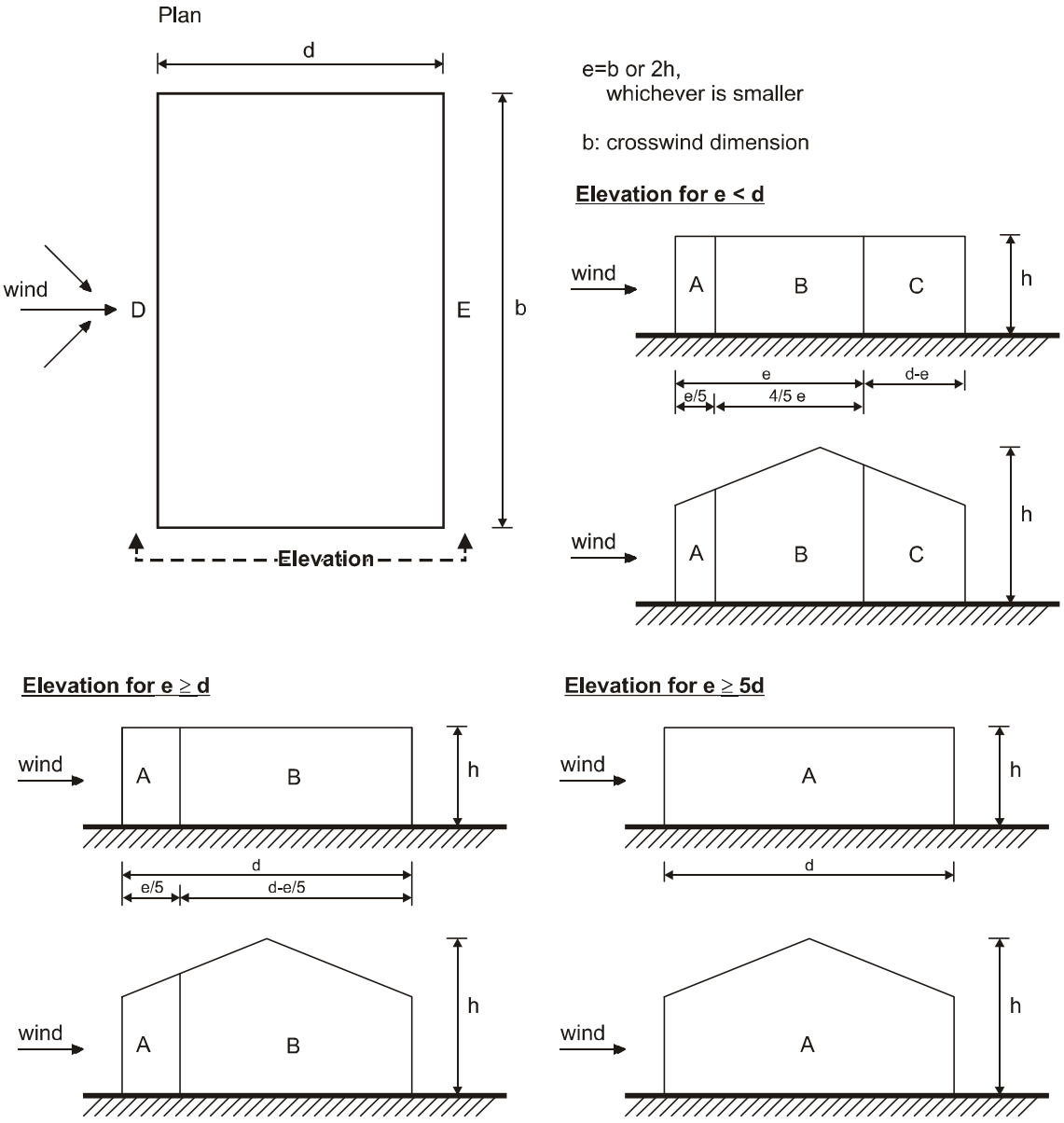


Figure 7.5 — Key for vertical walls

NOTE 1 The values of $c_{pe,10}$ and $c_{pe,1}$ may be given in the National Annex. The recommended values are given in Table 7.1, depending on the ratio h/d. For intermediate values of h/d, linear interpolation may be applied. The values of Table 7.1 also apply to walls of buildings with inclined roofs, such as duopitch and monopitch roofs.

Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

NOTE 2 For buildings with $h/d > 5$, the total wind loading may be based on the provisions given in Sections 7.6 to 7.8 and 7.9.2.

(3) In cases where the wind force on building structures is determined by application of the pressure coefficients c_{pe} on windward and leeward side (zones D and E) of the building simultaneously, the lack of correlation of wind pressures between the windward and leeward side may have to be taken into account.

NOTE The lack of correlation of wind pressures between the windward and leeward side may be considered as follows. For buildings with $h/d \geq 5$ the resulting force is multiplied by 1. For buildings with $h/d \leq 1$, the resulting force is multiplied by 0,85. For intermediate values of h/d, linear interpolation may be applied.

7.2.3 Flat roofs

(1) Flat roofs are defined as having a slope (α) of $-5° < \alpha < 5°$

(2) The roof should be divided into zones as shown in Figure 7.6.

(3) The reference height for flat roof and roofs with curved or mansard eaves should be taken as h. The reference height for flat roofs with parapets should be taken as $h + h_p$, see Figure 7.6.

(4) Pressure coefficients for each zone are given in Table 7.2.

(5) The resulting pressure coefficient on the parapet should be determined using 7.4.

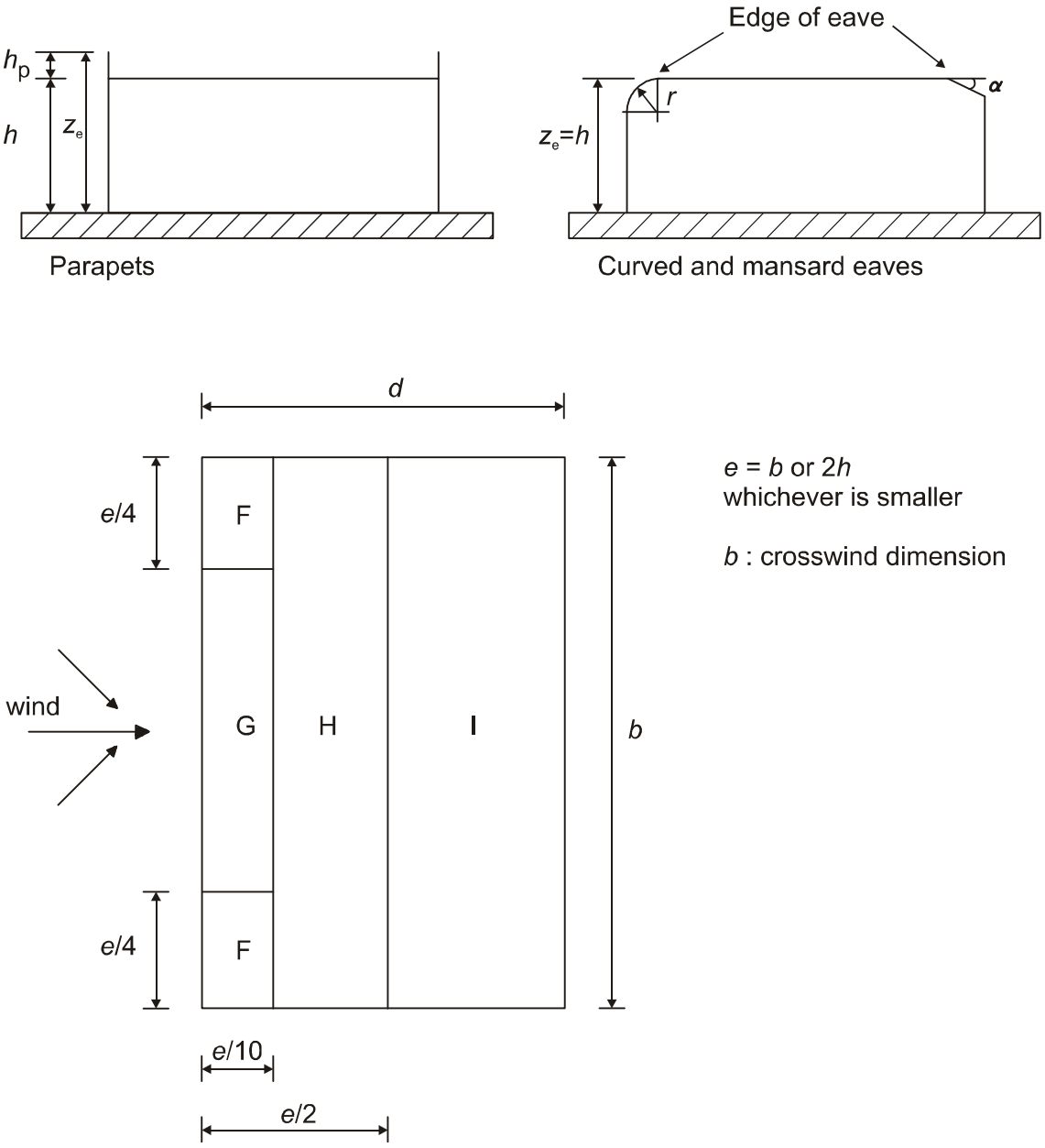


Figure 7.6 — Key for flat roofs

Table 7.2 — External pressure coefficients for flat roofs

Roof type		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	
								-0,2	
With Parapets	h_p/h=0,025	-1,6	-2,2	-1,1	-1,8	-0,7	-1,2	+0,2	
								-0,2	
	h_p/h=0,05	-1,4	-2,0	-0,9	-1,6	-0,7	-1,2	+0,2	
								-0,2	
	h_p/h=0,10	-1,2	-1,8	-0,8	-1,4	-0,7	-1,2	+0,2	
								-0,2	
Curved Eaves	r/h = 0,05	-1,0	-1,5	-1,2	-1,8	-0,4		+0,2	
								-0,2	
	r/h = 0,10	-0,7	-1,2	-0,8	-1,4	-0,3		+0,2	
								-0,2	
	r/h = 0,20	-0,5	-0,8	-0,5	-0,8	-0,3		+0,2	
								-0,2	
Mansard Eaves	α = 30°	-1,0	-1,5	-1,0	-1,5	-0,3		+0,2	
								-0,2	
	α = 45°	-1,2	-1,8	-1,3	-1,9	-0,4		+0,2	
								-0,2	
	α = 60°	-1,3	-1,9	-1,3	-1,9	-0,5		+0,2	
								-0,2	

NOTE 1 For roofs with parapets or curved eaves, linear interpolation may be used for intermediate values of h_p/h and r/h.

NOTE 2 For roofs with mansard eaves, linear interpolation between α = 30°, 45° and α = 60° may be used. For α > 60° linear interpolation between the values for α = 60° and the values for flat roofs with sharp eaves may be used.

NOTE 3 In Zone I, where positive and negative values are given, both values shall be considered.

NOTE 4 For the mansard eave itself, the external pressure coefficients are given in Table 7.4 "External pressure coefficients for duopitch roofs: wind direction 0° ", Zone F and G, depending on the pitch angle of the mansard eave.

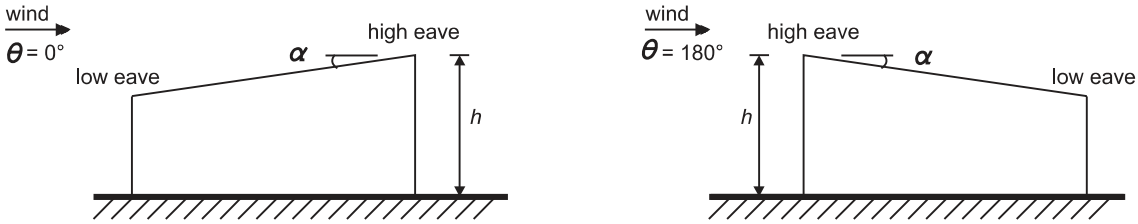
NOTE 5 For the curved eave itself, the external pressure coefficients are given by linear interpolation along the curve, between values on the wall and on the roof.

7.2.4 Monopitch roofs

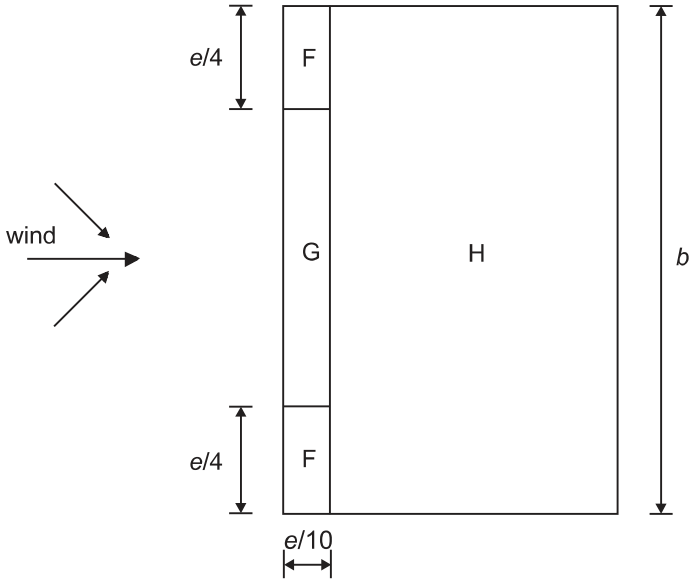
(1) The roof, including protruding parts, should be divided into zones as shown in Figure 7.7.

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

(3) The pressure coefficients for each zone that should be used are given in Table 7.3.



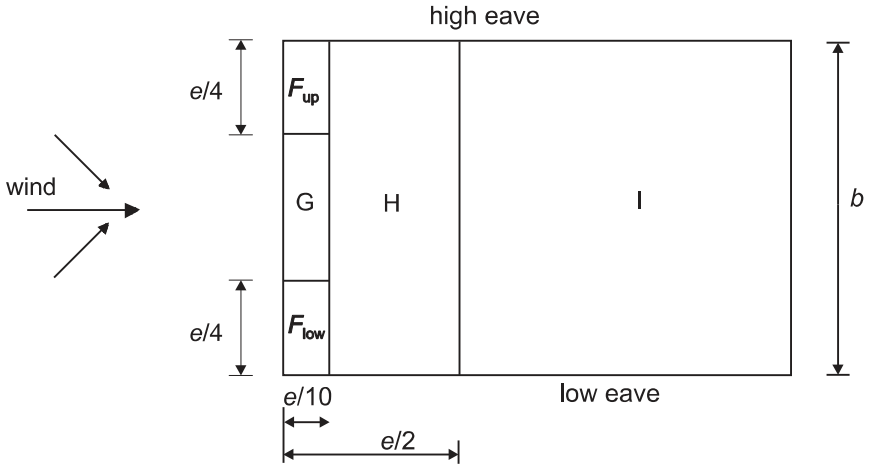
(a) general



(b) wind directions $\theta = 0°$ and $\theta = 180°$

$e = b$ or $2h$
whichever is smaller

b : crosswind dimension



(c) wind direction $\theta = 90°$

Figure 7.7 — Key for monopitch roofs

Table 7.3a — External pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction Θ = 0°						Zone for wind direction Θ = 180°					
	F		G		H		F		G		H	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
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
	+0,0		+0,0		+0,0							
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°	-0,0		-0,0		-0,0		-0,6	-1,3	-0,5		-0,7	
	+0,7		+0,7		+0,6							
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	

Table 7.3b — External pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction Θ = 90°									
	F_{up}		F_{low}		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-2,1	-2,6	-2,1	-2,4	-1,8	-2,0	-0,6	-1,2	-0,5	
15°	-2,4	-2,9	-1,6	-2,4	-1,9	-2,5	-0,8	-1,2	-0,7	-1,2
30°	-2,1	-2,9	-1,3	-2,0	-1,5	-2,0	-1,0	-1,3	-0,8	-1,2
45°	-1,5	-2,4	-1,3	-2,0	-1,4	-2,0	-1,0	-1,3	-0,9	-1,2
60°	-1,2	-2,0	-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	-1,2	-2,0	-1,0	-1,3	-0,5	

NOTE 1 At Θ = 0° (see table a)) the pressure changes rapidly between positive and negative values around a pitch angle of α = +5° to +45°, so both positive and negative values are given. For those roofs, two cases should be considered: one with all positive values, and one with all negative values. No mixing of positive and negative values is allowed on the same face.

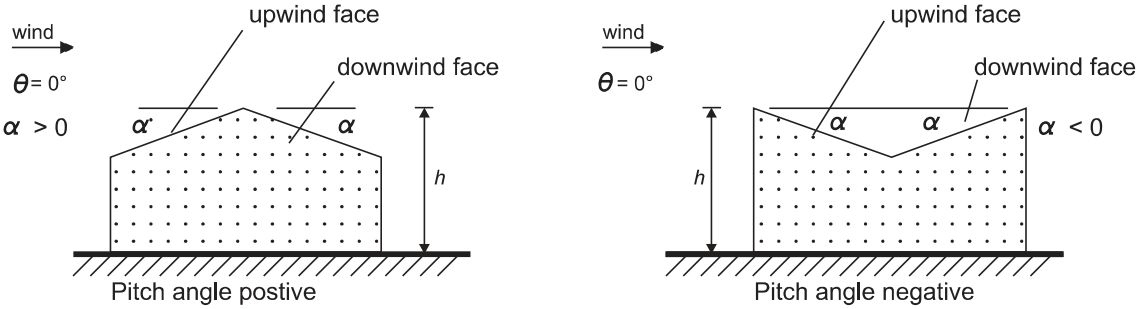
NOTE 2 Linear interpolation for intermediate pitch angles may be used between values of the same sign. The values equal to 0.0 are given for interpolation purposes

7.2.5 Duopitch roofs

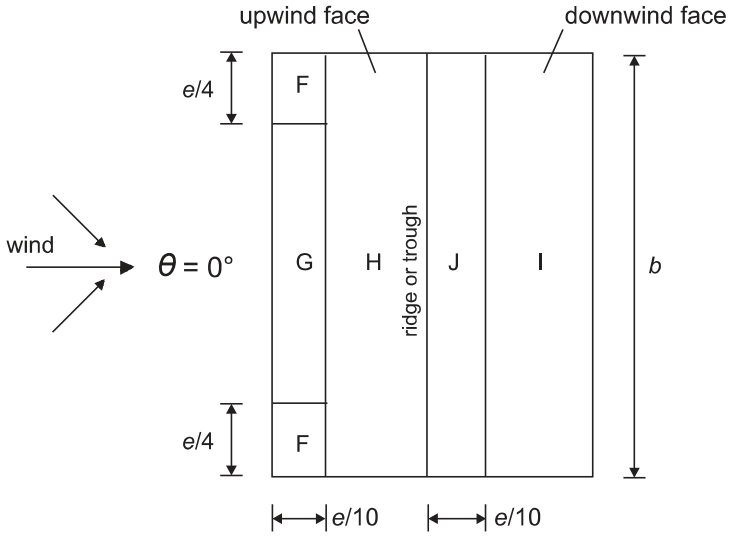
(1) The roof, including protruding parts, should be divided in zones as shown in Figure 7.8.

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

(3) The pressure coefficients for each zone that should be used are given in Table 7.4.



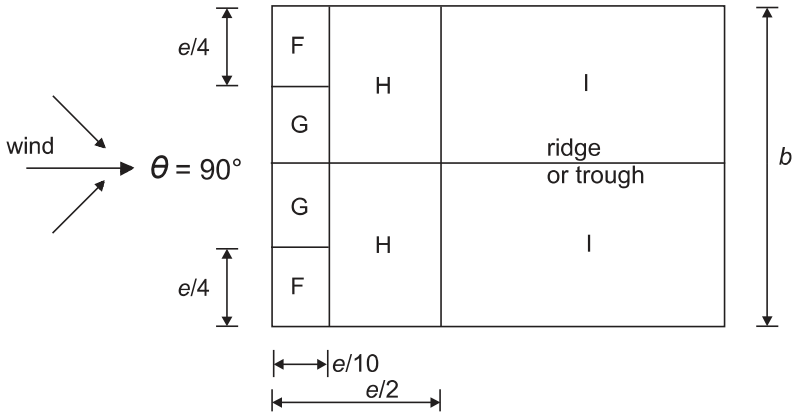
(a) general



(b) wind direction $\theta = 0°$

$e = b$ or $2h$
whichever is smaller

b : crosswind dimension



(c) wind direction $\theta = 90°$

Figure 7.8 — Key for duopitch roofs

Table 7.4a — External pressure coefficients for duopitch roofs

Pitch Angle α	Zone for wind direction Θ = 0°									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-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	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

NOTE 1 At Θ = 0° the pressure changes rapidly between positive and negative values on the windward face around a pitch angle of α = -5° to +45°, so both positive and negative values are given. For those roofs, four cases should be considered where the largest or smallest values of all areas F, G and H are combined with the largest or smallest values in areas I and J. No mixing of positive and negative values is allowed on the same face.

NOTE 2 Linear interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. (Do not interpolate between α = +5° and α = -5°, but use the data for flat roofs in 7.2.3). The values equal to 0,0 are given for interpolation purposes

Table 7.4b — External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction θ = 90°							
	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	-0,6	
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	

7.2.6 Hipped roofs

(1) The roof, including protruding parts, should be divided into zones as shown in Figure 7.9.

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

(3) The pressure coefficients that should be used are given in Table 7.5.

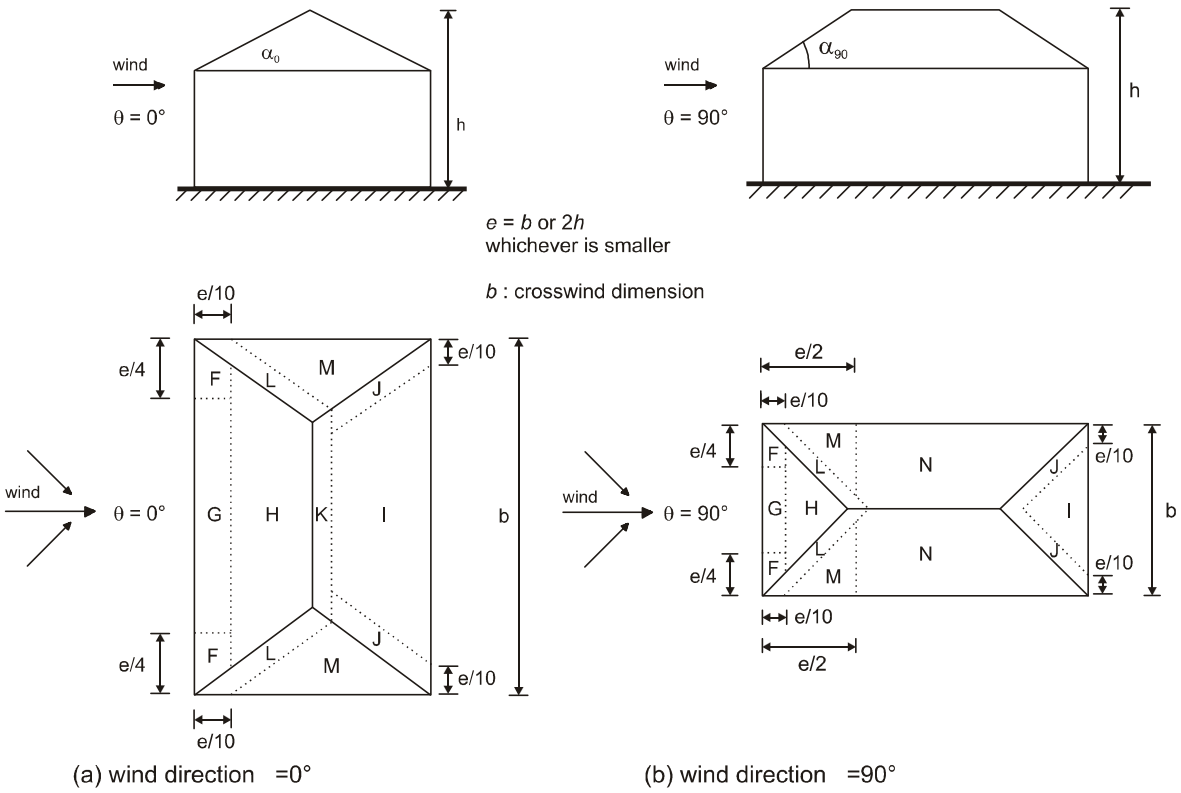


Figure 7.9 — Key for hipped roofs

Table 7.5 — External pressure coefficients for hipped roofs of buildings

Pitch angle	Zone for wind direction Θ= 0° and Θ= 90°																	
α_0 for Θ=0°	F		G		H		I		J		K		L		M		N	
α_{90} for Θ=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	
	+0,0		+0,0		+0,0													
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°	-0,0		-0,0		-0,0		-0,3		-0,6		-0,3		-1,3	-2,0	-0,8	-1,2	-0,2	
	+0,7		+0,7		+0,6													
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	

NOTE 1 At Θ = 0° the pressures changes rapidly between positive and negative values on the windward face at pitch angle of α = +5° to +45°, so both positive and negative values are given. For those roofs, two cases should be considered: one with all positive values, and one with all negative values. No mixing of positive and negative values are allowed.

NOTE 2 Linear interpolation for intermediate pitch angles of the same sign may be used between values of the same sign. The values equal to 0,0 are given for interpolation purposes

NOTE 3 The pitch angle of the windward face always will govern the pressure coefficients.

7.2.7 Multispan roofs

(1) Pressure coefficients for wind directions 0°, 90° and 180° for each span of a multispan roof may be derived from the pressure coefficient for each individual span.

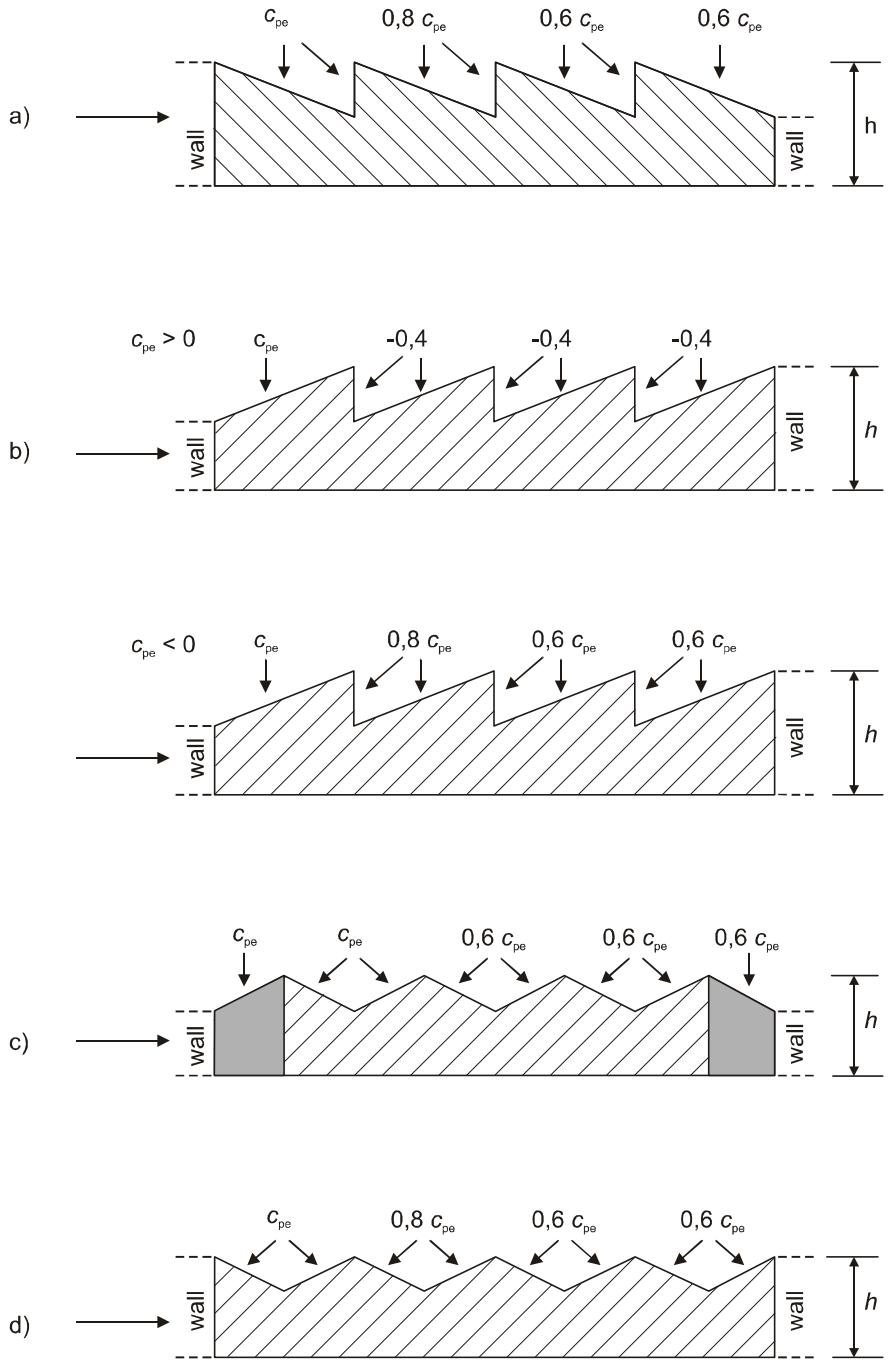
Modifying factors for the pressures (local and global) for wind directions 0° and 180° on each span should be derived:

– from 7.2.4 for monopitch roofs, modified for their position according to Figure 7.10 a and b.

– from 7.2.5 for duopitch roofs for α < 0 modified for their position according to Figure 7.10 c and d.

(2) The zones F/G/J used should be considered only for the upwind face. The zones H and I should be considered for each span of the multispan roof.

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



NOTE 1 In configuration *b* two cases should be considered depending on the sign of pressure coefficient c_{pe} on the first roof.

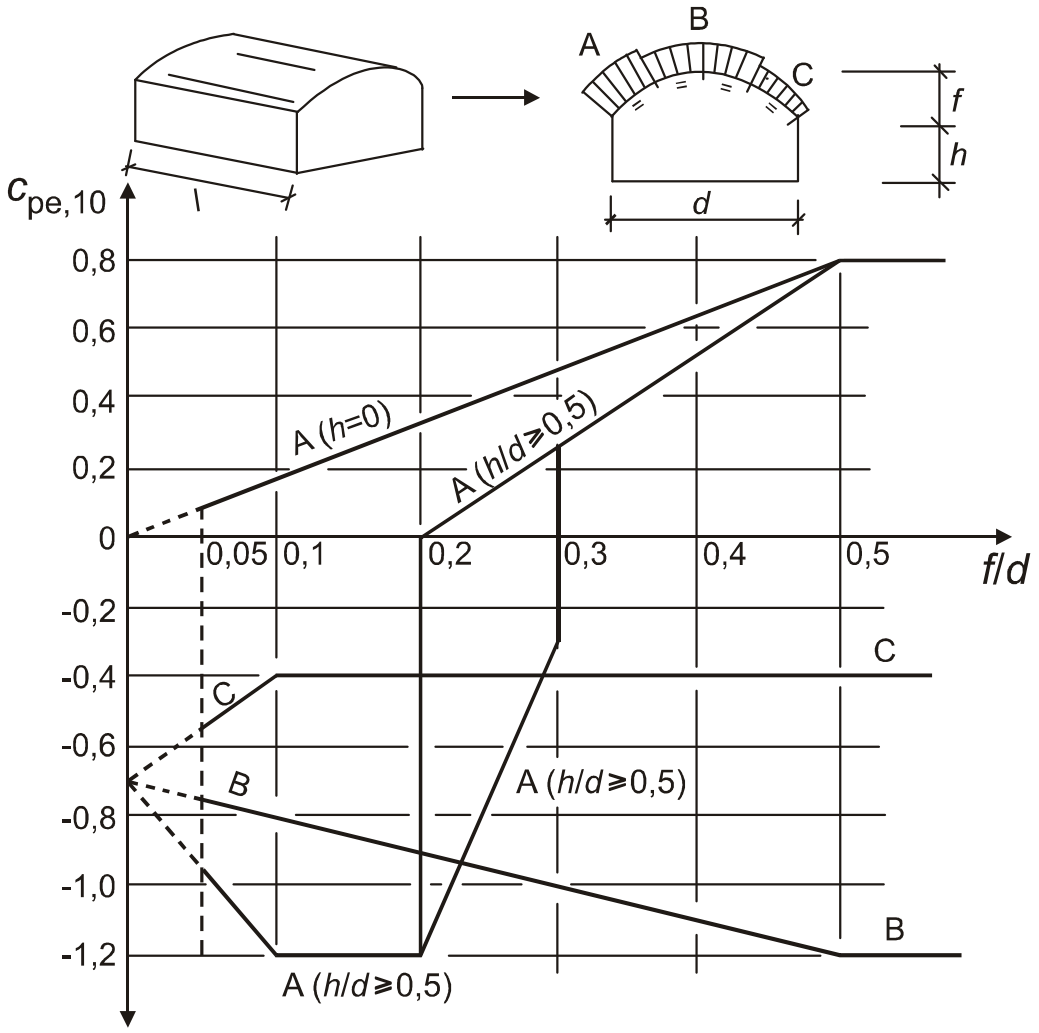
NOTE 2 In configuration *c* the first c_{pe} is the c_{pe} of the monopitch roof, the second and all following c_{pe} are the c_{pe} of the troughed duopitch roof.

Figure 7.10 — Key to multispan roofs

7.2.8 Vaulted roofs and domes

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

NOTE The values of $c_{pe,10}$ and $c_{pe,1}$ to be used for circular cylindrical roofs and domes may be given in the National Annex. The recommended values of $c_{pe,10}$ are given in Figures 7.11 and 7.12 for different zones. The reference height should be taken as $z_e = h + f$.

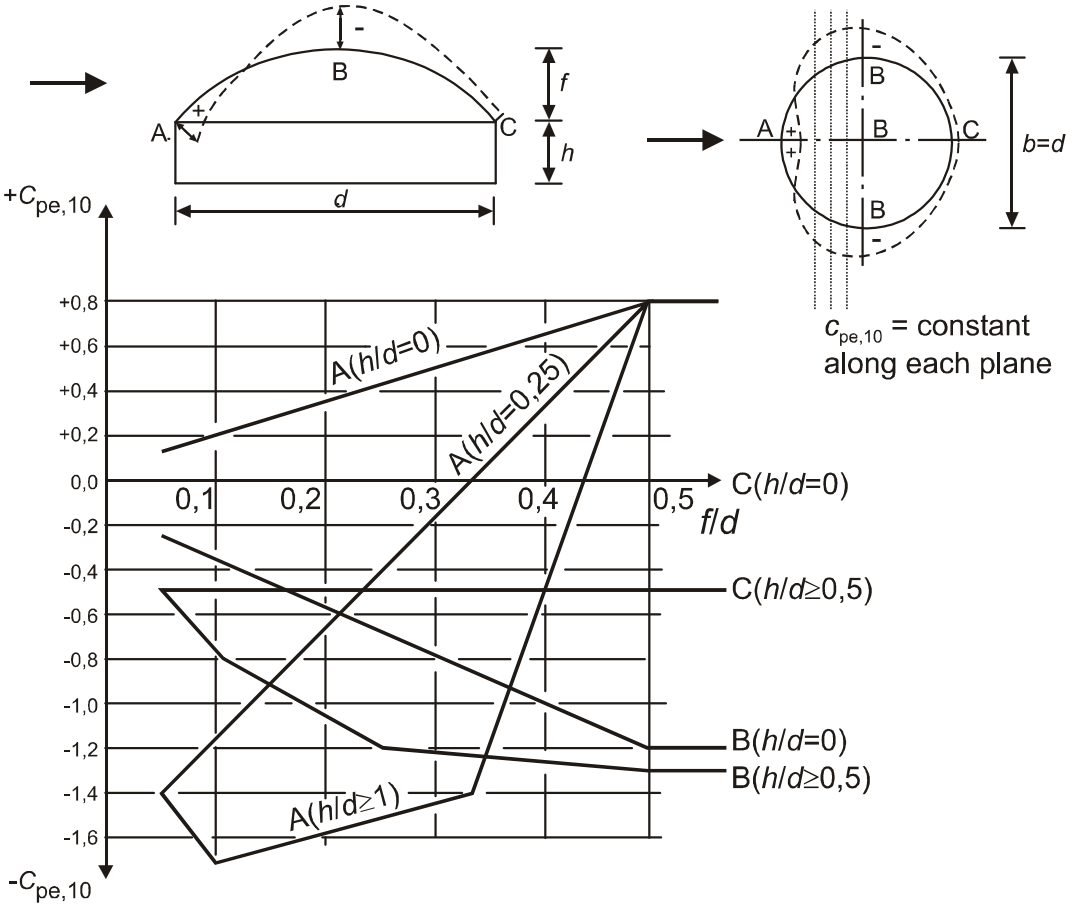


for $0 < h/d < 0,5$, $c_{pe,10}$ is obtained by linear interpolation

for $0,2 \le f/d \le 0,3$ and $h/d \ge 0,5$, two values of $c_{pe,10}$ have to be considered

the diagram is not applicable for flat roofs

Figure 7.11 — Recommended values of external pressure coefficients $c_{pe,10}$ for vaulted roofs with rectangular base



$c_{pe,10}$ is constant along arcs of circles, intersections of the sphere and of planes perpendicular to the wind; it can be determined as a first approximation by linear interpolation between the values in A, B and C along the arcs of circles parallel to the wind. In the same way the values of $c_{pe,10}$ in A if $0 < h/d < 1$ and in B or C if $0 < h/d < 0,5$ can be obtained by linear interpolation in the Figure above.

Figure 7.12 — Recommended values of external pressure coefficients $c_{pe,10}$ for domes with circular base

(2) Pressure coefficients for the walls of rectangular buildings with vaulted roofs should be taken from 7.2.2.

7.2.9 Internal pressure

(1)P Internal and external pressures shall be considered to act at the same time. The worst combination of external and internal pressures shall be considered for every combination of possible openings and other leakage paths.

(2) The internal pressure coefficient, c_{pi}, depends on the size and distribution of the openings in the building envelope. When in at least two sides of the buildings (facades or roof) the total area of openings in each side is more than 30 % of the area of that side, the actions on the structure should not be calculated from the rules given in this section but the rules of 7.3 and 7.4 should instead be used.

NOTE The openings of a building include small openings such as: open windows, ventilators, chimneys, etc. as well as background permeability such as air leakage around doors, windows, services and through the building envelope. The background permeability is typically in the range 0,01% to 0, 1% of the face area. Additional information may be given in a National Annex.

(3) Where an external opening, such as a door or a window, would be dominant when open but is considered to be closed in the ultimate limit state, during severe windstorms, the condition with the door or window open should be considered as an accidental design situation in accordance with EN 1990.

NOTE Checking of the accidental design situation is important for tall internal walls (with high risk of hazard) when the wall has to carry the full external wind action because of openings in the building envelope.

(4) A face of a building should be regarded as dominant when the area of openings at that face is at least twice the area of openings and leakages in the remaining faces of the building considered.

NOTE This can also be applied to individual internal volumes within the building.

(5) For a building with a dominant face the internal pressure should be taken as a fraction of the external pressure at the openings of the dominant face. The values given by Expressions (7.2) and (7.3) should be used.

When the area of the openings at the dominant face is twice the area of the openings in the remaining faces,

$$c_{pi} = 0{,}75 \cdot c_{pe} \qquad (7.2)$$

When the area of the openings at the dominant face is at least 3 times the area of the openings in the remaining faces,

$$c_{pi} = 0{,}90 \cdot c_{pe} \qquad (7.3)$$

where c_{pe} is the value for the external pressure coefficient at the openings in the dominant face. When these openings are located in zones with different values of external pressures an area weighted average value of c_{pe} should be used.

When the area of the openings at the dominant face is between 2 and 3 times the area of the openings in the remaining faces linear interpolation for calculating c_{pi} may be used.

(6) For buildings without a dominant face, the internal pressure coefficient c_{pi} should be determined from Figure 7.13, and is a function of the ratio of the height and the depth of the building, h/d, and the opening ratio μ for each wind direction θ, which should be determined from Expression (7.4).

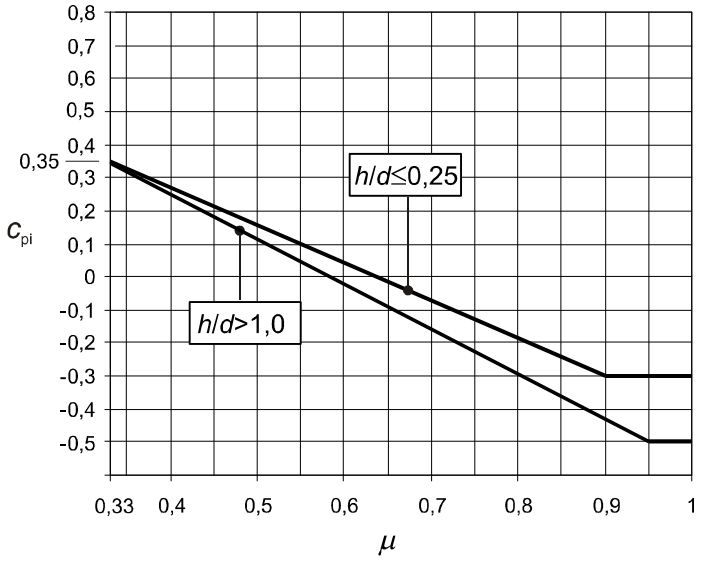


Figure 7.13 — Internal pressure coefficients for uniformly distributed openings

$$\mu = \frac{\sum \text{area of openings where } c_{pe} \text{ is negative or - 0,0}}{\sum \text{area of all openings}} \qquad (7.4)$$

NOTE 1 This applies to façades and roof of buildings with and without internal partitions.

NOTE 2 Where it is not possible, or not considered justified, to estimate μ for a particular case then c_{pi} should be taken as the more onerous of +0,2 and -0,3.

(7) The reference height z_i for the internal pressures should be equal to the reference height z_e for the external pressures (see 5.1) on the faces which contribute by their openings to the creation of the internal pressure. If there are several openings the largest value of z_e should be used to determine z_i .

(8) The internal pressure coefficient of open silos and chimneys should be based on Expression (7.5):

$$c_{pi} = -0{,}60 \qquad (7.5)$$

The internal pressure coefficient of vented tanks with small openings should be based on Expression (7.6):

$$c_{pi} = -0{,}40 \qquad (7.6)$$

The reference height z_i is equal to the height of the structure.