Section 27 Eurocode 1 EN 1991-1-4 Annex A

27.1 Terrain categories

Illustrations of the upper roughness of each terrain category are given in Section A.1. The mean wind velocity at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity. The terrain category are:

— terrain **category 0**: sea, coastal area exposed to the open sea

— terrain **category I**: lakes or area with negligible vegetation and without obstacles

— terrain **category II**: area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

— terrain **category III**: area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)

— terrain **category IV**: area in which at least 15% of the surface is covered with buildings and their average height exceeds 15 m.

27.2 Transition between roughness categories 0, I, II, III and IV

Two recommended procedures are given:

— Procedure 1

— Procedure 2.

PROCEDURE 1. If the structure is situated near a change of terrain roughness at a distance less than 2 km from the smoother category 0 or less than 1 km from the smoother categories I to III the smoother terrain category in the upwind direction should be used.

PROCEDURE 2. Determine the roughness categories for the upstream terrain in the angular sectors to be considered. For every angular sector, determine the distance x from the building to the upstream roughness changes. If the distance x from the building to a terrain with lower roughness length is smaller than the values given in Table A.1, then the lower value for the roughness length should be used for the angular sector considered. If this distance x is larger than the value in Table A.1, the higher value for the roughness length should be used. For intermediate values of height z, linear interpolation may be used. Where no distance x is given in Table A.1 or for heights exceeding 50 m, the smaller roughness length should be used.

⚠ Small areas (less than 10% of the area under consideration) with deviating roughness may be ignored in both procedures.

27.3 Numerical calculation of orography coefficients

At isolated hills and ridges or cliffs and escarpments different wind velocities occur dependent on the upstream slope $\Phi = H/L_u$ in the wind direction, where the height H and the length L_u are defined in Figure A. 1.

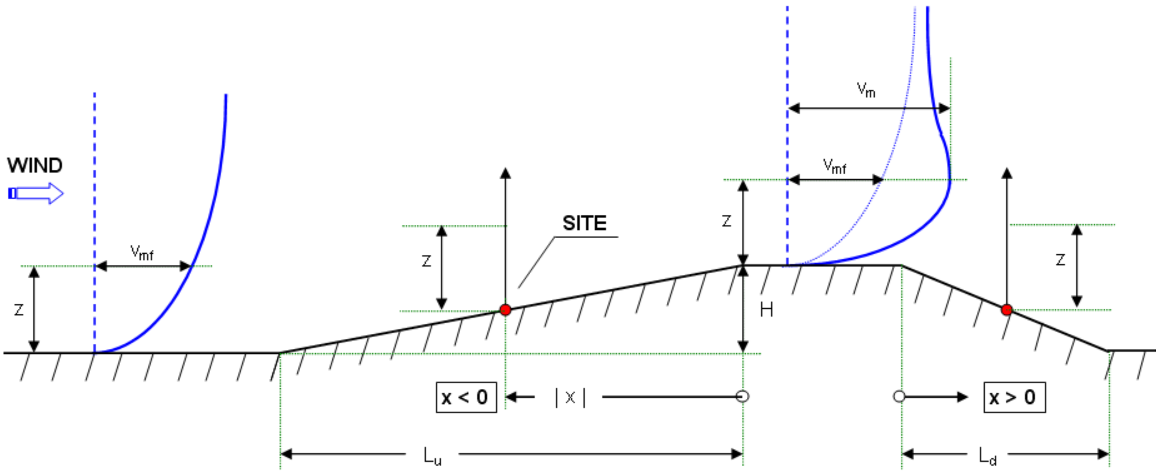

Figure 27.130 From Figure A.1 - Illustration of increase of wind velocities over orography.

The orography factor, $c_0(z) = v_m/v_{mf}$ accounts for the increase of mean wind speed over isolated hills and escarpments (not undulating and mountainous regions), where:

- v_m is the mean wind velocity at height z above terrain
- v_{mf} is the mean wind velocity above flat terrain.

The orography factor is related to the wind velocity at the base of the hill or escarpment. The effects of orography should be taken into account in the following situations:

a. for sites on upwind slopes of hills and ridges:
where $0,05 < \Phi \le 0,3$ and $|x| \le L_u/2$
b. for sites on downwind slopes of hills and ridges:
where $\Phi < 0,3$ and $x < L_d/2$
where $\Phi \ge 0,3$ and $x < 1,6H$
c. for sites on upwind slopes of cliffs and escarpments:
where $0,05 < \Phi \le 0,3$ and $|x| \le L_u/2$
d. for sites on downwind slopes of cliffs and escarpments:
where $\Phi < 0,3$ and $x < 1,5L_e$
where $\Phi \ge 0,3$ and $x < 5H$.

The orography factor is defined by:

$$c_0 = 1 \text{ for } \Phi < 0,05$$ **(Eq. 27-107)**

$$c_0 = 1 + 2s \cdot \Phi \text{ for } 0,05 < \Phi < 0,3$$ **(Eq. 27-108)**

$$c_0 = 1 + 0,6s \text{ for } \Phi > 0,3$$ **(Eq. 27-109)**

where:

- s is the orographic location factor
- Φ is the upwind slope H/L_u in the wind direction
- L_u is the actual length of the upwind slope in the wind direction
- L_e is the effective length of the upwind slope: $L_e = L_u$ for shallow slope $(0,05 < \Phi < 0,3)$, $L_e = H/0,3$ for steep slope $(\Phi > 0,3)$
- L_d is the actual length of the downwind slope in the wind direction
- H is the effective height of the feature
- x is the horizontal distance of the site from the top of the crest
- z is the vertical distance from the ground level of the site.

The following expressions may be used to compute the value of orographic location factor, s:

a) upwind section for all orography (Figures A.2 and A.3):

1. for the range:

$$-1,5 \le \frac{x}{L_u} \le 0 \text{ and } 0 \le \frac{z}{L_e} \le 2,0$$ **(Eq. 27-110)**

take:

$$s = A \cdot \exp\left(\frac{Bx}{L_u}\right)$$ **(Eq. 27-111)**

where:

$$A = 0,1552 \cdot \left(\frac{z}{L_e}\right)^4 - 0,8575 \cdot \left(\frac{z}{L_e}\right)^3 + 1,8133 \cdot \left(\frac{z}{L_e}\right)^2 - 1,9115 \cdot \left(\frac{z}{L_e}\right) + 1,0124 \quad \textbf{(Eq. 27-112)}$$

and:

$$B = 0,3542 \cdot \left(\frac{z}{L_e}\right)^2 - 1,0577 \cdot \left(\frac{z}{L_e}\right) + 2,6456 \quad \textbf{(Eq. 27-113)}$$

2. for the ranges:

$$\frac{x}{L_e} < -1,5 \text{ or } \frac{z}{L_e} > 2 \quad \textbf{(Eq. 27-114)}$$

take $s = 0$.

b) downwind section for cliffs and escarpments (Figure A.2):

1. for the ranges:

$$0,1 \le \frac{x}{L_e} \le 3,5 \text{ and } 0,1 \le \frac{z}{L_e} \le 2,0 \quad \textbf{(Eq. 27-115)}$$

take:

$$s = A \cdot \left(\log\left[\frac{x}{L_e}\right]\right)^2 + B \cdot \left(\log\left[\frac{x}{L_e}\right]\right) + C \quad \textbf{(Eq. 27-116)}$$

where:

$$A = -1,3420 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 - 0,8222 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 + 0,4609 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) - 0,0791 \quad \textbf{(Eq. 27-117)}$$

$$B = -1,0196 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 - 0,8910 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 + 0,5343 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) - 0,1156 \quad \textbf{(Eq. 27-118)}$$

$$C = 0,8030 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 + 0,4236 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 - 0,5738 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) + 0,1606 . \quad \textbf{(Eq. 27-119)}$$

2. for the range:

$$0 \le \frac{x}{L_e} \le 0,1 \quad \textbf{(Eq. 27-120)}$$

interpolate between values for x/L_e (with $s = A$ in Eq.27-112) and $x/L_e = 0,1$.

3. when $z/L_e < 0,1$ use the values for $z/L_e = 0,1$

4. for the ranges: $x/L_e > 3,5$ or $z/L_e > 2,0$ take the value $s = 0$.

c) downwind section for hills and ridges (Figure A.3):

1. for the ranges:

$$0 \le \frac{x}{L_d} \le 2,0 \text{ and } 0 \le \frac{z}{L_e} \le 2,0 \quad \text{(Eq. 27-121)}$$

take:

$$s = A \cdot \exp\left(\frac{Bx}{L_d}\right) \quad \text{(Eq. 27-122)}$$

where:

$$A = 0,1552 \cdot \left(\frac{z}{L_e}\right)^4 - 0,8575 \cdot \left(\frac{z}{L_e}\right)^3 + 1,8133 \cdot \left(\frac{z}{L_e}\right)^2 - 1,9115 \cdot \left(\frac{z}{L_e}\right) + 1,0124 \quad \text{(Eq. 27-123)}$$

$$B = -0,3056 \cdot \left(\frac{z}{L_e}\right)^2 + 1,0212 \cdot \left(\frac{z}{L_e}\right) - 1,7637 \quad \text{(Eq. 27-124)}$$

2. for the ranges:

$$\frac{x}{L_d} > 2,0 \text{ or } \frac{z}{L_e} > 2,0 \text{ take } s = 0. \quad \text{(Eq. 27-125)}$$

27.4 Neighbouring structures

If a building is more than twice as high as the average height h_{ave} of the neighbouring structures then, as a first approximation, the design of any of those nearby structures may be based on the peak velocity pressure at height z_n above ground. Let r be the radius given by expressions (see Figure below):

$r = h_{high}$ if $h_{high} \le 2d_{large}$

$r = 2d_{large}$ if $h_{high} > 2d_{large}$,

then, we have:

for $x \le r$, $z_n = 0,5r$ **(Eq. 27-126)**

for $r < x < 2r$, $z_n = 0,5 \cdot \left[r - \left(1 - \frac{2h_{low}}{r}\right) \cdot (x - r)\right]$ **(Eq. 27-127)**

for $x \ge 2r$, $z_n = h_{low}$ **(Eq. 27-128)** where:

- h_{high} is height of the tallest building
- d_{small}, d_{large} are the plan dimensions of the tallest building
- h_{ave} is the average height of the neighbouring structures
- h_{low} is the height of the nearby structure
- x is the distance from the tallest building (see x_1 or x_2 on figure below).

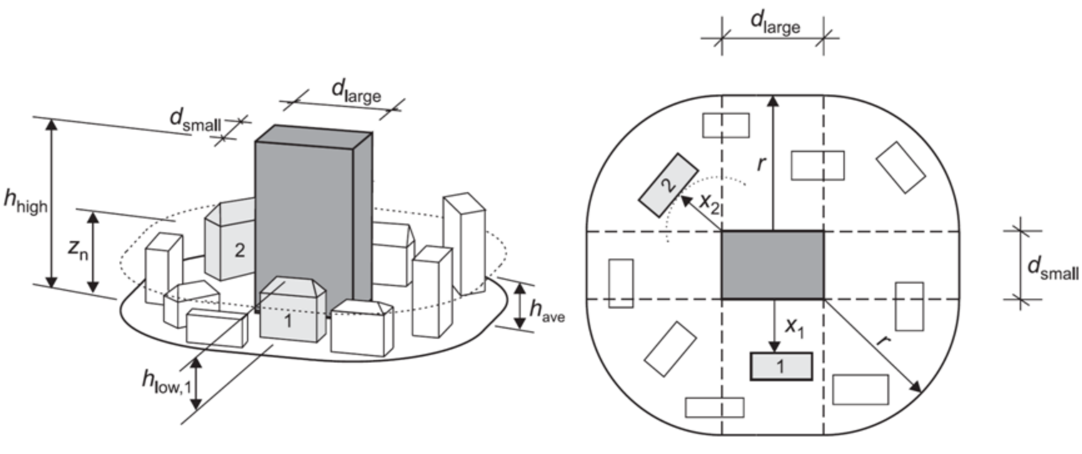

Figure 27.131 From Figure A.4 - Influence of a high rise building, on two different nearby structures (1 and 2)

27.5 Displacement height

For buildings in terrain category IV, closely spaced buildings and other obstructions causes the wind to behave as if the ground level was raised to a displacement height, h_{dis}. Hence, the profile of peak velocity pressure over height may be lifted by a height h_{dis}.

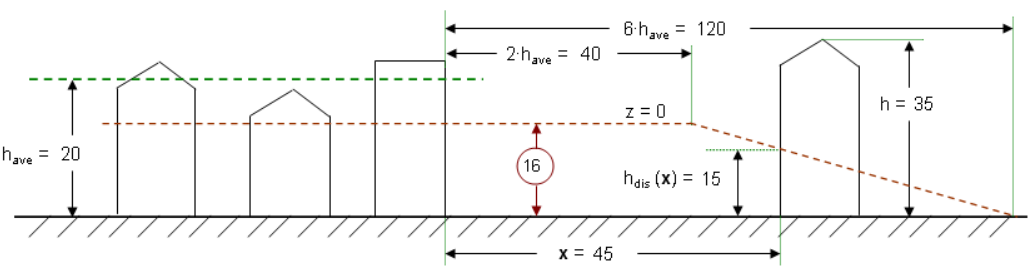

Figure 27.132 Obstruction height and upwind spacing (the figure shows a particular case).

For range: $x \le 2h_{ave}$, $h_{dis} = \min[0,8 \cdot h_{ave}; 0,6h]$ **(Eq. 27-129)**

for range: $2h_{ave} < x < 6h_{ave}$, $h_{dis} = \min[(1,2 \cdot h_{ave} - 0,2 \cdot x); 0,6h]$ **(Eq. 27-130)**

when $x \ge 6h_{ave}$ take: $h_{dis} = 0$. **(Eq. 27-131)**

Note In the absence of more accurate information the obstruction height may be taken as $h_{ave} = 15$ m for terrain category IV.

27.6 Verification tests

EN1991-1-4_(B).XLS. 6.73 MB. Created: 14 March 2013. Last/Rel.-date: 14 March 2013. Sheets:

— Splash
— Annex A.

EXAMPLE 27-CL- Transition between roughness categories 0, I, II, III and IV - **test1**

Given: The transition between different roughness categories has to be considered for calculations. Roughness categories for the upstream terrain in the angular sector are considered from terrain “Category I” to terrain “Category III” and viceversa. Assume an height above ground equal to $z = 9$ m and a distance from the building to a terrain with lower roughness length equal to $x = 21$ km. Find which value for the roughness length should be used. Use the “*Procedure 2*”.

[*Reference sheet:* Annex A]-[*Cell-Range: P9:R9-P10:R10-CommandButton*].

Solution: From Table A.1:

Height z	I to II	I to III
5 m	0,50 km	5,00 km
7 m	1,00 km	10,00 km
10 m	2,00 km	20,00 km
15 m	5,00 km	
20 m	12,00 km	
30 m	20,00 km	
50 m	50,00 km	

Table 27.59 From Table A.1 - Distance x.

for $z = 9$ m, entering the third column, we get (linear interpolation):

$$\frac{20,00-10,00}{10-7}=\frac{x-10,00}{z-7,00} \quad\Rightarrow\quad \frac{20,00-10,00}{10-7}=\frac{x-10,00}{9-7,00} \quad\Rightarrow\quad x = 16,67\ \mathrm{m}\,.$$

Then, we have: $x = 21\ \mathrm{km} > 16,67\ \mathrm{m}$. Thus, the higher value for the roughness length should be used: $z_0 = 0,3\ \mathrm{m}$ (see Table 4.1, EN 1991-1-4).

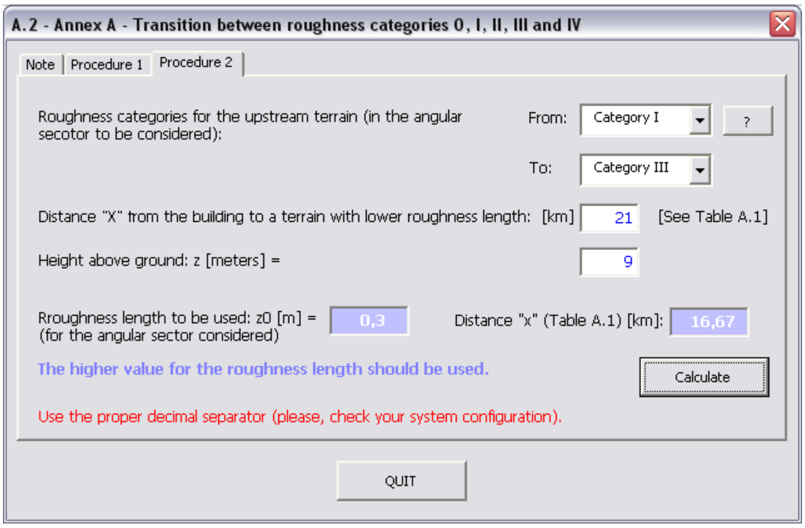

Figure 27.133 PreCalculus Excel® form: procedure for a quick pre-calculation.

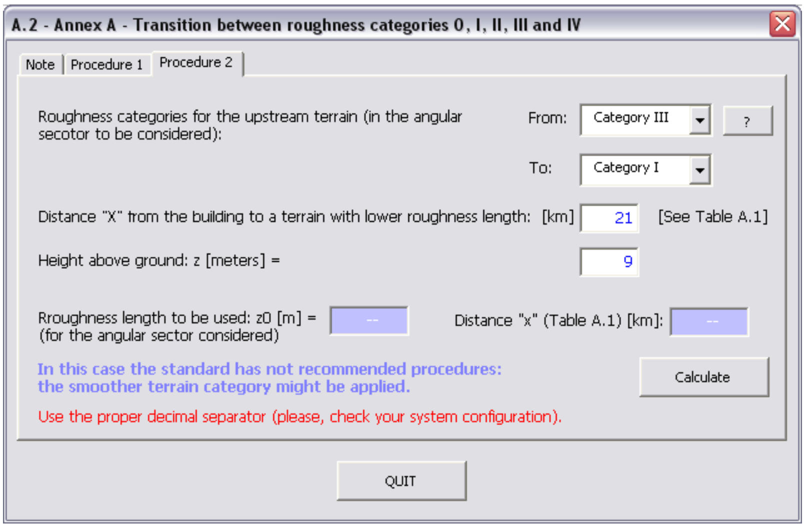

Figure 27.134 PreCalculus Excel form: procedure for a quick pre-calculation.

From terrain category III to category III the standard has not recommended procedures: the smoother terrain category might be applied.

example-end

EXAMPLE 27-CM- Transition between roughness categories 0, I, II, III and IV - **test1b**

Given: Using the same assumptions of the previous example, find the roughness length to be used for calculations for $z = 60$ m and $x = 21$ km. Use the "*Procedure 2*".

[*Reference sheet:* Annex A]-[*Cell-Range: P9:R9-P10:R10-CommandButton*].

Solution: As determined by the Standard (A.2(1)), where no distance x is given in Table A.1 or for heights exceeding 50 m, the smaller roughness length should be used.

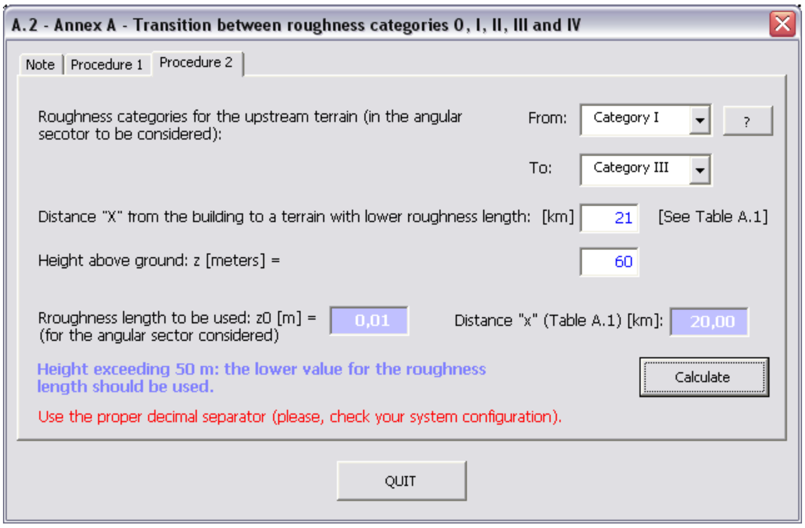

Figure 27.135 PreCalculus Excel form: procedure for a quick pre-calculation.

From Table 4.1 ("*Terrain categories and terrain parameters*"): $z_0 = \min[0,01; 0,3] = 0,01$ m.

example-end

EXAMPLE 27-CN- Transition between roughness categories 0, I, II, III and IV - **test1c**

Given: From terrain category II to category III, find the roughness length to be used for $z = 25$ m and $x = 8$ km. Use the "*Procedure 2*".

[*Reference sheet:* Annex A]-[*Cell-Range: P9:R9-P10:R10-CommandButton*].

Solution: For $z = 25$ m, entering Table A.1, we get (linear interpolation):
$x = (7,00 + 10,00)/2 = 8,50$ m.

Height z	II to III	II to IV
5 m	0,30 km	2,00 km
7 m	0,50 km	3,50 km
10 m	1,00 km	7,00 km
15 m	3,00 km	20,00 km
20 m	7,00 km	
30 m	10,00 km	
50 m	30,00 km	

Table 27.60 From Table A.1 - Distance x.

Then, we have: $x = 8$ km $< 8,50$ m.

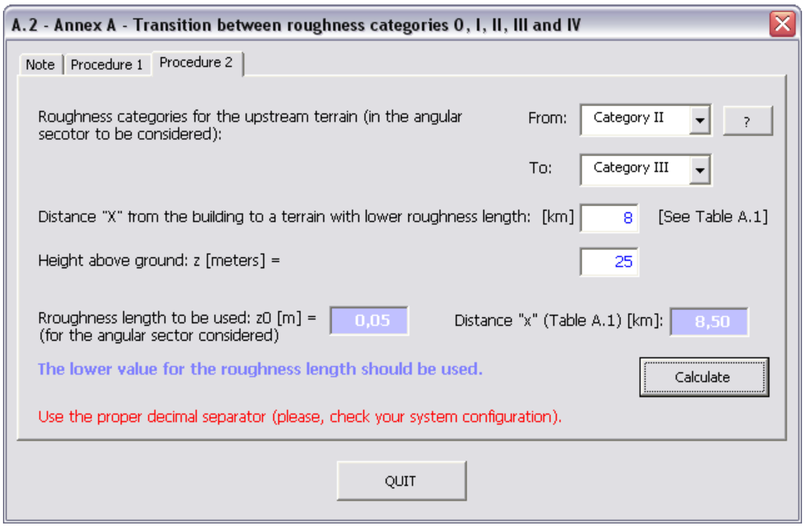

Figure 27.136 PreCalculus Excel form: procedure for a quick pre-calculation.

Thus, the lower value for the roughness length should be used: $z_0 = 0,05$ m.

example-end

EXAMPLE 27-CO- Transition between roughness categories 0, I, II, III and IV - **test1d**

Given: A building is situated near a change of terrain roughness at a distance of $x = 2500$ m from the smoother terrain category (Category 0). Find the terrain category in the upwind direction to be used for calculations. Use "*Procedure 1*".

[*Reference sheet:* Annex A]-[*Cell-Range: P9:R9-P10:R10-CommandButton*].

Solution: As determined by the Standard (A.2(1)), if the structure is situated near a change of terrain roughness at a distance less than 2 km from the smoother category 0 the smoother terrain category in the upwind direction should be used.

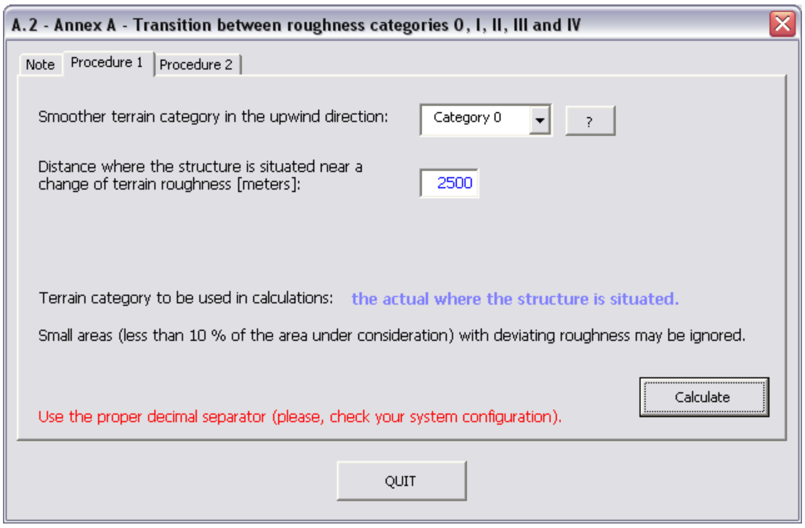

Figure 27.137 PreCalculus Excel form: procedure for a quick pre-calculation.

We have $x = 2500\ \mathrm{m} > 2\ \mathrm{km}$. Therefore, the actual terrain category where the building is situated should be used for calculations.

example-end

EXAMPLE 27-CP- Numerical calculation of orography coefficients - **test2**

Given: Find the *upstream slope*, the *orography location factor*, the *orography factor*, and the *type of slope* for a site with:

– an actual length of the upwind slope in the wind direction: $L_u = 250\ \mathrm{m}$

– an actual length of the downwind slope in the wind direction: $L_d = 100\ \mathrm{m}$

– a vertical distance from the ground level of the site: $z = 10\ \mathrm{m}$

– an effective height of the feature: $H = 50\ \mathrm{m}$

– an horizontal distance of the site from the top of the crest: $|x| = 160\ \mathrm{m}$.

[*Reference sheet:* Annex A]-[*Cell-Range: A1:N1-A120:N120*].

Solution: Upstream slope in the wind direction: $\Phi = H/L_u = 50/250 = 0,20$. From Table A.2 *"Values of the effective length L_e"*:

Type of slope (Φ = H/L_u)	
Shallow $(0,05 < \Phi < 0,3)$: $L_e = L_u$	Steep $(\Phi > 0,3)$: $L_e = H/0,3$

Table 27.61 From Table A.2.

orography factor for $(0,05 < \Phi < 0,3)$: $c_0 = 1 + 2s \cdot \Phi$. Effective length: $L_e = L_u = 250\ m$. The orography factor, $c_o(z) = v_m/v_{mf}$ accounts for the increase of mean wind speed over isolated hills and escarpments (not undulating and mountainous regions). It is related to the wind velocity at the base of the hill or escarpment. The effects of orography should be taken into account in the following situations:

a) for sites on upwind slopes of hills and ridges:

– where $0,05 < \Phi \le 0,3$ and $|x| = 160\ m \le L_u/2 = 125\ m$ [Case Not Applicable]

b) for sites on downwind slopes of hills and ridges:

– where $\Phi < 0,3$ and $x = 160\ m < L_d/2 = 50\ m$ [Case Applicable]

– where $\Phi = 0,20 \ge 0,30$ [Case Not Applicable] and $x < 1,6H$

c) for sites on upwind slopes of cliffs and escarpments:

– where $\Phi < 0,3$ and $|x| \le L_u/2 = 125\ m$ [Case Not Applicable]

d) for sites on downwind slopes of cliffs and escarpments:

– where $\Phi < 0,3$ and $x = 160\ m < 1,5L_e = 375\ m$ [Case Applicable]

– where $\Phi \ge 0,3$ [Case Not Applicable] and $x < 5H$.

a) Upwind section for all orography (see Figures A.2 and A.3):

In this case, considering $x = -160\ m$, for the range $-1,5 \le x/L_u \le 0$ and $0 \le z/L_e \le 2,0$, we have: $-1,5 \le -160/250 \le 0$ and $0 \le 10/250 \le 2,0$. [Case Applicable]

Therefore, with $z/L_e = 0,04$, we get:

$$A = 0,1552 \cdot \left(\frac{z}{L_e}\right)^4 - 0,8575 \cdot \left(\frac{z}{L_e}\right)^3 + 1,8133 \cdot \left(\frac{z}{L_e}\right)^2 - 1,9115 \cdot \left(\frac{z}{L_e}\right) + 1,0124$$

$$A = 0,1552 \cdot (0,04)^4 - 0,8575 \cdot (0,04)^3 + 1,8133 \cdot (0,04)^2 - 1,9115 \cdot (0,04) + 1,0124$$

$$A = 3,97 \times 10^{-7} - 548,8 \times 10^{-7} + 0,00290 - 0,07646 + 1,0124 = 0,9388.$$

$$B = 0,3542 \cdot \left(\frac{z}{L_e}\right)^2 - 1,0577 \cdot \left(\frac{z}{L_e}\right) + 2,6456 = 0,3542 \cdot (0,04)^2 - 1,0577 \cdot (0,04) + 2,6456$$

$B = 0,000567 - 0,04231 + 2,6456 = 2,6039$. Therefore, with $x/L_u = -0,64$, we get:

$$s = A \cdot \exp\left(B \cdot \frac{x}{L_u}\right) = 0,9388 \cdot \exp(-2,6039 \cdot 0,64) = 0,1773.$$

b) downwind section for cliffs and escarpments (Figure A.2):

In this case, considering $x = +160\ m$, for the range $0,1 \le x/L_e \le 3,5$ and $0,1 \le z/L_e \le 2,0$, we have: $0,1 \le 160/250 \le 3,5$ and $0,1 \le 10/250 \le 3,5$. [Case Not Applicable]

Therefore, with $z/L_e = 0,04$, we get:

$$A = -1,3420 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 - 0,8222 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 + 0,4609 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) - 0,0791$$

$$A = -1,3420 \cdot (\log[0,04])^3 - 0,8222 \cdot (\log[0,04])^2 + 0,4609 \cdot (\log[0,04]) - 0,0791$$

$$A = 3,66622 - 1,60677 - 0,64431 - 0,0791 = 1,3360.$$

$$B = -1,0196 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 - 0,8910 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 + 0,5343 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) - 0,1156$$

$$B = -1,0196 \cdot (\log[0,04])^3 - 0,8910 \cdot (\log[0,04])^2 + 0,5343 \cdot (\log[0,04]) - 0,1156$$

$$B = 2,78545 - 1,74122 - 0,74692 - 0,1156 = 0,1817.$$

$$C = 0,8030 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^3 + 0,4236 \cdot \left(\log\left[\frac{z}{L_e}\right]\right)^2 - 0,5738 \cdot \left(\log\left[\frac{z}{L_e}\right]\right) + 0,1606$$

$$C = 0,8030 \cdot (\log[0,04])^3 + 0,4236 \cdot (\log[0,04])^2 - 0,5738 \cdot (\log[0,04]) + 0,1606$$

$$C = -2,19372 + 0,82781 + 0,80214 + 0,1606 = -0,4032.$$

Therefore, with $x/L_e = 160/250 = 0,64$, we get:

$$s = A \cdot \left(\log\left[\frac{x}{L_e}\right]\right)^2 + B \cdot \left(\log\left[\frac{x}{L_e}\right]\right) + C = 1,3360 \cdot (\log[0,64])^2 + 0,1817 \cdot (\log[0,64]) - 0,4032$$

$$s = 0,05019 - 0,03522 - 0,4032 = -0,3882.$$

EXAMPLE 27-CQ- Numerical calculation of orography coefficients - **test2b**

Given: Assume that it is valid the case "*b) Downwind section for cliffs and escarpments*" within the range: $0 \le x/L_e \le 0,1$ with $x/L_e = 10/250 = 0,08$ and $z/L_e = 10/250 = 0,04$.

[*Reference sheet:* Annex A]-[*Cell-Range: A127:N127-A158:N158*].

Solution: Referring to the calculations above, we find with $x/L_e = 0,1$:

$A(x/L_e) = A(0,1) = -0,0202$; $B(x/L_e) = B(0,1) = -0,5213$;

$C(x/L_e) = C(0,1) = 0,3550$ (reference cells: U109; U112 and U115).

We get with $x/L_e = 0,1$:

$$s = A \cdot \left(\log\left[\frac{x}{L_e}\right]\right)^2 + B \cdot \left(\log\left[\frac{x}{L_e}\right]\right) + C = -0,0202 \cdot (\log[0,1])^2 - 0,5213 \cdot (\log[0,1]) + 0,3550$$

$$s(0,1) = -0,02 + 0,5213 + 0,3550 = 0,856.$$

Linear interpolation:

$$s(x/L_e) = s(0,08) = \frac{(0,9388 - 0,8561) \cdot (0,1 - 0,08)}{0,1} + 0,8561 = 0,8726.$$

with $x/L_e = 0$ for:

$$s(0) = A = 0,1552 \cdot \left(\frac{z}{L_e}\right)^4 - 0,8575 \cdot \left(\frac{z}{L_e}\right)^3 + 1,8133 \cdot \left(\frac{z}{L_e}\right)^2 - 1,9115 \cdot \left(\frac{z}{L_e}\right) + 1,0124 = 0,9388$$

(see previous example with $z/L_e = 0,04$).

example-end

EXAMPLE 27-CR- Numerical calculation of orography coefficients - **test2c**

Given: Find the orography location factor for "c) *Downwind section for hills and ridges*". Let us assume the same assumptions in the previous example.

[*Reference sheet:* Annex A]-[*Cell-Range: A162:N162-A180:N180*].

Solution: In this case, we are in the range: $0 \le x/L_d \le 2,0$ and $0 \le z/L_e \le 2,0$. In particular, from the previous examples we have: $x/L_d = 0,20$ and $z/L_e = 0,04$ with

$$A = 0,1552 \cdot \left(\frac{z}{L_e}\right)^4 - 0,8575 \cdot \left(\frac{z}{L_e}\right)^3 + 1,8133 \cdot \left(\frac{z}{L_e}\right)^2 - 1,9115 \cdot \left(\frac{z}{L_e}\right) + 1,0124$$

$$A = 0,1552 \cdot (0,04)^4 - 0,8575 \cdot (0,04)^3 + 1,8133 \cdot (0,04)^2 - 1,9115 \cdot (0,04) + 1,0124$$

$A = 0,9388$ (see example 27-CP on page 283).

$$B = -0,3056 \cdot \left(\frac{z}{L_e}\right)^2 + 1,0212 \cdot \left(\frac{z}{L_e}\right) - 1,7637$$

$$B = -0,3056 \cdot (0,04)^2 + 1,0212 \cdot (0,04) - 1,7637$$

$$B = -0,000489 + 0,040848 - 1,7637 = -1,7233.$$

We find:

$$s = A \cdot \exp\left(B \cdot \frac{x}{L_d}\right) = 0,9388 \cdot \exp(-1,7233 \cdot 0,20) = 0,665.$$

In this case, the orography factor is given by:

$$c_0(z) = 1 + 2s \cdot \Phi = 1 + 2 \cdot 0,665 \cdot 0,20 = 1,266.$$

example-end

EXAMPLE 27-CS- Neighbouring structures - **test3**

Given: Find the height $z_n = z_e$ above ground at which the peak velocity pressure may be based on for structure influenced by a high rise building. Assume:

– height of the tallest building: $h_{high} = 60$ m

– plan dimensions of the tallest building: $d_{large} = 20$ m; $d_{small} = 15$ m

– average height of the neighbouring structures: $h_{ave} = 20$ m

– height of the nearby structure: $h_{low} = 20$ m

– distance "x" of the considered structure from the tallest building: $x = 10$ m.

[*Reference sheet:* Annex A]-[*Cell-Range: A254:N254-A287:N287*].

Solution: For $h_{high} > 2d_{large} = 40$ m we have: $r = 2d_{large} = 40$ m (radius).

As determined by the Standard, for $x \leq r$: $z_n = 0,5r = 20$ m. In this case, increased wind velocities can't be disregarded: $h_{low} \leq 0,5h_{high}$. The considered building ($h_{low} = 20$ m) is more than twice as high as the average height $h_{ave} = 20$ m of the neighbouring structures:

$h_{high} \geq 2h_{ave}$ then, as a first approximation, the design of any of those nearby structures may be based on the peak velocity pressure calculated at height $z_n = 20$ m.

example-end

EXAMPLE 27-CT- Displacement height - **test4**

Given: Find the displacement height h_{dis} for:

– an average height of the neighbouring structures: $h_{ave} = 20$ m

– an height of the building: $h = 35$ m

– a distance building from nearby structures: $x = 45$ m.

[*Reference sheet:* Annex A]-[*Cell-Range: A312:N312-A328:N328*].

Solution: In this case, for the range $2h_{ave} < x < 6h_{ave}$, we get: $h_{dis} = \min[(1,2 \cdot h_{ave} - 0,2 \cdot x); 0,6h]$

$h_{dis} = \min[(1,2 \cdot 20 - 0,2 \cdot 45); 0,6 \cdot 35] = \min[15; 21] = 15$ m.

In the absence of more accurate information the obstruction height may be taken as $h_{ave} = 15$ m for terrain category IV.

example-end

27.7 References [Section 27]

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).

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