Global stability analysis using general method

General

The global stability analysis of structural elements or frames may be performed by the **general method** specified by **EN 1993-1-1 (6.3.4)**. The method is based on the calculation of the $\alpha_{ult,k}$ design load amplifier and the $\alpha_{cr,op}$ critical load amplifier. The $\alpha_{ult,k}$ amplifier is related to the resistance of the critical (most loaded) cross-section of the structure, while the $\alpha_{cr,op}$ amplifier is related to the elastic global stability of the whole structure. However, the main point of the method is the stability analysis, which should contain the lateral torsional buckling mode, and which is usually performed by finite element method. This method assumes that the whole structure has **a unified slenderness** ($\bar{\lambda}_{op}$). The method uses the buckling curves which are used for the flexural and the lateral torsional buckling modes. The features of the method are summarized in the following table:

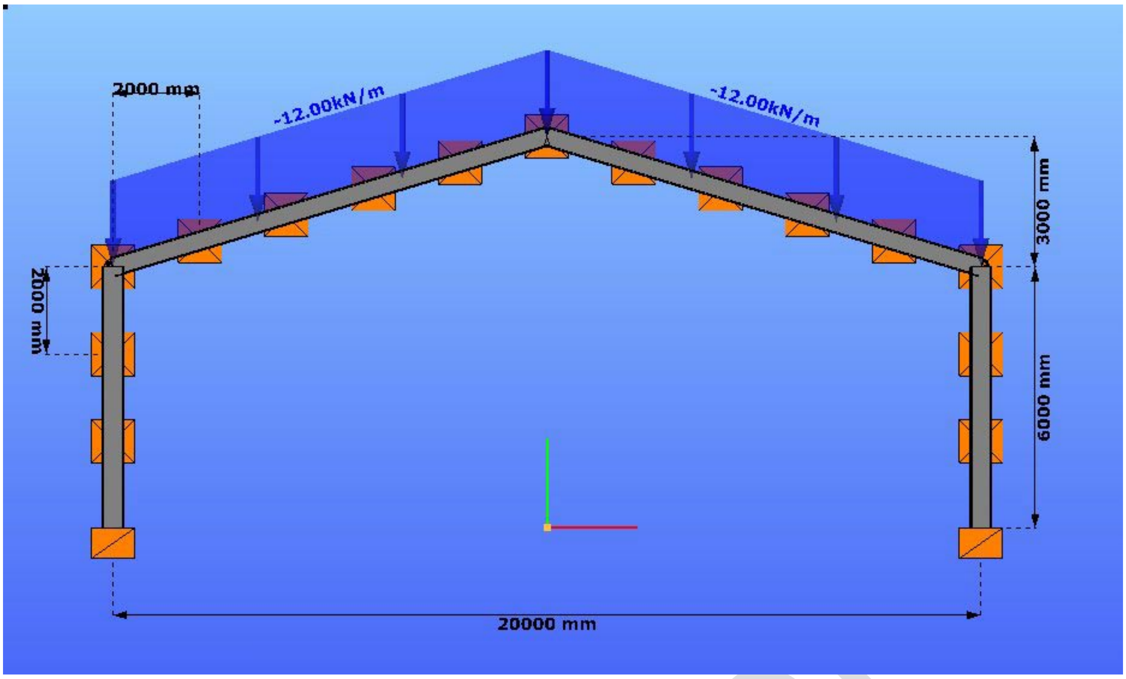
categories of models and analysis	**details of method**
imperfections	only global imperfection applying in the plane of the frame
analysis	usually second order
cross-section resistance	conservative interaction
member stability	conservative interaction with buckling curves

Numerical example

For the simplicity the following frame structure will be examined:

- Span of frame: 20,0 m
- Height of columns: 6,0 m
- Height of roof: 9,0 m
- Beam profile: IPE 450
- Column profile: IPE 500
- Column base: fix
- Support of columns: centrically and laterally by 3,000 meters
- Support of beams: centrically and laterally by 2,610 meters
- Grade of steel: S235
- Design load (acting only on roof): 12,0 kN/m (self weight is included)

The model of the above frame was built up in the ConSteel program:



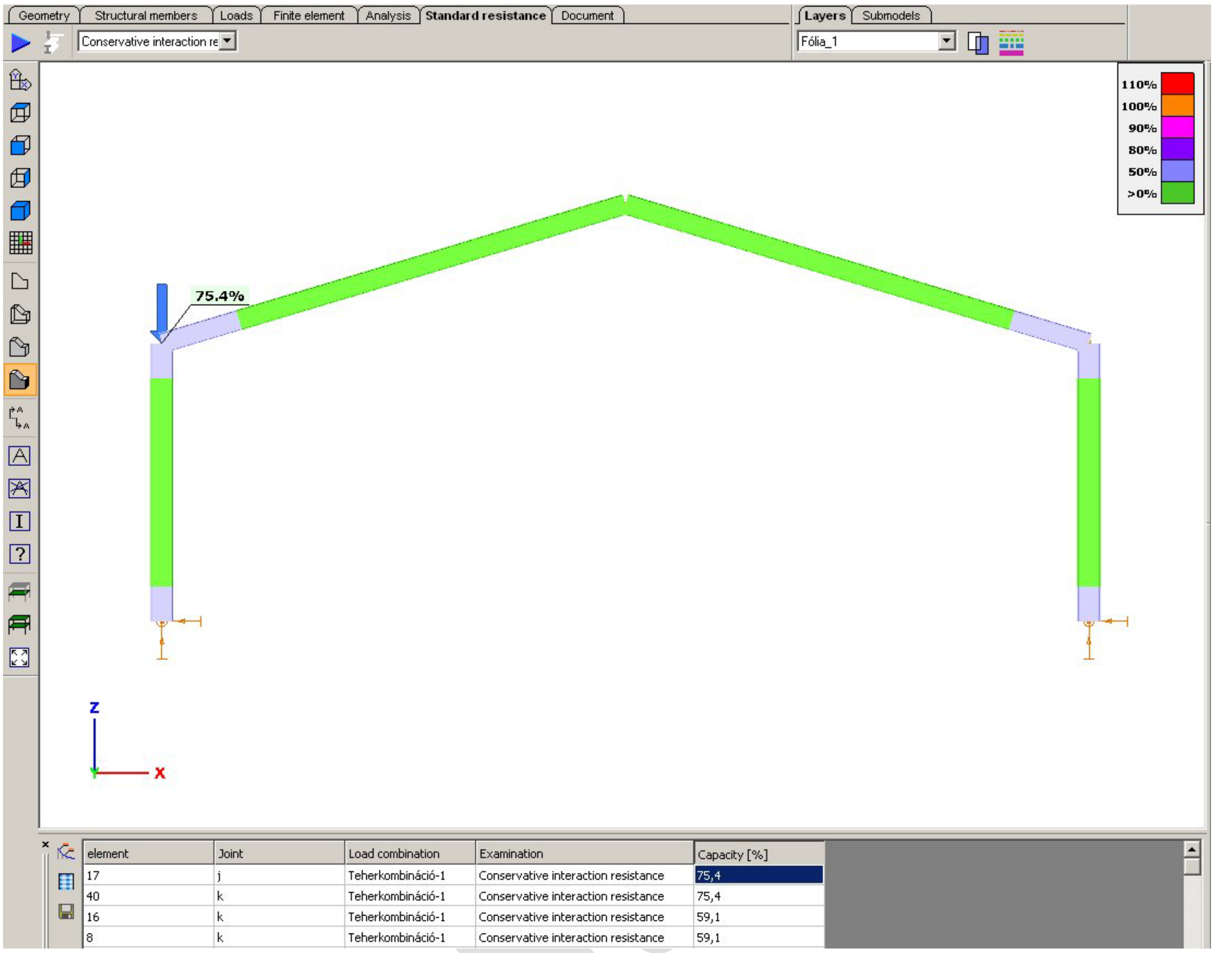
The procedure of the general method has the following 6 steps:

Step 1

The structural model was built up in the ConSteel program. The model was applied by realistic support system in order to get realistic result by elastic stability analysis. Firstly the cross-section design (calculation of resistances) was carried out (Step 2).

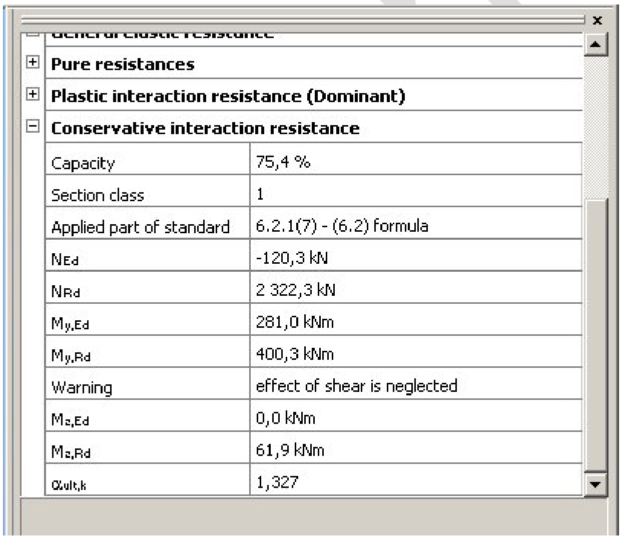
Step 2

The following picture was generated by the ConSteel program and shows the use of the cross-sectional resistances (the critical section is located at the end of the beams):



element	Joint	Load combination	Examination	Capacity [%]
17	j	Teherkombináció-1	Conservative interaction resistance	75,4
40	k	Teherkombináció-1	Conservative interaction resistance	75,4
16	k	Teherkombináció-1	Conservative interaction resistance	59,1
8	k	Teherkombináció-1	Conservative interaction resistance	59,1

The design parameters used in the conservative design interaction equation are the following:



Pure resistances

Plastic interaction resistance (Dominant)

Conservative interaction resistance

Capacity	75,4 %
Section class	1
Applied part of standard	6.2.1(7) - (6.2) formula
N_{Ed}	-120,3 kN
N_{Rd}	2 322,3 kN
$M_{y,Ed}$	281,0 kNm
$M_{y,Rd}$	400,3 kNm
Warning	effect of shear is neglected
$M_{z,Ed}$	0,0 kNm
$M_{z,Rd}$	61,9 kNm
$\alpha_{ult,k}$	1,327

- Design forces:

$$N_{Ed} = 120{,}3\ kN$$

$$M_{y,Ed} = 281{,}0\ kNm$$

- Characteristic values of the resistances for simple compression and bending, respectively:

$$N_{Rk} = 2.322\ kN$$

$$M_{y,Rk} = 400{,}3\ kNm$$

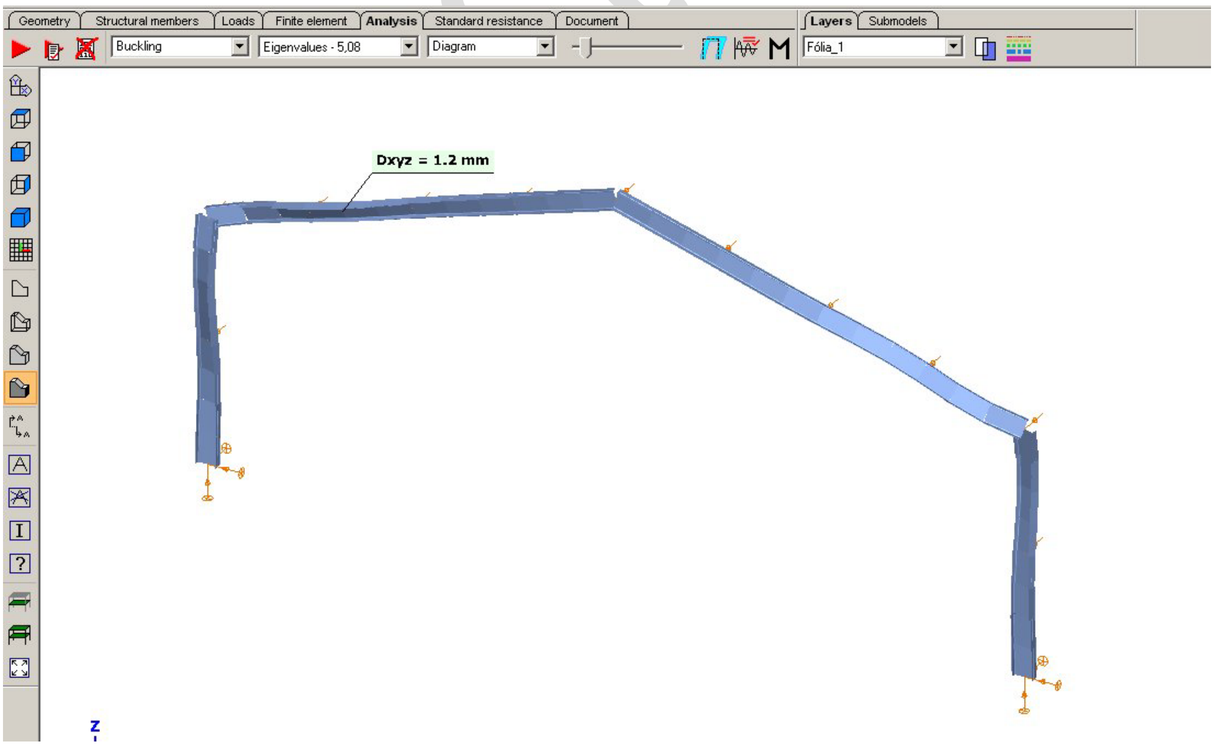
- The load amplifier using the conservative design interaction equation (EN 1993-1-1 6.3.4 (4) b)):

$$\frac{1}{\alpha_{ult,k}} = \frac{N_{Ed}}{N_{Rk}} + \frac{M_{y.Ed}}{M_{y,Rk}} = \frac{120{,}3}{2.322} + \frac{281{,}0}{400{,}3} = 0{,}754$$

$$\alpha_{ult,k} = 1{,}327$$

Step 3

According to the general method (EN 1993-1-1 6.3.4) the critical load amplifier is equal to the first eigenvalue - given by the elastic global stability analysis of the structure - which indicates lateral torsional buckling mode. In the case of the above example the ConSteel program proves the following result:



The first eigenvalue which indicates lateral torsional buckling mode is the following (EN 1993-1-1 6.3.4 (3)):

$$\alpha_{cr.op} = 5{,}080$$

Step 4

The generalized slenderness of the whole structure may be calculated as the following (EN 1993-1-1 6.3.4 (3)):

$$\bar{\lambda}_{op} = \sqrt{\frac{\alpha_{ult,k}}{\alpha_{cr,op}}} = \sqrt{\frac{1{,}327}{5{,}080}} = 0{,}511$$

Step 5

Using the generalized slenderness (Step 4) the reduction factors for flexural buckling and lateral torsional buckling, respectively, may be calculated as following:

- Reduction factor for *flexural buckling* about z-z (EN 1993-1-1 6.3.1):

  Curve "c" $\Rightarrow$ $\alpha = 0{,}49$

$$\phi = 0{,}5\left[1 + 0{,}49(0{,}511 - 0{,}2) + 0{,}511^2\right] = 0{,}707$$

$$\chi = \frac{1}{0{,}707 + \sqrt{0{,}707^2 - 0{,}511^2}} = 0{,}837$$

- Reduction factor for *lateral torsional buckling* (EN 1993-1-1 6.3.2):

  Curve "b" $\Rightarrow$ $\alpha_{LT} = 0{,}34$

$$\phi_{LT} = 0{,}5\left[1 + 0{,}34(0{,}511 - 0{,}2) + 0{,}511^2\right] = 0{,}683$$

$$\chi_{LT} = \frac{1}{0{,}683 + \sqrt{0{,}683^2 - 0{,}511^2}} = 0{,}879$$

Step 6

To check the global stability of the frame structure we may use the general design formula (EN 1993-1-1 6.3.4 (4) b)):

$$\frac{N_{Ed}}{\chi \cdot N_{Rd}} + \frac{M_{y.Ed}}{\chi_{LT} \cdot M_{y.Rd}} = \frac{120{,}3}{0{,}837 \cdot 2.322} + \frac{281{,}0}{0{,}879 \cdot 400{,}3} = 0{,}86 \leq 1{,}0$$

According to the general method the frame is adequate for global stability.