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Project:	SR-8-s1
Subject:	
Designer:	
Date:	

Eurocode 1

Wind Load on prism elements with Rectangular cross-section (force coefficient)

Description:
Calculation of wind load action effects on prism elements with rectangular cross-section. The total horizontal wind force is calculated from the force coefficient corresponding to the overall effect of the wind action on the structure

According to:
EN 1991-1-4:2005+A1:2010 Section 7.6

Applicable for:
Structures with rectangular plan, isolated elements with rectangular cross-section

Input

Basic wind velocity $v_b =$ 41 m/s

Terrain category = II ▾

Illustration of Terrain categories reproduced from EN1991-1-4 Annex A

Dimension of rectangular cross-section parallel to the wind direction $d =$ 0.2 m

Dimension of rectangular cross-section perpendicular to the wind direction $b =$ 0.82 m

Radius of rounded corners of cross-section $r =$ 0.01 m

Length of the element

	$l =$ 0.11	m
Maximum height above ground of the element	$z =$ 8.36	m
Orography factor at reference height z_e	$c_0(z_e) =$ 1	
Structural factor	$c_s c_d =$ 1	

Results

Effective wind pressure $w_{eff} = 2.824\ kN/m^2$

Total wind horizontal force $F_w = 0.255\ kN$

Notes

1. The calculated effective wind pressure w_{eff} and total wind force F_W correspond to the total wind action effects and they are appropriate for global verifications of the element according to the force coefficient method. For local verifications, appropriate wind pressure on local surfaces must be estimated according to the relevant external pressure coefficients, as specified in EN1991-1-4 Section 7
2. For plate-like sections (d/b < 0.2) lift forces at certain wind angles of attack may give rise to higher values of the force coefficient c_f, up to an increase of 25%, as specified in EN1991-1-4 §7.6(3).
3. The calculated wind action effects are characteristic values (unfactored). Appropriate load factors should be applied for the relevant design situation. For ULS verifications the partial load factor γ_Q = 1.50 is applicable for variable actions.

Details

Input Data

- Basic wind velocity: v_b = 41 m/s
- Terrain category: = II
- Dimension of rectangular cross-section parallel to the wind direction: d = 0.2 m
- Dimension of rectangular cross-section perpendicular to the wind direction: b = 0.82 m
- Radius of rounded corners of cross-section: r = 0.01 m
- Length of the element: l = 0.11 m
- Maximum height above ground of the element: z = 8.36 m
- Orography factor at reference height z_e: $c_0(z_e)$ = 1
- Structural factor: $c_s c_d$ = 1

Calculation of peak velocity pressure

Reference area and height

The reference height for the wind action z_e is equal to the maximum height above ground of the section being considered, as specified in *EN1991-1-4 §7.6(2)*. The reference area for the wind action A_{ref} is the projected area of the element being considered, as specified in *EN1991-1-4 §7.6(2)*. Therefore:

$z_e = z = 8.360$ m

$A_{ref} = b \cdot l = 0.820 \text{ m} \cdot 0.110 \text{ m} = 0.09 \text{ m}^2$

Basic wind velocity

The basic wind velocity v_b is defined in *EN1991-1-4 §4.2(2)P* as a function of the wind direction and time of year at 10 m above ground of terrain category II. It is calculated as:

$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$

where $v_{b,0}$ is the fundamental value of the basic wind velocity which is defined in *EN1991-1-4 §4.2(1)P* as the characteristic 10 minutes mean wind velocity at 10m above ground level for terrain category II. The value of $v_{b,0}$ is provided in the National Annex based on the climatic conditions of the region where the structure is located. The influence of altitude on the basic wind velocity v_b may also be specified in the National Annex.

The directional factor c_{dir} and the seasonal factor c_{season} are defined in *EN1991-1-4 §4.2(2)P* and they take into account the effects of wind direction and time of the year. Their values are generally equal to c_{dir} = 1.0 and c_{season} = 1.0. The National Annex may specify values of c_{dir} and c_{season} different than 1.0.

In the following calculations the basic wind velocity is considered as v_b = 41.00 m/s.

Terrain roughness

The roughness length z_0 and the minimum height z_{min} are specified in *EN1991-1-4 Table 4.1* as a function of the terrain category. For terrain category II the corresponding values are z_0 = 0.050 m and z_{min} = 2.0 m.

The terrain factor k_r depending on the roughness length z_0 = 0.050 m is calculated in accordance with *EN1991-1-4 equation (4.5)*:

$k_r = 0.19 \cdot (z_0 / z_{0,II})^{0.07} = 0.19 \cdot (0.050 \text{ m} / 0.050 \text{ m})^{0.07} = 0.1900 \text{ m}$

The roughness factor $c_r(z_e)$ at the reference height z_e accounts for the variability of the mean wind velocity at the site of the structure due to the height above ground level and the ground roughness of the terrain upwind of the structure. It is calculated in accordance with *EN1991-1-4 equation 4.4*.

For the case where $z_e \geq z_{min}$:

$c_r(z_e) = k_r \cdot \ln(z_e / z_0) = 0.1900 \text{ m} \cdot \ln(8.360 \text{ m} / 0.050 \text{ m}) = 0.9726$

Orography factor

Where orography (e.g. hills, cliffs etc.) increases wind velocities by more than 5% the effects should be taken into account using an orography factor $c_0(z_e)$ different than 1.0, as specified in *EN1994-1-1 §4.3.3*. In general the effects of orography may be neglected when the average slope of the upwind terrain is less than 3° up to a distance of 10 times the height of the isolated orographic feature.

In the following calculations the orography factor is considered as $c_0(z_e)$ = 1.000.

Mean wind velocity

The mean wind velocity $v_m(z_e)$ at reference height z_e depends on the terrain roughness, terrain orography and the basic wind velocity v_b. It is determined using *EN1991-1-4 equation (4.3)*:

$v_m(z_e) = c_r(z_e) \cdot c_0(z_e) \cdot v_b = 0.9726 \cdot 1.000 \cdot 41.00 \text{ m/s} = 39.88 \text{ m/s}$

Wind turbulence

The turbulence intensity $I_v(z_e)$ at reference height z_e is defined as the standard deviation of the turbulence divided by the mean wind velocity. It is calculated in accordance with *EN1991-1-4 equation*

4.7.

For the case where $z_e \geq z_{min}$:

$I_v(z_e) = k_I / [\ c_0(z_e) \cdot \ln(z_e / z_0)\ ] = 1.000 / [\ 1.000 \cdot \ln(8.360\ m / 0.050\ m)\ ] = 0.1953$

where the turbulence factor is considered as $k_I = 1.000$ in accordance with *EN1991-1-4 §4.4(1)*.

Basic velocity pressure

The basic velocity pressure q_b is the pressure corresponding to the wind momentum determined at the basic wind velocity v_b. The basic velocity pressure is calculated according to the following fundamental relation, as specified in *EN1991-14 §4.5(1)*:

$q_b = (1/2) \cdot \rho \cdot v_b^2 = (1/2) \cdot 1.25\ kg/m^3 \cdot (41.00\ m/s)^2 = 1.051\ kN/m^2$

where the density of the air is considered as $\rho = 1.25\ kg/m^3$ in accordance with *EN1991-1-4 §4.5(1)*.

Peak velocity pressure

The peak velocity pressure $q_p(z_e)$ at reference height z_e includes mean and short-term velocity fluctuations. It is determined according to *EN1991-1-4 equation 4.8* as:

$q_p(z_e) = (1 + 7 \cdot I_v(z_e)) \cdot (1/2) \cdot \rho \cdot v_m(z_e)^2 = (1 + 7 \cdot 0.1953) \cdot (1/2) \cdot 1.25\ kg/m^3 \cdot (39.88\ m/s)^2 = 2.353\ kN/m^2$

where the density of the air is considered as $\rho = 1.25\ kg/m^3$ in accordance with *EN1991-1-4 §4.5(1)*.

The exposure factor $c_e(z_e) = 2.2397$ is defined as the ratio of peak velocity pressure to basic velocity pressure:

$c_e(z_e) = q_p(z_e) / q_b = 2.353\ kN/m^2 / 1.051\ kN/m^2 = 2.2397$

Therefore the peak velocity pressure is calculated as $q_p(z_e) = 2.353\ kN/m^2$.

Calculation of wind forces on the structure

The wind force on the structure F_w for the overall wind effect is estimated according to the force coefficient method as specified in *EN1991-1-4 §5.3*.

$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref}$

Structural factor

The structural factor $c_s c_d$ takes into account the structure size effects from the non-simultaneous occurrence of peak wind pressures on the surface and the dynamic effects of structural vibrations due to turbulence. The structural factor $c_s c_d$ is determined in accordance with *EN1991-1-4 Section 6*. A value of $c_s c_d = 1.0$ is generally conservative for small structures not-susceptible to wind turbulence effects such as buildings with height less than 15 m or framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth.

In the following calculations the structural factor is considered as $c_s c_d = 1.000$.

Effective slenderness

The effective slenderness λ depends on the aspect ratio and the position of the structure and it is given in *EN1991-1-4 §7.13(2)*.

For elements with rectangular cross-section and length $l \leq 15$ m the effective slenderness λ is equal to:

$\lambda_{15} = \min(2.0 \cdot l / b, 70) = \min(2.0 \cdot 0.110\ m / 0.820\ m, 70) = 0.268$

For elements with rectangular cross-section and length $l \geq 50$ m the effective slenderness λ is equal to:

$$\lambda_{50} = \min(1.4 \cdot l\ /\ b, 70) = \min(1.4 \cdot 0.110\ \text{m}\ /\ 0.820\ \text{m}, 70) = 0.188$$

Therefore $\lambda = \lambda_{15} = 0.268$

End effect factor

The end effect factor ψ_λ takes into account the reduced resistance of the structure due to the wind flow around the end (end-effect). The value of ψ_λ is calculated in accordance with *EN1991-1-4 §7.13* . For solid structures (i.e. solidity ratio $\varphi = 1.000$) the value of the end effect factor ψ_λ is determined from *EN1991-1-4 Figure 7.36* as a function of the slenderness λ.

The estimated value for the end effect factor is $\psi_\lambda = 0.600$

Reduction factor for rounded corners

The reduction factor ψ_r takes into account the effect of rounded corners. The value of ψ_r is calculated in accordance with *EN1991-1-4 §7.6(1)* .

The value of the reduction factor ψ_r is determined from *EN1991-1-4 Figure 7.24* as a function of the normalized radius r/b.

For $r = 0.010$ m, $b = 0.820$ m, $r/b = 0.012$ The estimated value for the reduction factor for rounded corners is $\psi_r = 0.970$

Force coefficient without free-end flow

For elements with rectangular cross-section the force coefficient without free-end flow $c_{f,0}$ depends on the aspect ratio d/b of the cross-section. The force coefficient without free-end flow $c_{f,0}$ is specified in *EN1991-1-4 §7.6(1)*. The value of $c_{f,0}$ is determined according to *EN1991-1-4 Figure 7.23* for the values of $d = 0.200$ m, $b = 0.820$ m, $d/b = 0.244$.

The estimated value for the force coefficient without free-end flow is $c_{f,0} = 2.063$

Force coefficient

The force coefficient c_f for prism elements with rectangular cross-section is given in *EN1991-1-4 §7.6(1)* as:

$$c_f = c_{f,0} \cdot \psi_r \cdot \psi_\lambda$$

where $c_{f,0}$ is the force coefficient without free-end flow, ψ_r is the reduction factor for rounded corners, and ψ_λ the end effect factor, as calculated above. Therefore:

$$c_f = c_{f,0} \cdot \psi_r \cdot \psi_\lambda = 2.063 \cdot 0.970 \cdot 0.600 = 1.200$$

Total wind force

The total wind force on the structure F_w is estimated as:.

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref} = 1.000 \cdot 1.200 \cdot 2.353\ \text{kN/m}^2 \cdot 0.09\ \text{m}^2 = 0.255\ \text{kN}$$

The total wind force F_w takes into account the overall wind effect. The corresponding effective wind pressure w_{eff} on the reference wind area A_{ref} is equal to:

$$w_{eff} = F_w\ /\ A_{ref} = 0.255\ \text{kN}\ /\ 0.09\ \text{m}^2 = 2.824\ \text{kN/m}^2$$

Additonal notes

- The effective pressure w_{eff} = 2.824 kN/m^2 is appropriate for global verifications of the structure according to the force coefficient method. It is not appropriate for local verifications of structural elements. For the latter case appropriate wind pressure on local surfaces must be estimated according to the relevant pressure coefficients, as specified in *EN1991-1-4 Section 7*.
- The calculated wind action effects are characteristic values (unfactored). Appropriate load factors should be applied for the relevant design situation. For ULS verifications the partial load factor γ_Q = 1.50 is applicable for variable actions according to EN1990.

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