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COMPARISON OF WIND ACTIONS ACCORDING TO EUROCODE AND PREVIOUS REGULATIONS

European norms for civil engineering structures, well known as Eurocodes, are set of highly harmonized codes regarding structural issues. Main rules and recommendations for calculation of wind actions on structures are given in EN 1991-1-4 which is the basic document. Also, some advanced analysis regarding wind actions on towers and masts are given in EN 1993-3-1, with the intention to be transferred in the basic document in the later phase. This paper contains a short presentation of the main rules and recommendations for wind action analysis and their comparison with previous regulations JUS (SRPS). The main focus of the paper is on wind action on buildings and comparative numerical example is also given. Some experiences and conclusions from the process of Serbian National Annex preparation are also presented.

Keywords: wind actions, structures, buildings, Eurocodes, JUS (SRPS), National Annex

1. INTRODUCTION

Wind actions on structures are covered by following parts of Eurocode EN 1991-1-4 [2] and EN 1993-3-1 [1]. The basic document for calculation of wind action on structures is [2], but some special problems regarding wind action on slender structures, such as steel towers, masts and chimneys are treated in [1]. EN 1991-1-4 is the main document for wind analysis and it consists of eight chapters (General, Design situations, Modeling of wind actions, Wind velocity and velocity pressure, Wind actions, Structural factor, Pressure and force coefficients, Wind action on bridges) and six informative annexes (A-F). In this paper, some of the most important parts of this code are presented, commented and compared with previous Yugoslavian codes for wind actions [4]-[7]. Special attention is paid on wind velocities and pressure, as well as a structural factor, pressure coefficients and wind analysis for buildings.

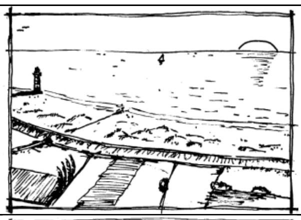
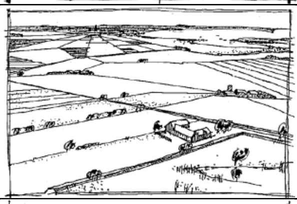
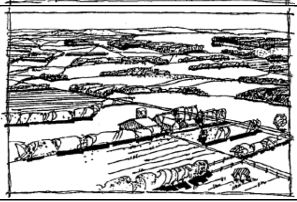
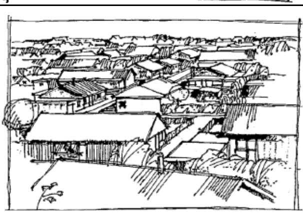
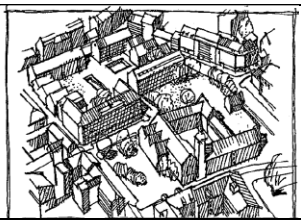
2. WIND VELOCITIES

Eurocode [2] deals with three different wind velocities: fundamental basic wind velocity, basic wind velocity and mean wind velocity.

Fundamental basic wind velocity ($v_{b,0}$) is the 10-minute mean wind velocity with an annual risk of being exceeded of p = 0.02 (return period of 50 years), irrespective of wind direction, at a height of 10 m above flat open country terrain (category II - area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights) and accounting for altitude effects. The values of fundamental basic wind velocities, with or without the influence of altitude, should be given in National Annexes of each country, in the form of wind map or/and table. In case those values of wind velocities are without the influence of altitude, that influence should be taken into account multiplying by factor calt. Serbian new wind map from National Annex [8] has been based on 10-minute mean wind velocities with the influence of altitude, so factor c_{alt} should not be used.

Considering that averaging time according to [2] is 10 minutes (600 s), values of fundamental basic wind velocity are generally higher than according to previous codes [4] which were based on one hour (3600 s) mean wind velocities. It is a first and important difference that should be taken into account in wind analysis. It is possible to make the conversion of wind velocities with different averaging time using averaging time factor k_t from [4], but results might be unreliable because of different terrain categories in [2] and [4].

Table 1. Terrain categories – descriptions and main parameters

Terrain categories			z_0	z_{min}	k_r	$c_r(z_{min})$
			[m]	[m]	[-]	[-]
0		Sea, coastal area exposed to the open sea	0.003	1	0.156	0.906
I		Lakes or area with negligible vegetation and without obstacles	0.01	1	0.170	0.782
II		Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0.05	2	0.190	0.701
III		Area with regular cover of vegetation or buildings or with isolated obstacles with separations of max. 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0.3	5	0.215	0.606
IV		Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1.0	10	0.234	0.540
z_0 and z_{min} are ground terrain roughness parameters, z_{max} = 200 m (maximum considered height of wind profile).						

Basic wind velocity (v_b) can take into account the effects of wind directions and season's character of the wind through the values of coefficients c_{dir} and c_{season}:

$$v_b = c_{dir} c_{season} v_{b,0} \tag{1}$$

where c_{dir} is the directional factor ($c_{dir} \leq 1.0$) and c_{season} is the season factor ($c_{season} \leq 1.0$).

In the absence of reliable wind records, these values should be taken as 1.0, so in that case, basic wind velocity is equal to fundamental wind velocity ($v_b = v_{b,0}$). In Serbian National Annex [8] values of these factors are adopted as 1.0.

As stated before, fundamental and basic wind velocities are based on return period T = 50 years or annual risk of being exceeded of p = 0.02. In case of different return period T or probability p, basic wind velocity should be corrected multiplying by the following factor:

$$c_{prob} = \left(\frac{1 - K \ln(-\ln(1-p))}{1 - K \ln(-\ln(0.98))} \right)^n \tag{2}$$

where p is the required probability of exceeding ($p = 1/T$) and K and n are parameters with following recommended values: K=0.2 and n=0.5.

With these recommended values of parameters, Eq. 2 gives similar results as return period factor k_T from previous regulation [4] (for example: c_{prob} =1.04 for return period T = 100 years, and c_{prob} = 0.90 for return period of 10 years) [9].

Mean wind velocity $v_m(z)$ takes into account terrain roughness and orography, as well as referent height above ground. In Eurocode, there are five different categories of terrain (see Table 1). Mean wind velocity should be calculated as follows:

$$v_m(z) = c_o(z)\; c_r(z)\; v_b \tag{3}$$

where $c_o(z)$ is the orography factor and $c_r(z)$ is the roughness factor.

Detailed procedures for numerical calculation of the orography factor $c_o(z)$ are given in Chapter A.3 of informative Annex A.

The roughness factor $c_r(z)$ takes into account the variability of the mean wind velocity at the site due to the ground roughness of the terrain upwind of the structure in the considered wind direction and the height (z) above ground level. Lowest roughness in upstream wind direction should be adopted. Small isolated zones with different terrain categories can be ignored (see Figure 1), but in the case when the structure is situated near the change of terrain category, transition of different categories should be considered, using one of two alternative procedures given in Chapter A.2 of Annex A. Both alternative procedures are allowed for use in [8].

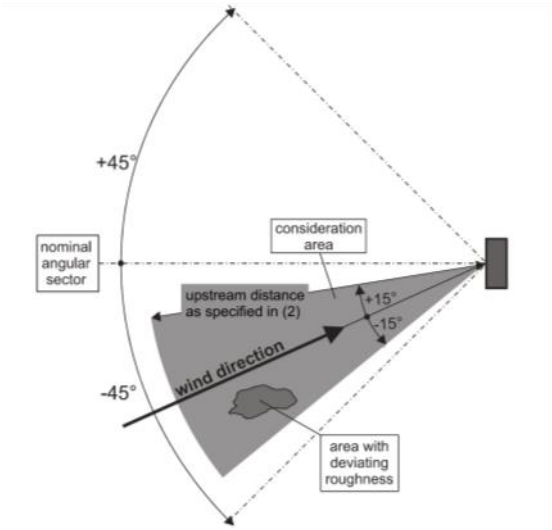


Figure 1. Assessment of terrain roughness [2]

The roughness factor $c_r(z)$ should be determined as follow:

$$c_r(z) = k_r \ln\left(\frac{z}{z_0}\right) \quad \text{for } z_{min} z < z_{max} = 200 \text{ m} \tag{4a}$$

$$c_r(z) = c_r(z_{min}) = k_r \ln\left(\frac{z_{min}}{z_0}\right) \quad \text{for } z \leq z_{min} \tag{4b}$$

where k_r is a terrain factor which is constant for each terrain category (see Table 1) and given by the following expression:

$$k_r = 0.19 \left(\frac{z_0}{z_{0,II}}\right)^{0.07} = 0.19 \left(\frac{z_0}{0.05}\right)^{0.07} \tag{5}$$

3. WIND PRESSURES AND FORCES

Wind pressure is, following Bernoulli equation, proportional to the square of wind velocity, so basic wind pressure (or basic velocity pressure as it stated in Eurocode) should be calculated as follows:

$$q_b = \frac{1}{2} \rho\, v_b^2 \approx \frac{v_b^2 [\text{m/s}]}{1600} \; [\text{kN/m}^2] \tag{6}$$

where v_b is basic wind velocity (according to Eq. 1) and ρ is the air density, which depends on altitude, air temperature and barometric pressure (recommended value is ρ=1.25 kg/m^3).

Fluctuating component of the wind velocity pressure or dynamic wind action should be taken into account by characteristic peak velocity pressure q_p(z) at referent height z which should be calculated by the following expression:

$$q_p(z) = \left[1+7I_v(z)\right]\ \frac{1}{2}\rho\ v_m^2(z) = c_e(z)\ q_b \quad (7)$$

where $I_v(z)$ is the turbulence intensity and $c_e(z)$ is the exposure factor that depends on turbulence intensity and terrain category.

The turbulence intensity of the wind at referent height z can be obtained as the quotient of the standard deviation of turbulence σ_V and mean wind velocity $v_m(z)$ for $z_{min} < z \leq z_{max}$ as follows:

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_r\sigma_V}{v_m(z)} = \frac{k_l}{c_o(z)\cdot\ln(z/z_0)} \quad (8a)$$

and for $z \leq z_{min}$

$$I_v(z) = I_v(z_{min}) \quad (8b)$$

where k_l is the turbulence factor whose value can be defined in National Annex (recommended value is k_l =1.0). Also, it should be noticed that turbulence intensity should be calculated as a unique value for the whole structure at referent height z_s.

There is no explicit expression for the calculation of $c_e(z)$ in [2], but the only general expression that is derived from Eq. 7. Using general Eq. 7, with Eq. 3, 4a and 8a, it can be finally obtained in the following shape:

$$c_e(z) = \frac{q_p(z)}{q_b} = \left[1+7\frac{k_l}{c_o(z)\ln(z/z_0)}\right]k_r^2\ln^2(z/z_0)c_0^2(z) \quad (9)$$

Looking at previous Eq. 9 it can be observed that the exposure factor $c_e(z)$ is a function of referent height z and terrain category and, in some way, define wind velocity pressure profile.

Wind actions on the whole structure, cladding or structural elements, depending on the type of structure and wind analysis, can be analyzed through using wind pressure on surfaces or wind forces.

Wind pressure on surfaces can be external (w_e) and internal (w_i) and should be taken as positive or negative. The pressure which is directed towards the surface should be taken as positive, but suction, directed away from the surface, should be taken negative (see Figure 2).

Total, net wind pressure is equal to the sum of pressures (with appropriate signs) that acts on opposite sides of considered surfaces such as walls or roofs (see Figure 2).

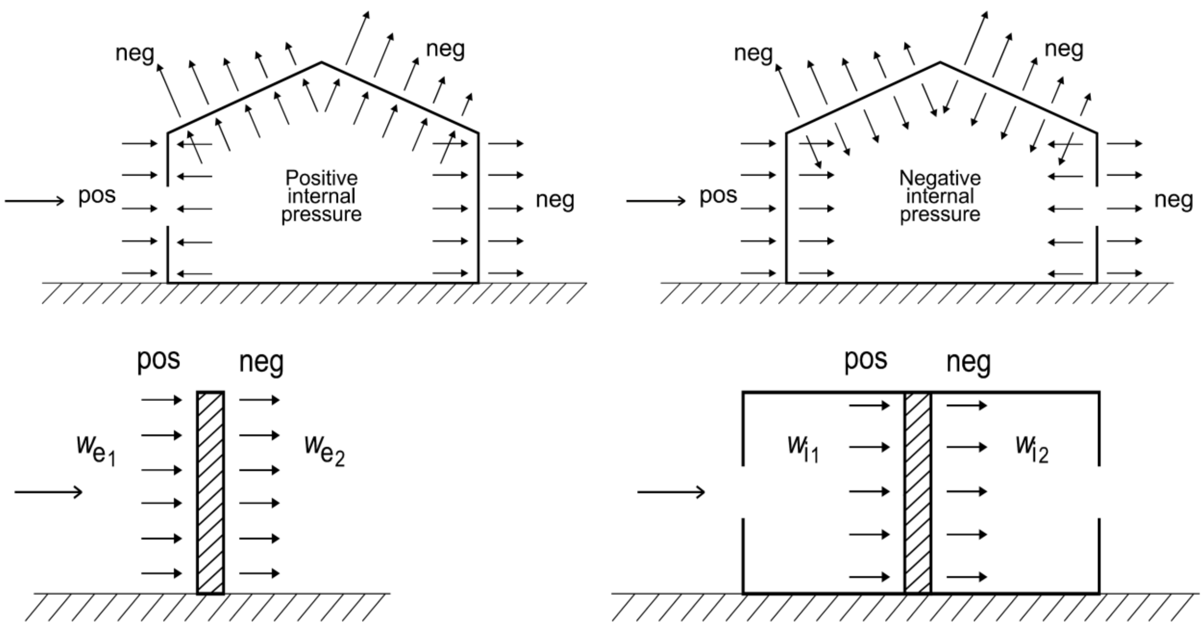


Figure 2. Wind pressures on surfaces – convention for positive and negative pressure

External and internal wind pressures on surfaces for referent height (z_e or z_i) should be calculated by the following expressions:

$$w_e(z_e) = q_p(z_e)c_{pe} \quad (10)$$

$$w_i(z_i) = q_p(z_i)c_{pi} \quad (11)$$

where $q_p(z)$ is peak velocity pressure and c_{pe} and c_{pi} are external and internal pressure coefficients, respectively, which are given in Chapter 7 of EN 1991-1-4 for different types of buildings.

According to [2] wind actions on the structure or a structural component should be analyzed using wind forces. Wind forces can be determined by calculation of forces using force coefficient c_f or by calculating wind pressure on surfaces (with pressure coefficients). The first approach, with force coefficient, is usually used for wind action on structural elements. In that case, wind force should be determined by the next expression:

$$F_w(z) = q_p(z)c_s c_d c_f A_{ref} \quad (12)$$

where $q_p(z)$ is the peak velocity pressure, see Eq. 7, $c_s c_d$ is the structural factor, see Eq. 16, c_f is the force coefficient for structure or structural element, A_{ref} is referent area of the structure or structural element.

For wind actions on buildings, using the second approach with wind pressure on surfaces is more convenient. Forces on structure from external wind pressures on surfaces, in that case, should be obtained as follow:

$$F_{w,e}(z_e) = w_{pe}(z_e)c_s c_d A_{ref} \quad (13)$$

and for and internal wind pressures:

$$F_{w,i}(z_i) = w_{pi}(z_i)c_s c_d A_{ref} \quad (14)$$

Replacing $w_p(z_e)$ with Eq. 10 and $q_p(z)$ with Eq. 7, and using Eq. 1 and 3, Eq. 13 can be transformed into the form which is presented with Eq. 14. In this way expression for wind force on structure according to Eurocode [2] is transformed in the form which is similar to one given in previous Yugoslavian codes [4]-[7]. Also, the structural factor $c_s c_d$ should be replaced with Eq. 16 to get the final expression that is completely comparative with previous Yugoslavian codes.

$$F_{w,e}(z) = \frac{1}{2}\rho\left(v_{b,0}c_{dir}c_{season}c_{prob}c_r(z)c_o(z)\right)^2 \cdot\left[1+7I_v(z_s)\right]c_s c_d c_{pe} A_{ref} \quad (15)$$

4. STRUCTURAL FACTOR - DYNAMIC RESPONSE OF STRUCTURE

The structural factor $c_s c_d$ takes into account the effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surface c_s together with the effect of the vibrations of the structure due to turbulence c_d. Procedure for calculation of structural factor $c_s c_d$ is given in Section 6 of EN 1991-1-4 and its alternative in Annexes B and C.

As a simplification, the structural factor may be taken as 1 ($c_s c_d$ = 1) in the following cases:

a) for buildings with a height less than 15 m;
b) for facade and roof elements having a natural frequency greater than 5 Hz (glazing spans smaller than 3 m usually lead to natural frequencies greater than 5 Hz);
c) for 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;
d) for chimneys with circular cross-sections whose height is less than 60 m and 6.5 times the diameter.

For civil engineering works (other than bridges, which are considered in Section 8), and chimneys and buildings outside the limitations given in a), c) and d) above, and alternatively for all cases, values of $c_s c_d$ should be determined as follow:

$$c_s c_d = \frac{1+2k_p\, I_v(z_s)\,\sqrt{B^2+R^2}}{1+7I_v(z_s)} \quad (16)$$

where k_p is the peak factor, defined as the ratio of the maximum value of the fluctuating part of the response to its standard deviation; B^2 is the background factor, allowing for the lack of full correlation of the pressure on the structure surface; R^2 is the resonance response factor, allowing for turbulence in resonance with the vibration mode.

5. AERODYNAMIC COEFFICIENTS FOR WIND ACTION ON BUILDINGS

Eurocode [2] recognizes different types of aerodynamic coefficients for buildings: external and internal pressure coefficients, net pressure coefficients, friction coefficients and force coefficients.

The external pressure coefficients c_{pe} should be used for calculation of wind action on walls and roof surfaces. Different types of roofs are covered by Eurocode: flat, monopitch, duopitch, hipped, multispan, vaulted roofs and domes. The external pressure coefficients c_{pe} for buildings or parts of buildings depend on the size of the loaded area A.

There are two types of external pressure coefficient for buildings: $c_{pe,1}$ and $c_{pe,10}$. For small loaded areas ($A \leq 1.0$ m^2), the external pressure coefficient $c_{pe,1}$ should be used. So, $c_{pe,1}$ is the local coefficient intended for the design of small elements such as cladding elements and roofing elements. Otherwise, values of external pressure coefficient $c_{pe,10}$ should be used for larger loaded areas ($A \leq 10.0$ m^2). It is global coefficient that should be used for design of main structure of building.

The values of both coefficients $c_{pe,1}$ and $c_{pe,10}$ are given in appropriate tables for walls and different types of roofs. In case of the loaded area A between 1 and 10 m^2 value of coefficient c_{pe} can be obtained by linear logarithmic interpolation, using following recommended expression:

$$c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10})\log_{10} A \qquad (17)$$

Chapter 7 of [2] gives values of both coefficients $c_{pe,1}$ and $c_{pe,10}$ for different zones of vertical walls and roofs with different configurations (flat, monopitch, duopitch, hipped, multispan, vaulted roofs and domes). For cases of roofs (buildings) that are not covered by Eurocode, wind tunnel tests are recommended for determination of aerodynamic coefficients.

The values of internal pressure coefficient c_{pi} depend on the size and distribution of the openings (windows, doors, chimneys) in the building, as well as on background permeability (air leakage around doors). In case of uniformly distributed openings, which is characteristic for regular buildings, the internal coefficient should be obtained using parameter μ which presents the ratio of the area of openings with negative or zero value of c_{pe} and the total area of all openings. Where it is not possible to reliably estimate the mentioned parameter μ the value of internal coefficient c_{pi} should be adopted as the more onerous of +0.2 and -0.3. Internal and external pressures shall be considered to act together at the same time, and the worst combination shall be taken.

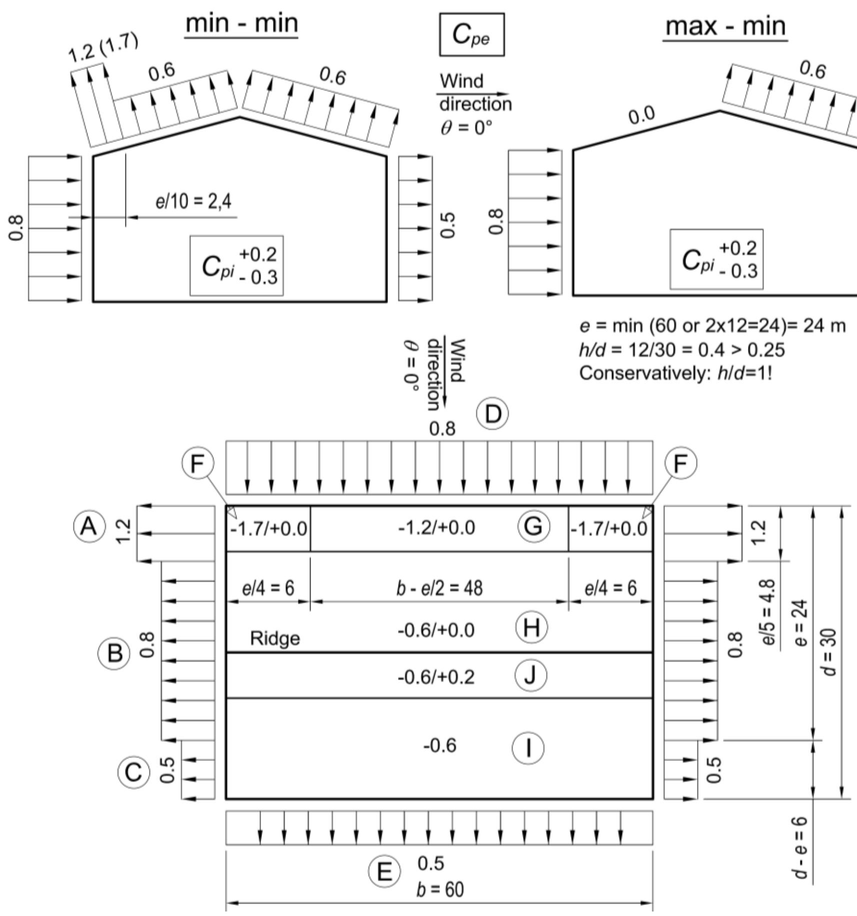


Figure 3. External and internal coefficients for a typical industrial building [10]

In some cases, such as canopies, free-standing walls, parapets etc., unique, total net pressure coefficients $c_{p,net}$ should be used.

Force coefficients c_f are regularly used for: signboards, structural elements with different cross-sections (rectangular, sharp-edged, regular polygonal, circular), lattice structures and scaffoldings and flags.

External and internal aerodynamic coefficients, as well as wind load distribution for typical industrial building (*b*/*d*/*h*=30/60/12 m) with duopitch roof (with the slope of 5°) are given in Figure 3.

6. COMPARATIVE ANALYSIS - EC VS. JUS (SRPS)

Comparing EC and JUS regarding wind actions, the first important difference is in averaging time for basic wind velocity. Namely, fundamental basic wind velocity $v_{b,0}$ from EC is based on 10-minutes averaging time, but JUS (SRPS) deal with one hour mean wind velocity $v_{m,50,10}$, so EC operates with higher wind velocity (about 8-10%).

Only because of that, considering that wind velocity is main input data for calculation of wind actions that depends on square of wind velocity, the intensity of wind pressures and forces are more than 20% higher. Also, EC gives the possibility for adjustment of wind velocity through direction and season factors, what is not the case in JUS (SRPS). It should be noticed that the return period of 50 years is the same in EC and JUS (SRPS).

Beside of that, there are five different terrain categories in EC (0, I, II, III and IV) instead of three (A, B and C) in JUS (SRPS). So, EC gives more possibilities for the description of site location and more accurate results of wind analysis. Expressions for exposure factor are different: EC uses logarithmic function but JUS (SRPS) uses the exponential function. Comparing the exposure factors, that are shown on Figure 4, it can be observed that, despite different nature of expressions, functions of exposure factors for default terrain categories (II and B) are very similar. The same situation is with turbulence intensity.

Generally, algorithms for the calculation of wind actions (forces or pressures) are similar. Some terms are different, as well as expressions for calculation of some intervalues in different steps of the calculation, but it can be shown that the final expressions are quite similar (see Table 2).

Criteria for dynamically susceptible structures are essentially different in EC and JUS (SRPS). For dynamically susceptible structures (with $c_s c_d \neq 1$), EC proscribes additional calculation of structural factor $c_s c_d$ (see Eq. 16), in accordance with Chapter 6 and Annex B. JUS (SRPS) has a completely different procedure for calculation of dynamic coefficient G_z for structures that are susceptible to resonance (slender structures) and that are not (big rigid structures) for big rigid structures, as follows:

$$G_z = 1 + 2g\, I_z\, B = 1 + 6\, I_z\, B \tag{18}$$

and for slender structures:

$$G_z = 1 + 2g\, I_z\, B\, \sqrt{1 + (R/B)^2} = 1 + 2g\, I_z\, \sqrt{B^2 + R^2} \tag{19}$$

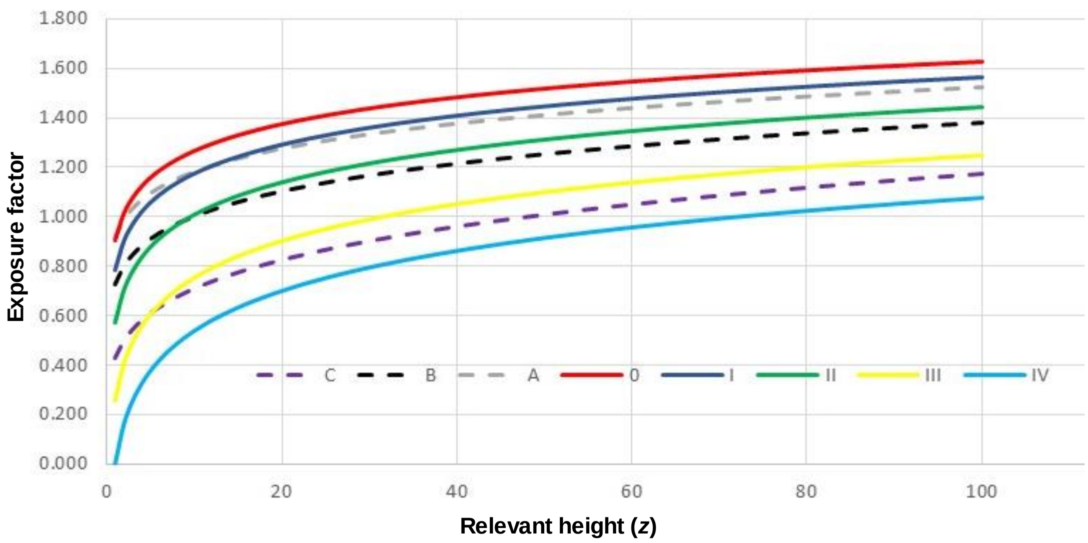


Figure 4. Exposure factor for different terrain categories A, B and C (JUS) and 0, I, II, III and IV (EC)

where g is the gust factor, almost the same as the peak factor k_p from EC:

$$g = \sqrt{2\ln(\nu T)} + \frac{0.577}{\sqrt{2\ln(\nu T)}} \qquad (20)$$

The basic expression for the peak velocity pressure $q_p(z)$, according to EC, includes certain dynamic amplification $(1+7I_v(z))$, that is similar to dynamic coefficient G_z for big rigid structures (buildings). On the other hand, if the criteria for a simplified calculation of structural factor are not met, dynamic effects should be taken. In those cases, final expression for wind force can be obtained replacing $c_s c_d$ in Eq. 15 with Eq. 16. Comparison of most important final expressions for wind analysis, such as wind velocity, wind pressure and wind force, according to EC and JUS (SRPS) is given in Table 2.

It should also be noticed that there are some differences in aerodynamic coefficients. Eurocode provides aerodynamic coefficients for almost all usual types of buildings that can be met in engineering practice. In that sense, EC is more comprehensive than JUS (SRPS). Comparison of aerodynamic coefficients for simple industrial building, according to EC [2] and JUS (SRPS) [3] - [7] is shown on Figure 5.

Finally, differences in the calculation of wind action on a typical industrial building according to EC and JUS (SRPS) are shown through a numerical example. Results of calculation of wind actions are given in Table 3. Wind load layouts are shown in Figure 6 and internal forces and moments are presented in Figure 7. Analysing the results of numerical example, it is obvious that the final results of wind actions on structure (internal forces and moments) are significantly higher according to EC than JUS (SRPS).

Table 2. Comparison of main expressions from EC and JUS (SRPS)

Wind velocity	
EC	$v_m(z) = v_{b,0}\ c_{dir}\ c_{season}\ c_{prob}\ c_r(z)\ c_o(z)$
JUS (SRPS)	$v_{m,T,z}(z) = v_{m,50,10}\ k_t\ k_T\ S_z\ K_z(z)$
External wind pressure on structure (for small rigid buildings - $c_s c_d = 1$)	
EC	$w_e(z) = \frac{1}{2}\rho\ \left(v_{b,0}\ c_{dir}\ c_{season}\ c_{prob}\ c_r(z)\ c_o(z)\right)^2 \left[1+7I_v(z_s)\right]\ c_{pe}$
JUS (SRPS)	$q_w(z) = \frac{1}{2}\rho\ \left(v_{m,50,10}\ k_t\ k_T\ S_z\ K_z(z)\right)^2 (1+6I_z B)\ C$ (for g = 3.0)
Wind force – general case ($c_s c_d \neq 1$)	
EC	$F_w = \frac{1}{2}\rho\ \left(v_{b,0}\ c_{dir}\ c_{season}\ c_{prob}\ c_r(z)\ c_o(z)\right)^2 \left(1+2k_p I_v\sqrt{B^2+R^2}\right)\ c_{pe} A_{ref}$
JUS (SRPS)	$F_w = \frac{1}{2}\rho\ \left(v_{m,50,10}\ k_t\ k_T\ S_z\ K_z(z)\right)^2 \left(1+2gI_z\sqrt{B^2+R^2}\right)\ C\ A$

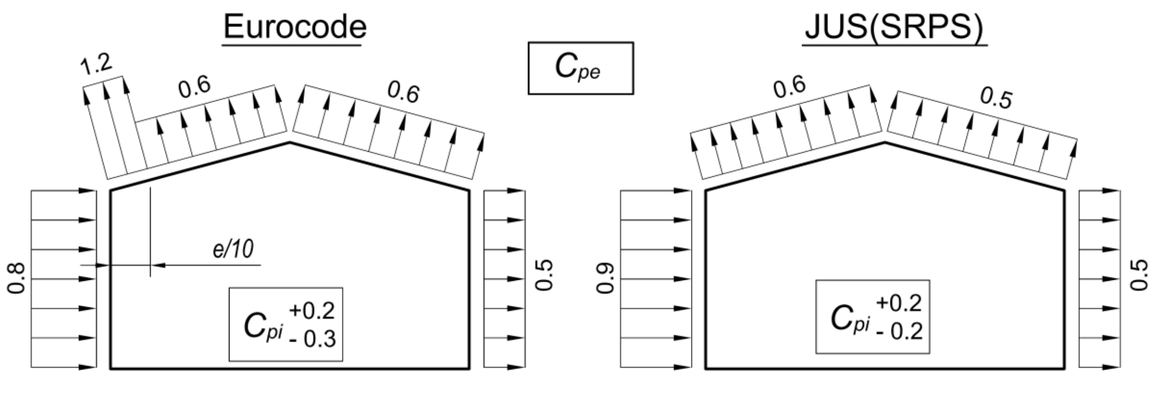


Figure 5. Comparison of aerodynamic coefficients c_{pe} and c_{pi} for typical industrial building

Table 3. Comparative analysis of wind pressure according to EN and JUS (SRPS) – Numerical example for simple industrial building (h = 12 m < 15 m, $c_s c_d$ = 1)

JUS (SRPS)	EC
Terrain category: B	Terrain category: II
Basic wind velocity	Fundamental and basic wind velocities
$v^B_{m,T,10}$ = **26 m/s** (averaging time 3600 s) k_t = 1.0 k_T = 1.0 (for 50 years return period)	$v_{b,0} = k_t^B v^B_{m,T,10} = 1.6509 \cdot 600^{-0.0645}$ = 28.41 m/s (averaging time 600 s) $v_b = c_{dir} c_{season} v_{b,0} = 1 \cdot 1 \cdot 28.41$ = **28.41 m/s**
Orography factor: S_z = 1.0	Orography factor: $c_o(z)$ = 1.0
Exposure factor (for z = 12 m)	Exposure factor (for z = 12 m)
$K_z(12) = \sqrt{b}\ (z/10)^{\alpha} = \sqrt{1} \cdot (12/10)^{0.14}$ = 1.026	$c_r(12) = k_r \ln(12/z_0) = 0.19 \ln(12/0.05)$ =1.041
Mean wind velocity	Mean wind velocity
$v_{m,T,z} = k_t k_T K_z S_z v^B_{m,50,10} = 1 \cdot 1 \cdot 1.026 \cdot 1 \cdot 26 =$ **26.67 m/s**	$v_m(z) = c_r(z) c_o(z) v_b = 1.041 \cdot 1 \cdot 28.41 =$ **29.59 m/s**
Aerodynamic wind pressure	Peak velocity pressure
$q_{m,T,z} = \frac{1}{2}\ \rho\ v^2_{m,T,z} = \frac{1}{2} 1.225 \cdot 10^{-3} \cdot 26.67^2 =$ 0.436 kN/m² $q_{g,T,z} = G_z\ q_{m,T,z} = 2.0 \cdot 0.436$ = **0.872 kN/m²** (for G_z = 2.0)	$I_v(z) = \frac{k_I}{c_o(z) \ln(z/z_0)} = \frac{1}{1 \cdot \ln(12/0.05)}$ = 0.182 $q_p(z) = [1 + 7 \cdot 0.182] \frac{1}{2} 1.225 \cdot 10^{-3} \cdot 29.59^2$ $q_p(z) = 2.277 \cdot 0.536 =$ **1.221 kN/m²**

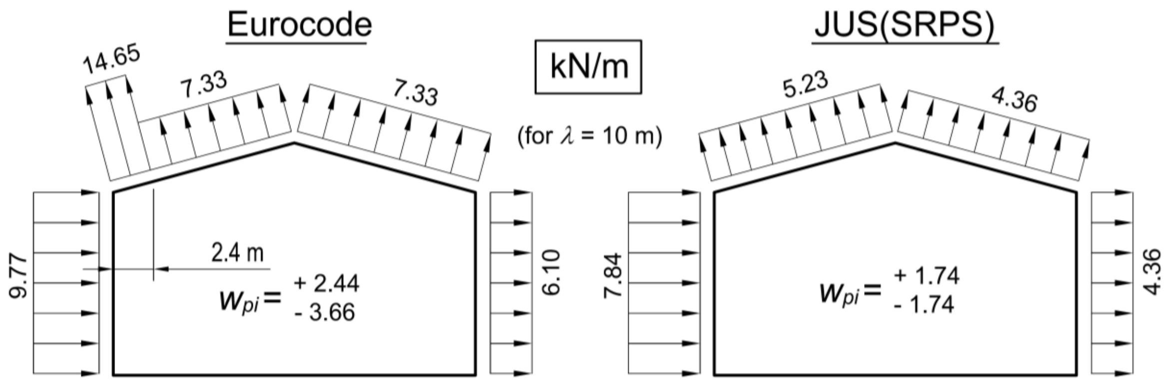


Figure 6. Wind actions on industrial building – EN vs. JUS (SRPS)

Maximal bending moment in beam-column is higher for 34% (503.9/377.3), axial forces in the top and bottom chord of truss girder are higher for 50% (407.2/271.2) and 49 % (393.2/263.9), respectively (see Figure 7). Also, it should be noticed that EC is based on limit state theory and partial safety factors, but JUS (SRPS) deal with allowed stresses for different design cases with unique safety factors. Because of that, it is not easy to precisely compare final results of design according to these different codes. But, USL load combinations with wind action as dominant variable action give more unfavourable effects of wind actions than JUS (SRPS), especially in case of wind suction on roof girders.

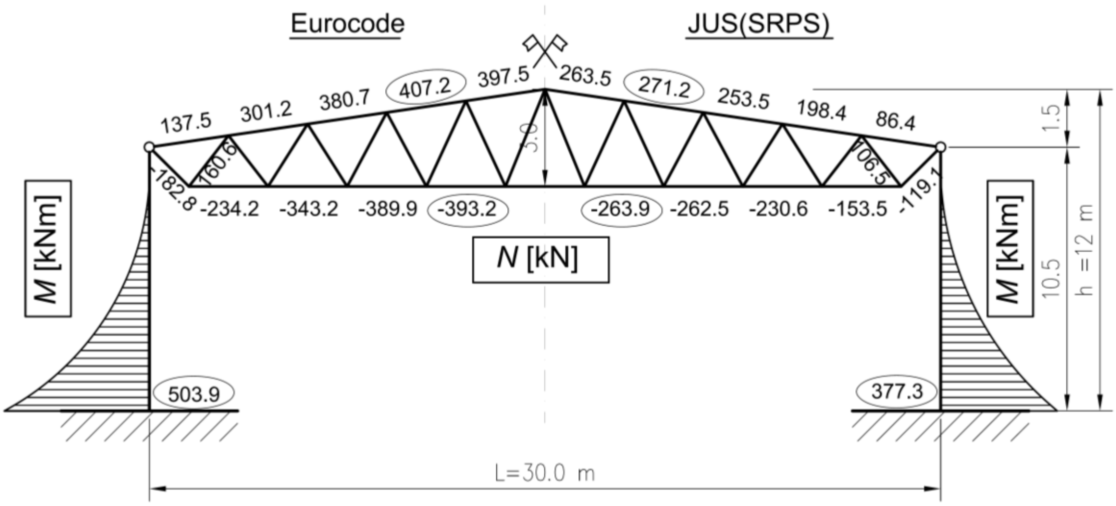


Figure 7. Internal forces and moments due to wind actions on industrial building – EN vs. JUS (SRPS)

7. CONCLUSIONS

Eurocode is, without doubt, the most contemporary and the most comprehensive set of codes for civil engineering structures. But, in its part that deals with wind actions, as well as in some other parts, there are some shortcomings and inconsistencies. Speaking about wind actions, one of the biggest problems is the huge number of clauses in which National choice is allowed (even 65). Also, leading European countries (Germany, France and UK) had very different approaches in the process of adoption of Nationally Defined Parameters (NDPs). Beside of that, Annexes of EN 1991-1-4 are quite discussible and even unreliable, so most of them are not recommended for using or have only informative status, without clearly defined alternatives. Rules for design of wind action on slender structures (towers, masts and chimneys) and their dynamic response, as well as criteria for application of multimodal dynamic analysis, are not given in basic standard for wind actions [2], but in part of Eurocode for steel structures EN 1993-3-1 [1]. Observed shortcomings and inconsistencies will be corrected in the new generation of Eurocode.

Regarding previous codes, they were, generally similar to Eurocode but they gave importantly lesser intensity of wind effects on structures than Eurocode. The main reason for that is one-hour averaging time for wind velocity and smaller values of aerodynamic coefficients. If some inconsistencies regarding the choice of aerodynamic coefficients and big changes of wind actions for slender structure with ratio $(R/B)^2$ close to 0.5, as well as some discussible wind velocities are excluded, these codes can be considered quite correct, especially for the time when they have been published (1991).

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