Section 20 **Eurocode 1**

EN 1991-1-4
Section 7 (Page 61 to 65)

20.1 Free-standing walls, parapets, fences and signboards

For free-standing walls and parapets resulting pressure coefficients $c_{p,net}$ should be specified for the zones A, B, C and D as shown in Figure 7.19.

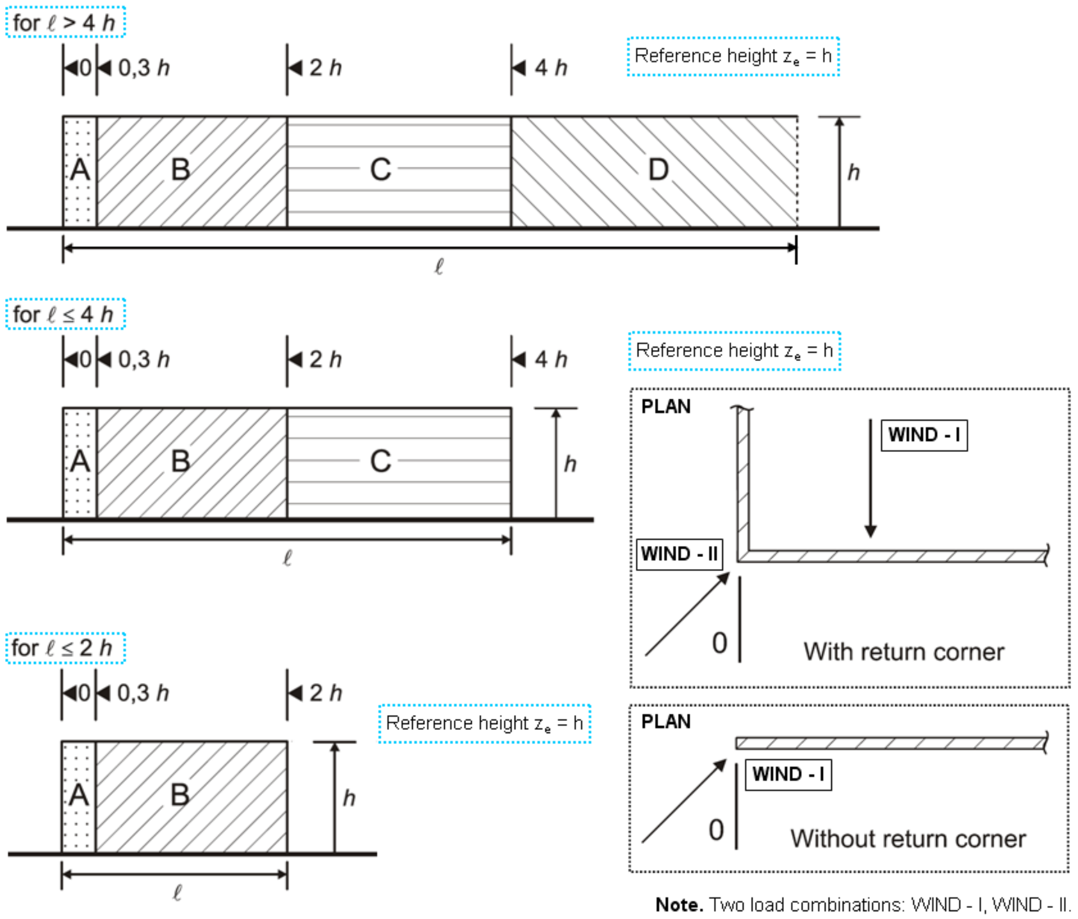


Figure 20.95 From Figure 7.19 [modified] - Key to zones of free-standing walls and parapets.

The values of the resulting pressure coefficients $c_{p,net}$ for free-standing walls and parapets depend on the solidity ratio φ. For solid walls the solidity φ should be taken as 1, and for walls which are 80% solid (i.e. have 20% openings) $\varphi = 0{,}8$. Porous walls and fences with a solidity ratio $\varphi \leq 0{,}8$ should be treated as plane lattices in accordance with 7.11.

Values of the resulting pressure coefficients $c_{p,net}$ for free-standing walls and parapets may be given in the National Annex. Recommended values are given in Table 7.9 for two different solidity ratio. These recommended values correspond to a direction of oblique wind compared to the wall without return corner (see Figure 7.19) and, in the case of the wall with return corner, to the two opposite directions indicated in Figure 7.19 (modified)(11). The reference area in both cases is the gross area. Linear interpolation may be used for solidity ratio between 0,8 and 1.

Solidity	Zone		A	B	C	D
$\varphi = 1$	with return corners	$l/h \leq 3$	2,3	1,4	1,2	1,2
		$l/h = 5$	2,9	1,8	1,4	1,2
		$l/h \geq 10$	3,4	2,1	1,7	1,2
	with return corners of length ≥ h(a)		2,1	1,8	1,4	1,2
$\varphi = 0{,}8$			1,2	1,2	1,2	1,2

Table 20.49 Recommended pressure coefficients $c_{p,net}$ for free-standing walls and parapets.

(a). Linear interpolation may be used for return corner lengths between 0,0 and h.

The reference height for free standing walls and fences should be taken as $z_e = h$, see Figure 7.19. The reference height for parapets on buildings should be taken as $z_e = (h + h_p)$, see Figure 7.6.

20.2 Shelter factors for walls and fences

If there are other walls or fences upwind that are equal in height or taller than the wall or fence of height, h, under consideration, then an additional shelter factor can be used with the net pressure coefficients for walls and lattice fences. The value of the shelter factor ψ_s depends on the spacing between the walls or fences x, and the solidity φ, of the upwind (sheltering) wall or fence. Values of ψ_s are given in Figure 7.20. The resulting net pressure coefficient on the sheltered wall, $c_{p,net,s}$, is given by:

$$c_{p,net,s} = \psi_s \cdot c_{p,net} . \qquad \textbf{(Eq. 20-74)}$$

(11) See “WIND-I” and “WIND-II”.

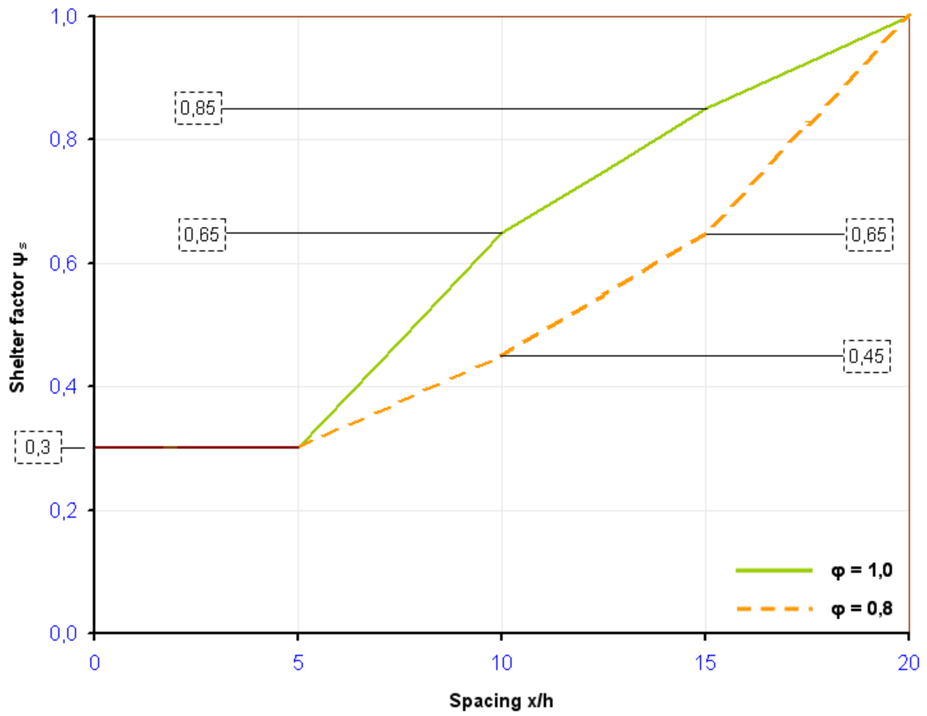


Figure 20.96 From Figure 7.20 - Shelter factor ψ_s for walls and fences for φ -values between 0,8 and 1,0.

The shelter factor should not be applied in the end zones within a distance of h measured from the free end of the wall. In addition, no advantage from shelter should be taken on parts of the downwind wall which extend beyond the projected ends of the upwind wall.

20.3 Signboards

For signboards separated from the ground by a height z_g greater than h/4 (see Figure 7.21) or less than h/4 with $b/h \le 1$, the force coefficients are given by Expression (7.7):

$$c_f = 1,80 \,. \quad \textbf{(Eq. 20-75)}$$

The resultant force normal to the signboard should be taken to act at the height of the centre of the signboard with a horizontal eccentricity "e". The value of the horizontal eccentricity e may be given in the National Annex. The recommended value is:

$$e = \pm 0,25 \cdot b \,. \quad \textbf{(Eq. 20-76)}$$

Signboards separated from the ground by a height z_g less than h/4 and with $b/h > 1$ should be treated as boundary walls, see 7.4.1. Divergence or stall flutter instabilities should be checked.

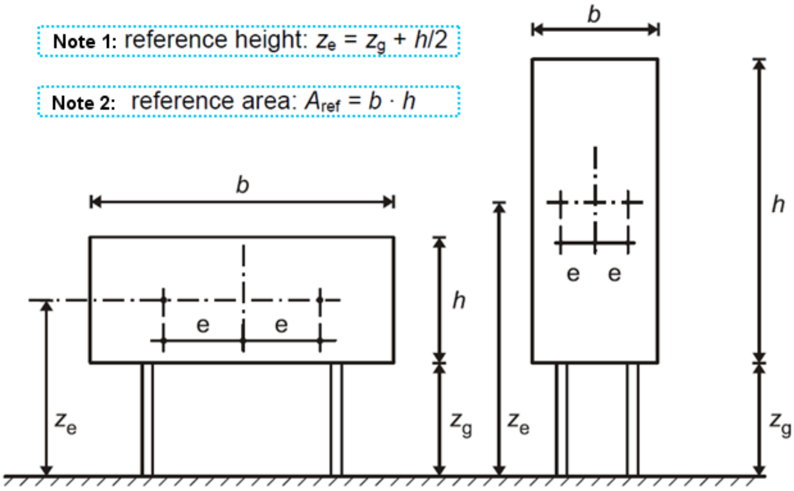


Figure 20.97 From Figure 7.21 - Key for signboards.

20.4 Friction coefficients

Friction should be considered for the cases defined in 5.3(3). Friction forces can arise when the wind blows parallel to external surfaces such as walls or roofs. Friction coefficients c_{fr}, for walls and roof surfaces are given in Table 7.10. The

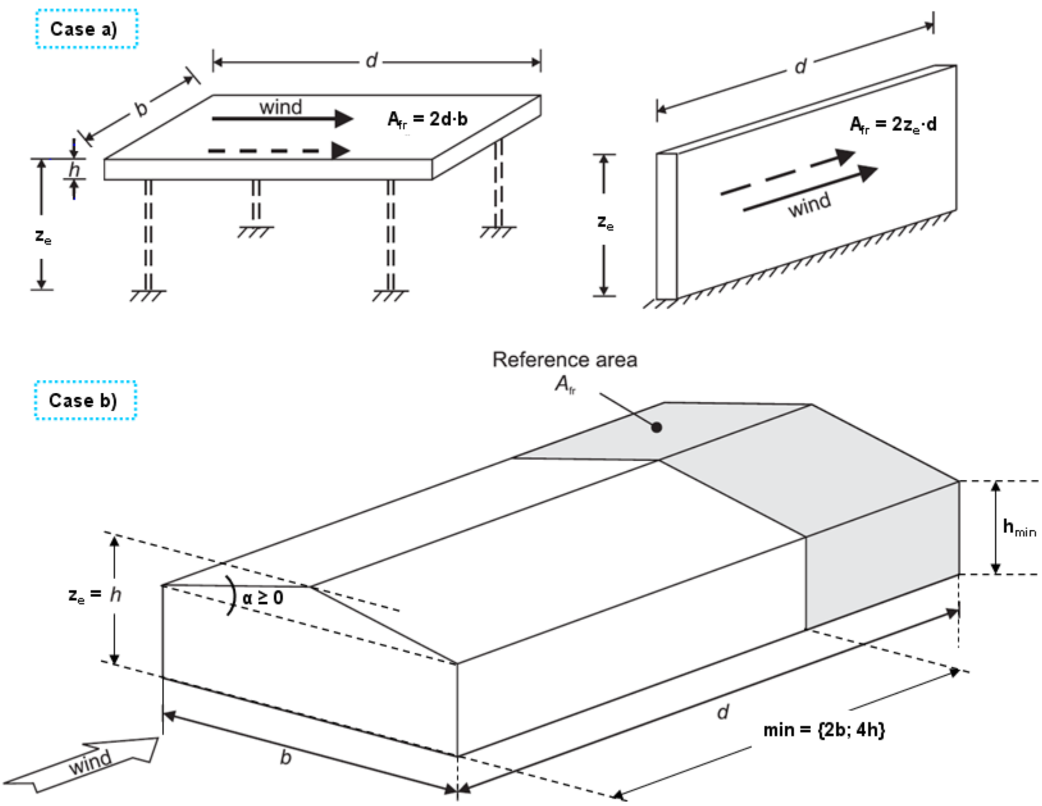


Figure 20.98 From Figure 7.22 [modified]- Reference area for friction.

reference area A_{fr} is given in Figure 7.22. Friction forces should be applied on the part of the external surfaces parallel to the wind, located beyond a distance from the upwind eaves or corners, equal to the smallest value of 2b or 4h.

Surface	Friction coefficient c_{fr}
Smooth (i.e. steel, smooth concrete)	0,01
Rough (i.e. rough concrete, tar-boards)	0,02
very rough (i.e. ripples, ribs, folds)	0,04

Table 20.50 From Table 7.10 - Frictional coefficients c_{fr} for walls, parapets and roof surfaces.

The reference height z_e should be taken equal to the structure height above ground or building height “h”, see Figure 7.22.

20.5 Verification tests

EN1991-1-4_(A)_12.XLS. 6.34 MB. Created: 24 July 2013. Last/Rel.-date: 24 July 2013. Sheets:

— Splash
— CodeSec7(61to64)
— CodeSec7(64to65).

EXAMPLE 20-BS- Free-standing walls and parapets - Sec. 7.4.1 - **test1**

Given: A free standing wall with return corner is given. Height of the free standing wall h = 4,00 m. Length of the free standing wall L = 3,50 m. Solidity ratio $\varphi = 0,85$. According to Table 7.9, find the recommended pressure coefficients $c_{p,net}$.

[*Reference sheet:* CodeSec7(61to64)]-[*Cell-Range: A1:O1-A78:O78*].

Solution: We have: 0,3h = 1,20 m; 2h = 8,00 m; 4h = 16,00 m; L/h = 3,50/4,00 = 0,88 (rounded value). Solidity $0,8 < \varphi < 1$ with return corners and $0 < L < h$: linear interpolation between 0,0 and h. From Table 7.9: $\varphi = 0,8$ with $c_{p,net}$ = 1,2 (zones A, B, C, D), $\varphi = 1$ with return corners of length $\geq$ h with $c_{p,net}$ = 2,1 (zone A); 1,8 (zone B); 1,4 (zone C); 1,2 (zone D).

Case with $L \leq 2h$ applies (see Figure 7.18): only the zones A and B. Linear interpolation between 0,0 and h = 4,00 m with $\varphi = 1$ and L = 3,50 m:

$$\frac{2,1-0}{4-0} = \frac{c_{p,\,net}-0}{3,50-0} \quad \rightarrow \quad c_{p,\,net} = 1,8375 \approx 1,84 \text{ (zone } \mathbf{A} \text{ with } \varphi = 1\text{)}$$

$$\frac{1,8-0}{4-0} = \frac{c_{p,\,net}-0}{3,50-0} \quad \rightarrow \quad c_{p,\,net} = 1,575 \approx 1,58 \text{ (zone } \mathbf{B} \text{ with } \varphi = 1\text{)}.$$

For zone A linear interpolation between $\varphi = 0,8$ with $c_{p,net}$ = 1,2 and $\varphi = 1$ with $c_{p,net}$ = 1,84:

$$\frac{1,84-1,2}{1,0-0,8} = \frac{c_{p,\,net}-1,2}{0,85-0,80} \quad \rightarrow \quad c_{p,\,net} = 1,36 .$$

For zone B linear interp. between $\varphi = 0,8$ with $c_{p,net} = 1{,}2$ and $\varphi = 1$ with $c_{p,net} = 1{,}58$:

$$\frac{1,58-1,2}{1,0-0,8} = \frac{c_{p,\,net}-1,2}{0,85-0,80} \quad \rightarrow \quad c_{p,\,net} = 1,295 \approx 1,30 .$$

The reference height for free standing walls should be taken as $z_e = h = 4{,}00$ m, see Figure 7.19.

example-end

EXAMPLE 20-BT- Shelter factors for walls and fences - Sec. 7.4.2 - **test2**

Given: A wall upwind taller than the wall of height h = 4,00 m considered in the previous example is given. The solidity φ of the upwind sheltering wall is equal to 0,9. The spacing between the walls is $x \leq 40{,}00$ m. Find the resulting pressure coefficient $c_{p,net,s}$ on the sheltered wall.

[*Reference sheet:* CodeSec7(61to64)]-[*Cell-Range: A82:O82-A144:O144*].

Solution: Height of wall under consideration: h = 4,00 m. Therefore: x/h = (40,00)/(4,00) = 10. From Figure 7.20 - "*Shelter factor ψ_s for walls and fences for φ-values between 0,8 and 1,0*":
$\psi_s = 0,65$ for $\varphi = 1$ with x/h = 10; $\psi_s = 0,45$ for $\varphi = 0,8$ with x/h = 10.

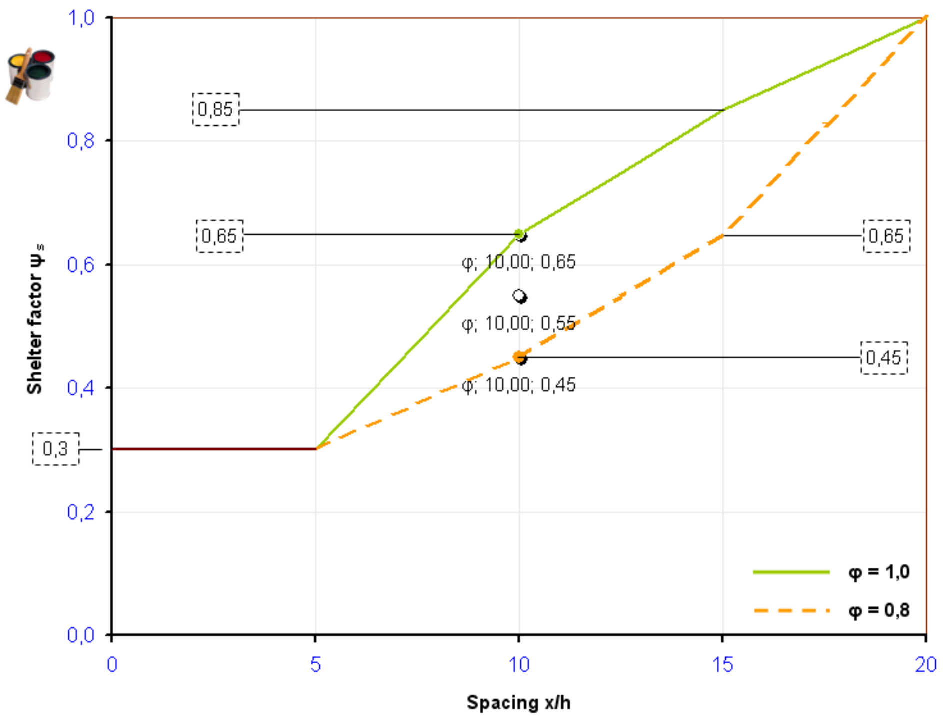


Figure 20.99 From Excel® output.

Linear interpolation (sheltering wall with $\varphi = 0,9$) for $0,8 < \varphi < 1$:
$\psi_s = (0,65 + 0,45)/2 = 0,55$.

From previous example we have (case with $L \leq 2h$ applies): $c_{p,net}$ = 1,36 (zone A); 1,30 (zone B). Therefore the resulting net pressure coefficients are:

$c_{p,net,s} = \psi_s \cdot c_{p,net} = 0,55 \cdot 1,36 = 0,75$ (zone A);

$c_{p,net,s} = \psi_s \cdot c_{p,net} = 0,55 \cdot 1,30 = 0,72$ (zone B).

⚠ The shelter factors should not be applied in the end zones within a distance of h measured from the free end of the wall.

example-end

EXAMPLE 20-BU- Signboards - Sec. 7.4.3 - **test3**

Given: A signboard separated from the ground by a height z_g = 2,00 m is given. The dimension of the signboard are h = 10,00 m (height), b = 3,00 (width). The peak velocity pressure at the reference height $z_e = z_g + 0,5h = 7,00$ m is $q_p(z_e) = 1,50$ kN/m². Calculate the shear and bending reaction at the base of the structure.

[*Reference sheet:* CodeSec7(61to64)]-[*Cell-Range: A149:O149-A253:O253*].

Solution: Reference area: $A_{ref} = b \cdot h = (3,00) \cdot (10,00) = 30,00\ m^2$. Case 2 applies with:

$z_g < h/4 \rightarrow 2,00 < (10,00/4) = 2,50$

$b/h \leq 1 \rightarrow 3,00/10,00 = 0,30 \leq 1$.

Therefore, we have $c_f = 1,80$ and $e = \pm 0,25b = \pm 0,25 \cdot (3,00) = \pm 0,75$ m.

Shear and bending reactions acting at the base of the structure

$F_w = c_s \cdot c_d \cdot q_p(z_e) \cdot c_f \cdot A_{ref} = c_s \cdot c_d \cdot 1,50 \cdot 1,80 \cdot 30,00 = c_s \cdot c_d \cdot 81,00$ kN.

$M_{wV} = F_w \cdot e = \pm(c_s \cdot c_d \cdot 81,00) \times 0,75 = \pm c_s \cdot c_d \cdot 60,75$ kNm.

$M_{wH} = F_w \cdot z_e = \pm(c_s \cdot c_d \cdot 81,00) \times 7,00 = \pm c_s \cdot c_d \cdot 567,00$ kNm.

example-end

EXAMPLE 20-BV- Friction coefficients - Sec. 7.5 - **test4**

Given: A simple rectangular building with duopitch roof is given. The dimensions of the building are: ridge height $h = z_e$ = 6,00 m, gutter height h_{min} = 2,00 m, width b = 15,00 m (crosswind dimension) and depth d = 30,00 m. Find the frictional force considering a lack of correlation of wind pressures.

[*Reference sheet:* CodeSec7(64to65)]-[*Cell-Range: A1:O1-A128:O128*].

Solution: Pitch roof angle:

$$\frac{h - h_{min}}{0,5b} = \tan\alpha = \frac{4,00}{7,50} \approx 0,53 \rightarrow \alpha \approx 28° \rightarrow \cos\alpha \approx 0,88 .$$

Substituting the given numerical data we obtain:

$\min\{2b; 4h\} = \min\{2 \cdot (15,00); 4 \cdot (6,00)\} = 24,00 \text{ m}$,

$d - \min\{2b; 4h\} = 30,00 - 24,00 = 6,00 \text{ m}$,

$A_{fr} = 2[d - \min\{2b; 4h\}] \cdot (h_{min} + 0,5b/\cos\alpha) = 2 \cdot (6,00) \cdot [2,00 + 0,5 \cdot (15,00)/(0,88)]$

$A_{fr} = 126,00 \text{ m}^2$.

With a peak velocity pressure (say) $q_p(z_e) = 1,50 \text{ kN/m}^2$ and a frictional coefficient $c_{fr} = 0,02$, we get:

$F_{fr} = c_{fr} \cdot q_p(z_e) \cdot A_{fr} = 0,02 \cdot 1,50 \cdot 126,00 = 3,78 \text{ kN}$,

$F_{fr}/A_{fr} = c_{fr} \cdot q_p(z_e) = 0,02 \cdot 1,50 = 0,03 \text{ kN/m}^2$.

⚠ In the summation of the wind forces acting on building structures, the lack of correlation of wind pressures between the windward and leeward sides may be taken into account. 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.

Building with $h/d = 6,00/30,00 = 0,20 \rightarrow h/d \leq 1$. Therefore, the resulting frictional force should be multiplied by $\xi = 0,85$:

$F_{fr} = 0,85 \cdot (3,78) = 3,21 \text{ kN}$;

$F_{fr}/A_{fr} = c_{fr} \cdot q_p(z_e) \cdot \xi = 0,02 \cdot 1,50 \cdot 0,85 = 0,0255 \text{ kN/m}^2$.

example-end

EXAMPLE 20-BW- Free-standing walls and parapets - Wind actions (Sec. 5.3 - Eq. (5.3)) - **test5**

Given: Using the same data given in the Example 20-BS, find the wind forces acting on the free-standing wall. Let us assume the following assumptions:

– peak velocity pressure at the reference height $z_e = h = 4,00 \text{ m}$: $q_p(z_e) = 600 \text{ N/m}^2$

– structural factor (as defined in Sec. 6): $c_s c_d = 1,0$.

[*Reference sheet:* CodeSec7(61to64)]-[*Cell-Range: A1:O1-A78:O78*].

Solution: From Example 11-V we have:

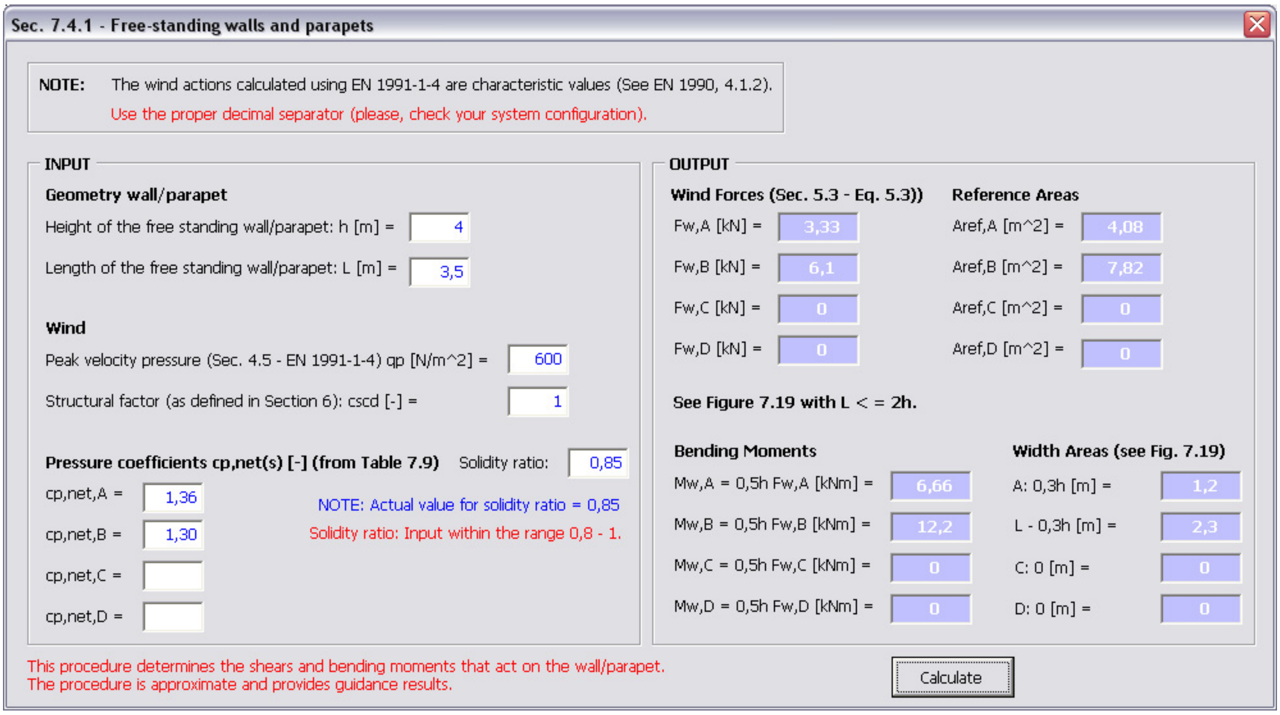
Case with $L \leq 2h$ (see Figure 7.18).

Linear interpolation from Table 7.9 with solidity ratio equal to $\varphi = 0,85$ [-]:

– Zone **A**: $c_{p,net} = 1,36$

– Zone **B**: $c_{p,net} = 1,30$.

From Figure 7.19 - “*Key to zones of free-standing walls and parapets*” (case $L \leq 2h$), we get:



Sec. 7.4.1 - Free-standing walls and parapets

NOTE: The wind actions calculated using EN 1991-1-4 are characteristic values (See EN 1990, 4.1.2).
Use the proper decimal separator (please, check your system configuration).

INPUT

Geometry wall/parapet

Height of the free standing wall/parapet: h [m] = 4

Length of the free standing wall/parapet: L [m] = 3,5

Wind

Peak velocity pressure (Sec. 4.5 - EN 1991-1-4) qp [N/m^2] = 600

Structural factor (as defined in Section 6): cscd [-] = 1

Pressure coefficients cp,net(s) [-] (from Table 7.9) Solidity ratio: 0,85

cp,net,A = 1,36

cp,net,B = 1,30

cp,net,C =

cp,net,D =

NOTE: Actual value for solidity ratio = 0,85
Solidity ratio: Input within the range 0,8 - 1.

OUTPUT

Wind Forces (Sec. 5.3 - Eq. 5.3)) | Reference Areas

Fw,A [kN] = 3,33 | Aref,A [m^2] = 4,08

Fw,B [kN] = 6,1 | Aref,B [m^2] = 7,82

Fw,C [kN] = 0 | Aref,C [m^2] = 0

Fw,D [kN] = 0 | Aref,D [m^2] = 0

See Figure 7.19 with L < = 2h.

Bending Moments | Width Areas (see Fig. 7.19)

Mw,A = 0,5h Fw,A [kNm] = 6,66 | A: 0,3h [m] = 1,2

Mw,B = 0,5h Fw,B [kNm] = 12,2 | L - 0,3h [m] = 2,3

Mw,C = 0,5h Fw,C [kNm] = 0 | C: 0 [m] = 0

Mw,D = 0,5h Fw,D [kNm] = 0 | D: 0 [m] = 0

This procedure determines the shears and bending moments that act on the wall/parapet.
The procedure is approximate and provides guidance results.

Calculate

Figure 20.100 PreCalculus Excel® form: procedure for a quick pre-calculation.

Zone A: $0,3h = 0,3 \cdot (4,00) = 1,20$ m with

$A_{ref,A} = \varphi \cdot 0,3h^2 = 0,85 \cdot 0,3 \cdot (4,00)^2 = 4,08\ m^2$ (rounded value),

Zone **B**: $L - 0,3h = 3,50 - 0,3 \cdot (4,00) = 2,30$ m with

$A_{ref,B} = \varphi \cdot (L - 0,3 \cdot h) \cdot h = 0,85 \cdot [3,50 - 0,3 \cdot (4,00)] \cdot 4,00 = 7,82\ m^2$ (rounded value),

Shear and bending reactions acting at the base of the structure

Zone A

$$F_{w,A} = c_s c_d \cdot q_p(z_e) \cdot c_{p,net} \cdot A_{ref,A} = 1,0 \cdot 0,60 \cdot 1,36 \cdot 4,08 = 3,33\ kN.$$

$$M_{wA} = F_{w,A} \cdot 0,5h = (3,33) \times 2,00 = 6,66\ kNm.$$

Zone B

$$F_{w,B} = c_s c_d \cdot q_p(z_e) \cdot c_{p,net} \cdot A_{ref,B} = 1,0 \cdot 0,60 \cdot 1,30 \cdot 7,82 = 6,10\ kN.$$

$$M_{wB} = F_w \cdot 0,5h = (6,10) \times 2,00 = 12,20\ kNm.$$

example-end

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20.6 References [Section 20]

EN 1991-1-4:2005/A1:2010. Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions. Brussels: CEN/TC 250 - Structural Eurocodes, April 2010.

EN 1991-1-4:2005. Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions. Brussels: CEN/TC 250 - Structural Eurocodes, March 2005 (DAV).

Manual for the design of building structures to Eurocode 1 and Basis of Structural Design, April 2010. © 2010 The Institution of Structural Engineers.