Design of tapered structural member with Class 4 cross-section

General

The global stability analysis of irregular structural members (for example tapered beam-columns) may be performed by the **general method** specified in **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, while the $\alpha_{cr,op}$ amplifier is related to the elastic global stability of the structure. The stability analysis – as the main point of the procedure - should contain the lateral torsional buckling mode. However, it is assumed that the behavior of the structure can be described by the **unified slenderness** ($\bar{\lambda}_{op}$). The method uses the buckling curves which are specified for the design of the flexural and the lateral torsional buckling. The features of the method are summarized in the following table:

categories of models and analysis	details of method
imperfections	no
analysis	second order
cross-section resistance	conservative interaction formula
member stability	conservative interaction formula with buckling curves

Numerical example

For the simplicity the following structural member will be examined:

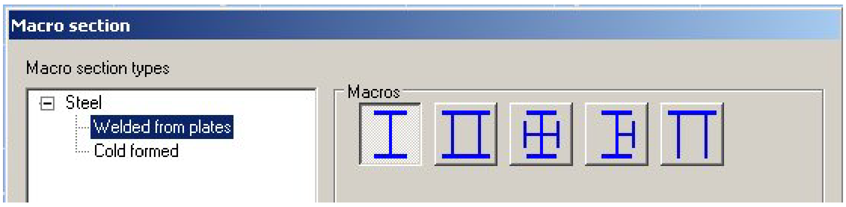
- Length of member: 10,0 m
- Type of cross-section: symmetric welded I section
- Web dimension: (300-1200)-6 mm
- Flange dimension: 300-16
- End supports: simple
- Grade of steel: S355
- Design moment at higher end: 600 kNm (self weight is excluded)

The design procedure has the following steps:

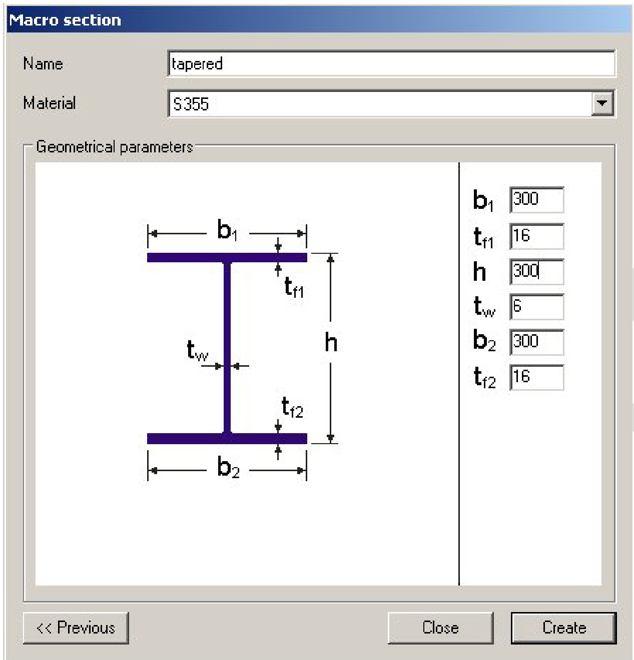
1. cross-section model
2. tapered member model
3. cross-section resistance
4. global stability resistance
5. verification by shell model

1. Cross section model

The cross-section model may be generated by the ***Structural members/Section administration/Macro sections*** option,

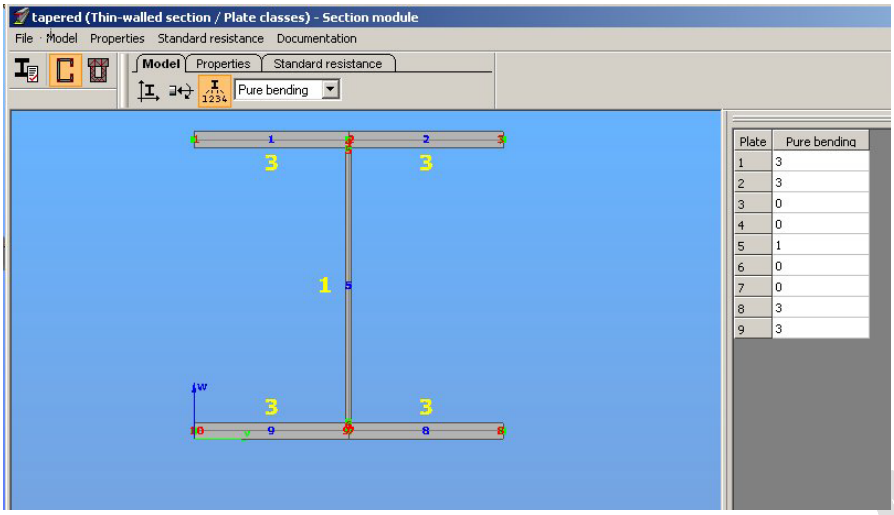


where the cross-section parameters at the lower end of the member are the following:

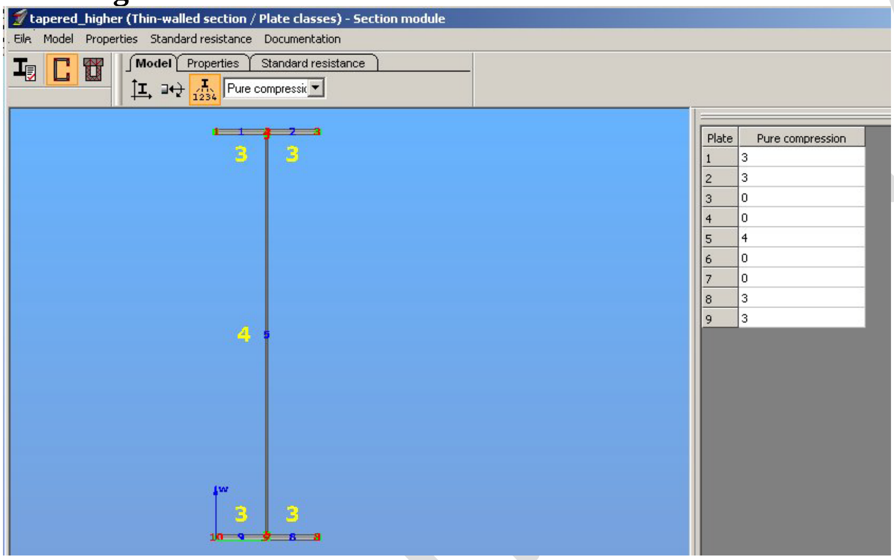


The ConSteel/Section module (***Structural members/Section administration/Properties*** option) can show the class of the cross-section (classes of the sectional plates):

- **at lower end**



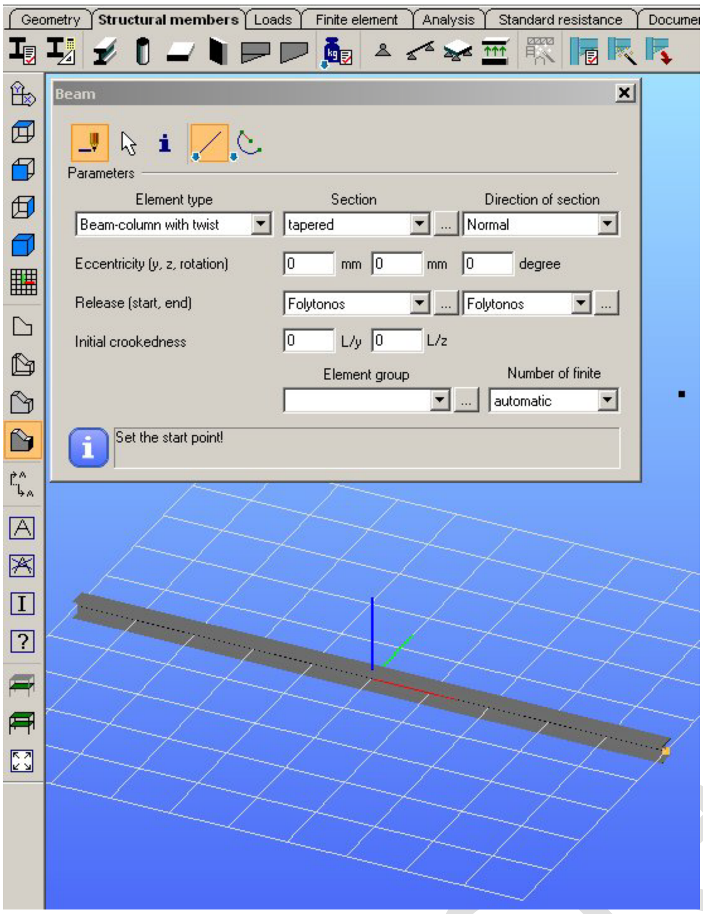
- **at higher end**



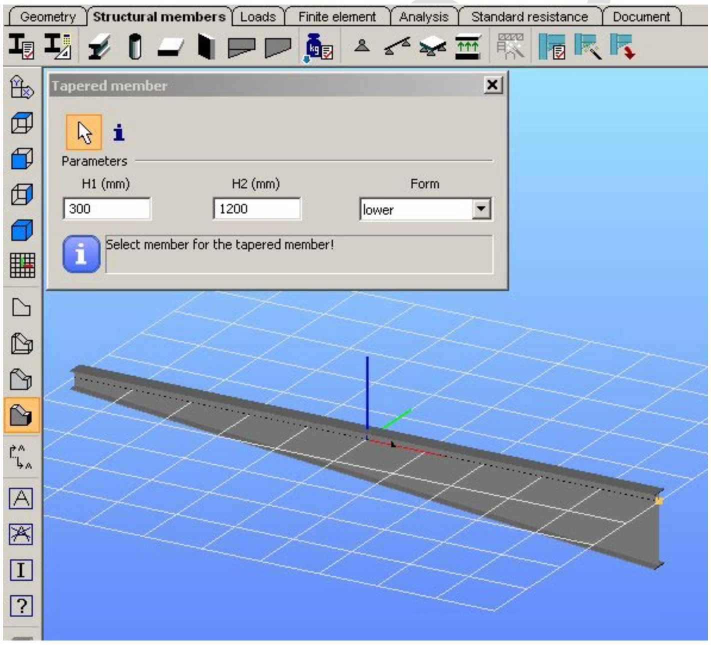
According to the examination the tapered member subjected to pure bending is Class 4 member at about the higher end (the web is Class 4, while the flanges are Class 3). However, in the design equations we should take the effective cross section into consideration (ConSteel does it automatically!).

2. Tapered member model

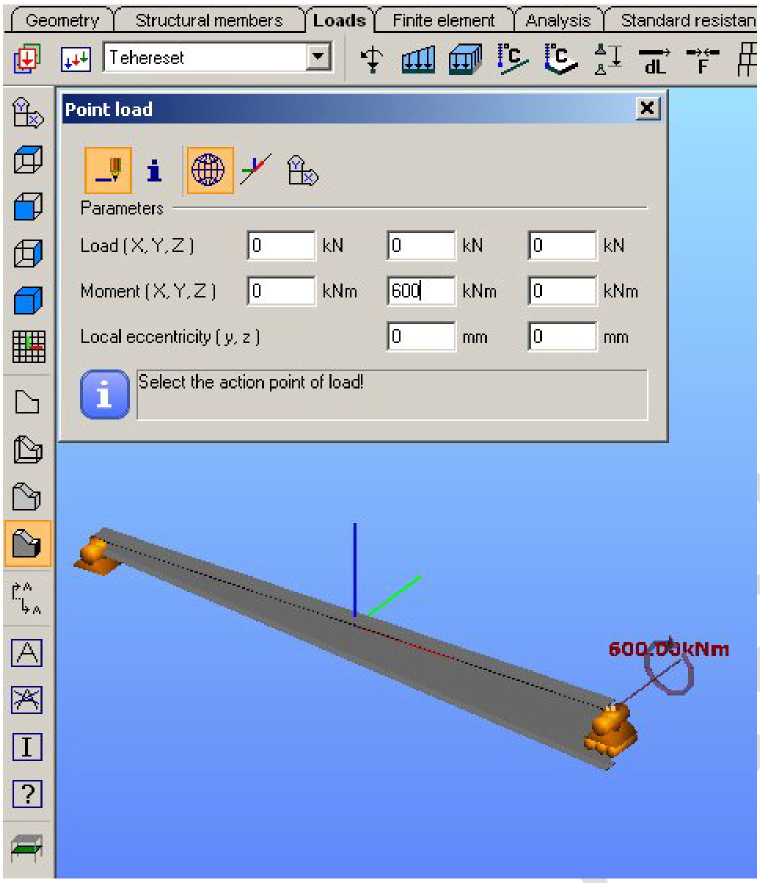
Firstly we define the structural member as a uniform beam with cross-section located at the lower end of the tapered member,



than we define the tapered member,

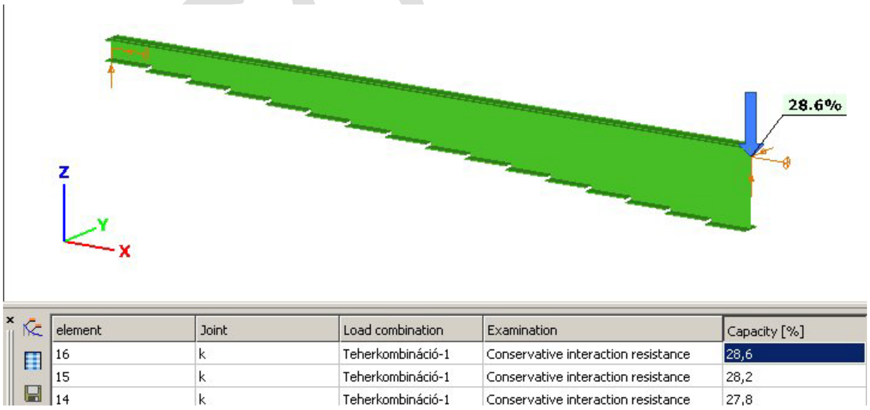


where ***H1*** is the height of the web at the lower end, ***H2*** is the height of the web at higher end, ***Form*** is a parameter that gives the flange which is **not parallel** to the axis (design raster). The member is simple supported at the ends, and the 600 kNm design bending moment acts at the higher end of the member (the bottom flange is compressed):



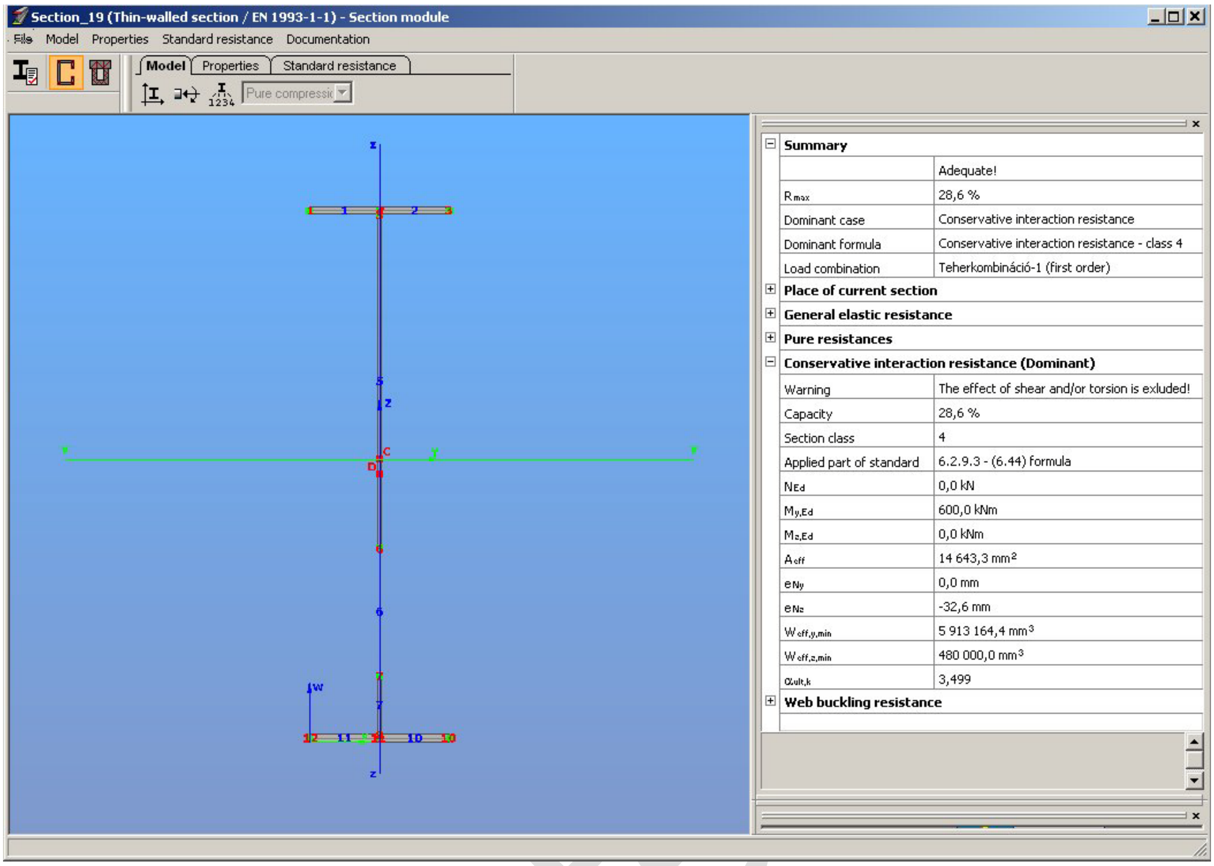
3. Cross-section resistance

The first step of the design procedure is the check of the cross-section resistances. To do this we use the ***Standard resistance*** option, where we select the most critical cross section:



element	Joint	Load combination	Examination	Capacity [%]
16	k	Teherkombináció-1	Conservative interaction resistance	28,6
15	k	Teherkombináció-1	Conservative interaction resistance	28,2
14	k	Teherkombináció-1	Conservative interaction resistance	27,8

Using the Section module, we can get the details of the calculation of the cross-section resistance:

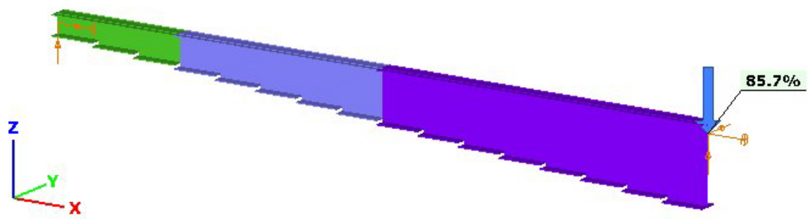


From the table we can see the following:

- the critical cross-section is located at the higher end of the member;
- the cross-section (web) is Class 4 section;
- the appropriate design formula is the **conservative interaction formula**;
- the critical use of the resistance is **28,6%** ($\alpha_{ult,k} = 1/0,286 = 3,49$).

4. Global stability resistance

The critical cross-sectional resistance gives the load amplifier which is one of the basic parameters of the general method for global stability resistance (see General):

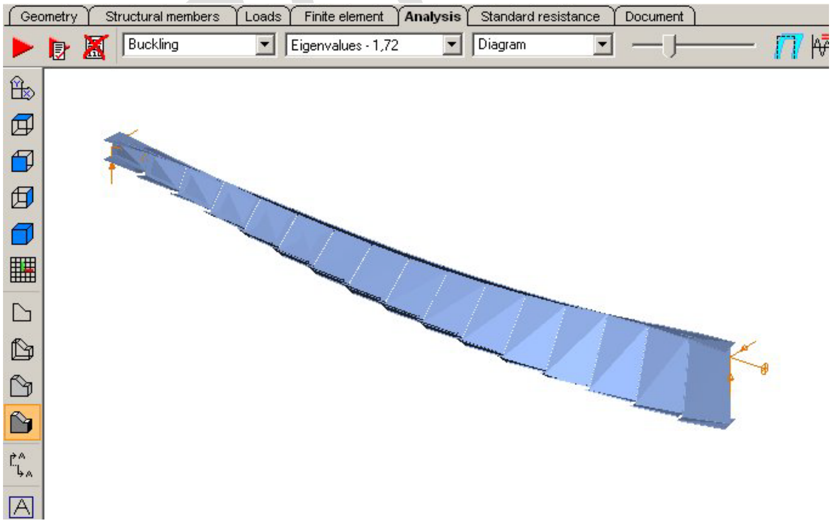


element	Joint	Load combination	Examination	Capacity [%]
16	k	Teherkombináció-1	Global stability resistance	85,7
15	k	Teherkombináció-1	Global stability resistance	85,5
14	k	Teherkombináció-1	Global stability resistance	85,3
13	k	Teherkombináció-1	Global stability resistance	84,8
12	k	Teherkombináció-1	Global stability resistance	84,2

The conservative interaction design equation of the general method is evaluated at the most critical cross section (see the details in example for "*Global stability analysis using general method*"),

Load combination	Teherkombináció-1 (first order)
Place of current section	
General elastic resistance	
Pure resistances	
Conservative interaction resistance	
Web buckling resistance	
Global stability resistance (Dominant)	
Capacity	85,7 %
Applied part of standard	6.3.4 (2)-(3), (4)b - (6.63, 6.64, 6.66) formu
$\alpha_{ult,k}$	3,499
$\alpha_{cr,op}$	1,720
λ_{op}	1,426
α	0,490
Φ	1,817
χ	0,340
α_{LT}	0,760
Φ_{LT}	1,983
χ_{LT}	0,298
N_{Ed}	0,0 kN
$M_{y,Ed}$	600,0 kNm
$M_{z,Ed}$	0,0 kNm
N_{Rk}	5 198,4 kN
$M_{y,Rk}$	2 353,3 kNm
$M_{z,Rk}$	170,4 kNm
γ_{M1}	1,0

where the critical load amplifier ($\alpha_{cr,op} = 1,72$) belongs to the lateral torsional buckling mode:



$$\alpha_{cr,op} = 1,72$$

According to the general method the examined tapered member is adequate for global stability (85,7%).