Customer: Mountain Intl. – Project reference: Mountain side Restaurant
Executed by Vincent Juhel Ouaip, on Friday, 22 March 2019.
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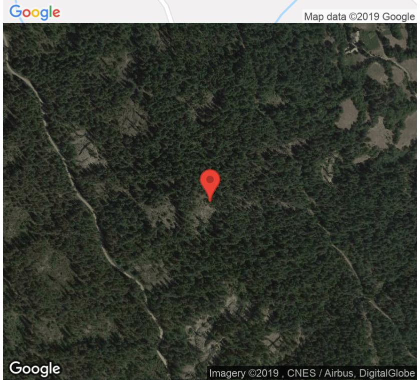
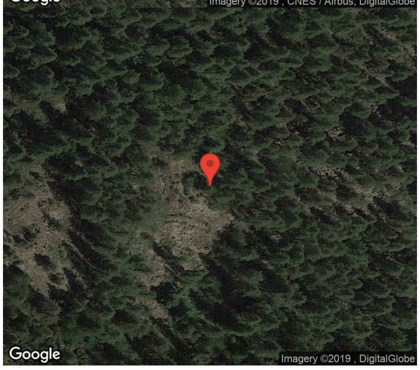
Global data

Building address: Unnamed Road, 05100 Briançon, France
Altitude: 1,538 m Gravity: 9.801 N/kg
Eurocodes standards :

- *basis : EN 1990 (03/2003) + FR NA (12/2011)*
  (Consequences class CC2 = Medium consequence for loss of human life, economic, social or environmental consequences considerable.)
- *snow loads : EN 1991-1-3 (07/2003) + FR NA (05/2007)*
- *wind actions : EN 1991-1-4 (2005) + FR NA (03/2008)*
- *seismic actions : EN 1998-1 (12/2004) + FR NA (12/2013)*
- *fire actions : EN 1991-1-2 (11/2002) + FR NA (02/2007)*





Wind

The building is located in wind zone 1.

Wind standard

The standard applicable for wind load calculation on this building is *EN 1991-1-4 (2005)* and its national annex *FR NA (03/2008)*.

Fundamental values of the basic wind velocity

The fundamental value of the basic wind velocity, v_{b0}, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in terrain of 'open country' type.
The fundamental values of the basic wind velocity are specified by the National Annex.
This one provides a country map divided into climatic zones.
For the zone 1, the specified value of the velocity is: $v_{b0} = 22$ m/s .

Basic wind velocity v_b on the building site during a period of 50 years

Probability coefficient of exceeding

The probability p of exceedance is considered on the useful life of the project, itself based on the use of the project.
The design working lives are given in the NF EN 1990 /NA Tableau 2.1(NF) depending on the use.
For our building project, the use is "ERP", the recommended duration of use, necessary for determining the return period, is therefore 50 years.
The 10 minutes mean wind velocity having the probability p for an annual exceedence is determined by multiplying the basic wind velocity v_b by the probability factor of severe wind c_{prob}:

$$c_{prob} = \left(\frac{1 - K \cdot \ln(-\ln(1-p))}{1 - K \cdot \ln(-\ln(0.98))}\right)^n$$ *(NF EN 1991-1-4 Equation 4.2)*

$$c_{prob} = \left(\frac{1 - 0.15 \cdot \ln(-\ln(1 - \frac{1}{50.0}))}{1 - 0.15 \cdot \ln(-\ln(0.98))}\right)^{0.5}$$

$$c_{prob} = 1.0000$$

Directional factor of wind

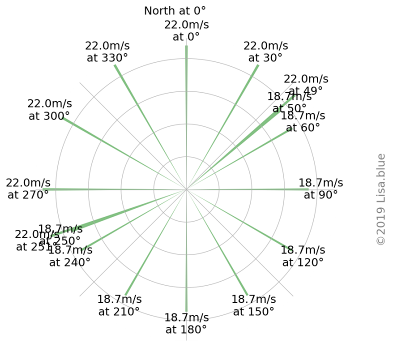
'wind direction' means the direction from which the wind comes.
By convention, this direction is indicated by the angle it forms with the North, increasing from 0° to 360° in the direction of clockwise.
High velocities of wind are observed more frequently in some sectors directions; the directional factor allows a reduction when the wind comes from a direction where the probability of occurrence of severe winds is lesser.
The envisaged reduction should be permitted in all the nominal wind sector considered to be validly adopted.
The impact of this reduction is important because the coefficient c_{dir} is taken into account when calculating the velocity and that the wind pressure is evaluated from the square of this velocity.

The values of the directional factor of wind $c_{dir,\ zone\ 3}$ for different wind directions are indicated in the NF EN 1991-1-4 Figure 4.4(NA).

Season factor

The value of the season factor c_{season} is given in the NF EN 1991-1-4 Figure 4.5(NA).
It is considered here that the project duration is longer than 1 year and does not allow for seasonal decrease in the risk of strong winds, therefore $c_{season} = 1$.

The basic wind velocity v_b on the building site, defined for each direction of the wind at 10 m above ground level in terrain of 'open country' type falling into the terrain category II, is shown in the graph below:

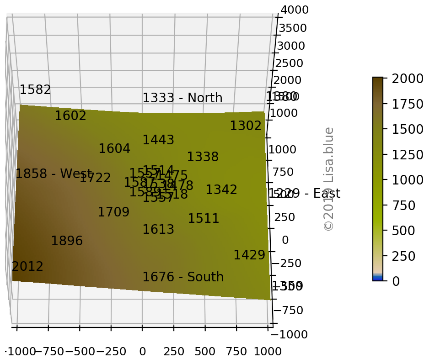


with: $v_b = (c_{dir} \cdot c_{season} \cdot v_{b0}) \cdot c_{prob}$ *(EN 1991-1-4 Equation 4.1)*

Orography

The altitudes are arbitrarily identified at 150m, 500m and 1000m around the construction.

A 3D interpolation of these points allows to evaluate the shape of the terrain in the vicinity of the construction shown in the graph below:



Peak velocity pressure q_p

For each surfaces of the building, wind effects are observed in 4 nominal angular sectors of 90°:

- the highest basic wind velocity v_b contained in each of its sectors is retained
- this velocity is amplified by the orography factor c_o taking into account the relief of the terrain.
- it is then adjusted taking account of the impact of terrain roughness on the variability of the mean wind velocity.
- the peak velocity pressure q_p is finally calculated with taking account of the density of air and the rapid fluctuations in velocity.

Roof top

- Wind from 25° :
  - Effect from orography
    Orographic profile = Cliffs and escarpments upwind
    Mean slope = -29.7 %
    $c_o(z) = 1 + s_{max} \cdot \left(1 - \frac{|X|}{k_{red} \cdot L}\right) \cdot e^{\frac{-\alpha \cdot z}{L}}$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*
    $c_o(z) = 1 + 0.65 \cdot \left(1 - \frac{|1000.0|}{1.5 \cdot 1188.0}\right) \cdot e^{\frac{-2.5 \cdot 297.0}{1188.0}}$
    $c_o(z) = 1.153$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*

    with:
    - effective length of the upwind slope :
      $L = 2 \cdot h = 2 \cdot 594.0 = 1188.0$ m
    - actual length of the upwind slope in the wind direction : L_u = -2,000 m
    - effective height of the feature : H = 594 m
    - horizontal distance of the site from the top of the crest : X = 1,000 m
    - vertical distance from the ground level of the site to the top of the crest : z = 297.0 m
    - orographic location factor :
      $s = 1.3 \cdot \frac{H}{L} = 1.3 \cdot \frac{594.0}{1188.0} = 0.650$
  - Effect from terrain roughness:
    Terrain category IIIa *(National annex to EN 1991-1-4 §4.3.2(1))*
    Campaign with hedges, vineyards, grove, sparsely populated
    - terrain factor:
      $k_r = 0.19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0.07}$ *(EN 1991-1-4 equation 4.5)*
      $k_r = 0.19 \cdot \left(\frac{0.2}{0.05}\right)^{0.07}$
      $k_r = 0.2094$
    - height above ground level or the minimum height depending on the terrain category:
      z = 20.000 m
    - roughness factor:
      $c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right)$ *(EN 1991-1-4 equation 4.4)*
      $c_r(z) = 0.2094 \cdot \ln\left(\frac{20.0}{0.2}\right)$
      $c_r(z) = 0.964$
  - Peak velocity pressure:
    $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot 0.5 \cdot \rho \cdot v_m^2(z)$ *(NF EN 1991-1-4 equation 4.8)*
    $q_p(z) = [1 + 7 \cdot 0.183] \cdot 0.5 \cdot 1.225 \cdot 24.45^2$
    $q_p(z) = 0.835$ kN/m²

with:

- mean wind velocity:
  $v_m(z) = v_b \cdot c_r(z) \cdot c_o(z)$ *(NF EN 1991-1-4 equation 4.3)*
  $v_m(z) = 22.0 \cdot 0.964 \cdot 1.153$
  $v_m(z) = 24.450$ m/s
- air density:
  $\rho = 1.225$kg/m^3 *(NF EN 1991-1-4 clause 4.5(1) NOTE 2)*
- turbulence factor:
  $k_l = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(z_0) + 3)^6$ *(NF EN 1991-1-4 equation 4.19-NA)*
  $k_l = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(0.2) + 3)^6$
  $k_l = 0.970$
- turbulence intensity:
  $i_v = \frac{k_l}{c_o(z) \cdot \ln\left(\frac{z}{z_0}\right)}$ *(NF EN 1991-1-4 equation 4.7)*
  $i_v = \frac{0.97}{1.153 \cdot \ln\left(\frac{20.0}{0.2}\right)}$
  $i_v = 0.183$

- Wind from 115° :
  - Effect from orography
    Orographic profile = Complex: obstacles of various heights and shapes
    Mean slope = -13.2 %
    $c_o(z) = 1 + 0.004 \cdot \left(A_C - \frac{2 \cdot A_C + \sum_{A_{500}} + \sum_{A_{1000}}}{18}\right) \cdot e^{-0.014 \cdot \max_{(10, z-10)}}$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 1)*
    $c_o(z) =$
    $1 + 0.004 \cdot \left(1538 - \frac{2 \cdot 1538 + (1443 + 1338 + 1342 + 1511 + 1613 + 1709 + 1722 + 1604) + (1333 + 1302 + 1229 + 1429 + 1676 + 1896 + 1858 + 1602)}{18}\right) \cdot e^{-0.014 \cdot \max_{(10, 10.0)}}$
    $c_o(z) = 1$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 1)*

  - Effect from terrain roughness:
    Terrain category IIIa *(National annex to EN 1991-1-4 §4.3.2(1))*
    Campaign with hedges, vineyards, grove, sparsely populated
    - terrain factor:
      $k_r = 0.19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0.07}$ *(EN 1991-1-4 equation 4.5)*
      $k_r = 0.19 \cdot \left(\frac{0.2}{0.05}\right)^{0.07}$
      $k_r = 0.2094$
    - height above ground level or the minimum height depending on the terrain category:
      z = 20.000 m
    - roughness factor:
      $c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right)$ *(EN 1991-1-4 equation 4.4)*
      $c_r(z) = 0.2094 \cdot \ln\left(\frac{20.0}{0.2}\right)$
      $c_r(z) = 0.964$

  - Peak velocity pressure:
    $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot 0.5 \cdot \rho \cdot v_m^2(z)$ *(NF EN 1991-1-4 equation 4.8)*
    $q_p(z) = [1 + 7 \cdot 0.211] \cdot 0.5 \cdot 1.225 \cdot 18.033^2$
    $q_p(z) = 0.493$ kN/m²

    with:
    - mean wind velocity:
      $v_m(z) = v_b \cdot c_r(z) \cdot c_o(z)$ *(NF EN 1991-1-4 equation 4.3)*
      $v_m(z) = 18.7 \cdot 0.964 \cdot 1.0$
      $v_m(z) = 18.033$ m/s
    - air density:
      $\rho = 1.225$kg/m^3 *(NF EN 1991-1-4 clause 4.5(1) NOTE 2)*
    - turbulence factor:
      $k_l = c_o(z) \cdot \left[1 - 2 \cdot 10^{-4} \cdot (\log_{10}(z_0) + 3)^6\right]$ *(NF EN 1991-1-4 equation 4.20-NA)*
      $k_l = 1.0 \cdot \left[1 - 2 \cdot 10^{-4} \cdot (\log_{10}(0.2) + 3)^6\right]$
      $k_l = 0.971$
    - turbulence intensity:
      $i_v = \frac{k_l}{c_o(z) \cdot \ln\left(\frac{z}{z_0}\right)}$ *(NF EN 1991-1-4 equation 4.7)*
      $i_v = \frac{0.971}{1.0 \cdot \ln\left(\frac{20.0}{0.2}\right)}$
      $i_v = 0.211$

- Wind from 205° :
  - Effect from orography
    Orographic profile = Cliffs and escarpments downwind
    Mean slope = 35.8 %
    $c_o(z) = 1 + s_{max} \cdot \left(1 - \frac{|X|}{k_{red} \cdot L}\right) \cdot e^{\frac{-\alpha \cdot z}{L}}$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*
    $c_o(z) = 1 + 0.65 \cdot \left(1 - \frac{|1000.0|}{4.0 \cdot 716.0}\right) \cdot e^{\frac{-2.5 \cdot 358.0}{716.0}}$
    $c_o(z) = 1.121$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*

    with:
    - effective length of the upwind slope :
      $L = 2 \cdot h = 2 \cdot 358.0 = 716.0$ m
    - actual length of the upwind slope in the wind direction : L_u = 1,000 m
    - effective height of the feature : H = 358 m

  - horizontal distance of the site from the top of the crest : X = 1,000 m
  - vertical distance from the ground level of the site to the top of the crest : z = 358.0 m
  - orographic location factor :
    $s = 1.3 \cdot \frac{H}{L} = 1.3 \cdot \frac{358.0}{716.0} = 0.650$

- Effect from terrain roughness:
  Terrain category IV *(National annex to EN 1991-1-4 §4.3.2(1))*
  Urban areas with at least 15% of the surface is covered with buildings whose average height is greater than 15 m; forests
  - terrain factor:
    $k_r = 0.19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0.07}$ *(EN 1991-1-4 equation 4.5)*
    $k_r = 0.19 \cdot \left(\frac{1.0}{0.05}\right)^{0.07}$
    $k_r = 0.2343$
  - height above ground level or the minimum height depending on the terrain category:
    z = 20.000 m
  - roughness factor:
    $c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right)$ *(EN 1991-1-4 equation 4.4)*
    $c_r(z) = 0.2343 \cdot \ln\left(\frac{20.0}{1.0}\right)$
    $c_r(z) = 0.702$

- Peak velocity pressure:
  $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot 0.5 \cdot \rho \cdot v_m^2(z)$ *(NF EN 1991-1-4 equation 4.8)*
  $q_p(z) = [1 + 7 \cdot 0.254] \cdot 0.5 \cdot 1.225 \cdot 14.718^2$
  $q_p(z) = 0.369\ kN/m^2$

  with:
  - mean wind velocity:
    $v_m(z) = v_b \cdot c_r(z) \cdot c_o(z)$ *(NF EN 1991-1-4 equation 4.3)*
    $v_m(z) = 18.7 \cdot 0.702 \cdot 1.121$
    $v_m(z) = 14.718\ m/s$
  - air density:
    $\rho = 1.225 kg/m^3$ *(NF EN 1991-1-4 clause 4.5(1) NOTE 2)*
  - turbulence factor:
    $k_l = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(z_0) + 3)^6$ *(NF EN 1991-1-4 equation 4.19-NA)*
    $k_l = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(1.0) + 3)^6$
    $k_l = 0.854$
  - turbulence intensity:
    $i_v = \frac{k_l}{c_o(z) \cdot \ln\left(\frac{z}{z_0}\right)}$ *(NF EN 1991-1-4 equation 4.7)*
    $i_v = \frac{0.854}{1.121 \cdot \ln\left(\frac{20.0}{1.0}\right)}$
    $i_v = 0.254$

- Wind from 295° :
  - Effect from orography
    Orographic profile = Hills chain downwind
    Mean slope = 11.7 %
    $c_o(z) = 1 + s_{max} \cdot \left(1 - \frac{|X|}{k_{red} \cdot L}\right) \cdot e^{\frac{-\alpha \cdot z}{L}}$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*
    $c_o(z) = 1 + 0.513 \cdot \left(1 - \frac{|500.0|}{1.5 \cdot 750.0}\right) \cdot e^{\frac{-3 \cdot 58.333}{750.0}}$
    $c_o(z) = 1.226$ *(NF EN 1991-1-4 Clause 4.3.3(1) PROCEDURE 2)*

    with:
    - effective length of the upwind slope :
      $L = \frac{L_u}{2} = \frac{1500.0}{2} = 750.0$ m
    - actual length of the upwind slope in the wind direction : L_u = 1,500 m
    - effective height of the feature : H = 175 m
    - horizontal distance of the site from the top of the crest : X = 500 m
    - vertical distance from the ground level of the site to the top of the crest : z = 58.3 m
    - orographic location factor :
      $s = 2.2 \cdot \frac{H}{L} = 2.2 \cdot \frac{175.0}{750.0} = 0.513$

  - Effect from terrain roughness:
    Terrain category IV *(National annex to EN 1991-1-4 §4.3.2(1))*
    Urban areas with at least 15% of the surface is covered with buildings whose average height is greater than 15 m; forests
    - terrain factor:
      $k_r = 0.19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0.07}$ *(EN 1991-1-4 equation 4.5)*
      $k_r = 0.19 \cdot \left(\frac{1.0}{0.05}\right)^{0.07}$
      $k_r = 0.2343$
    - height above ground level or the minimum height depending on the terrain category:
      z = 20.000 m
    - roughness factor:
      $c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right)$ *(EN 1991-1-4 equation 4.4)*
      $c_r(z) = 0.2343 \cdot \ln\left(\frac{20.0}{1.0}\right)$
      $c_r(z) = 0.702$

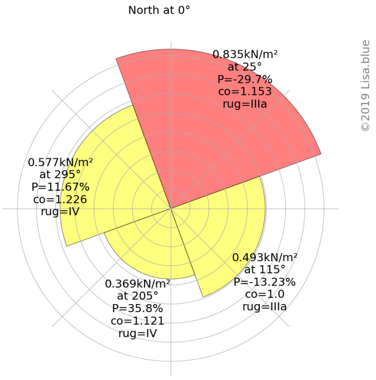
  - Peak velocity pressure:
    $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot 0.5 \cdot \rho \cdot v_m^2(z)$ *(NF EN 1991-1-4 equation 4.8)*
    $q_p(z) = [1 + 7 \cdot 0.233] \cdot 0.5 \cdot 1.225 \cdot 18.931^2$
    $q_p(z) = 0.577\ kN/m^2$

    with:
    - mean wind velocity:

$\mathrm{v_m(z)} = v_b \cdot c_r(z) \cdot c_o(z)$ *(NF EN 1991-1-4 equation 4.3)*
$\mathrm{v_m(z)} = 22.0 \cdot 0.702 \cdot 1.226$
$\mathrm{v_m(z)} = 18.931\ \mathrm{m/s}$

- air density:
  $\rho = 1.225\mathrm{kg/m^3}$ *(NF EN 1991-1-4 clause 4.5(1) NOTE 2)*
- turbulence factor:
  $\mathrm{k_l} = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(z_0) + 3)^6$ *(NF EN 1991-1-4 equation 4.19-NA)*
  $\mathrm{k_l} = 1 - 2 \cdot 10^{-4} \cdot (\log_{10}(1.0) + 3)^6$
  $\mathrm{k_l} = 0.854$
- turbulence intensity:
  $\mathrm{i_v} = \dfrac{k_l}{c_o(z) \cdot \ln\left(\dfrac{z}{z_0}\right)}$ *(NF EN 1991-1-4 equation 4.7)*
  $\mathrm{i_v} = \dfrac{0.854}{1.226 \cdot \ln\left(\dfrac{20.0}{1.0}\right)}$
  $\mathrm{i_v} = 0.233$

- The peak velocity pressures $\mathrm{q_p}$, applied on the surface Roof top at a level of 20m, are drawn on this graph for each sector of wind:



Maximum equivalent peak wind velocity (at the ridge Lvl +20.0m)

- 133 km/h to control the vibrations and the deformations of the structure at serviceability limit states (SLS).
  $\mathrm{v} = \sqrt{\dfrac{q_p}{0.5 * \rho}} \cdot 3.6 = \sqrt{\dfrac{835.0}{0.5 * 1.225}} \cdot 3.6 = 133\ \mathrm{km/h}$
- 163 km/h to control the resistance of the structure at ultimate limit state (ULS).
  $\mathrm{v} = \sqrt{\dfrac{1.5 \cdot q_p}{0.5 * \rho}} \cdot 3.6 = \sqrt{\dfrac{1.5 \cdot 835.0}{0.5 * 1.225}} \cdot 3.6 = 163\ \mathrm{km/h}$