Design of tapered structural member with Class 4 crosssection

General

The global stability analysis of irregular structural members (for example tapered beamcolumns) 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 $\alpha_{ulr,k}$ 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) crosssection, 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 (λ_o). 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:

10,0 m

300-16

- Length of member:
- Type of cross-section:
- Web dimension:
- Flange dimension:
- End supports:
- Grade of steel:
 - Design moment at higher end:

simple S355

symmetric welded I section

(300-1200)-6 mm

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

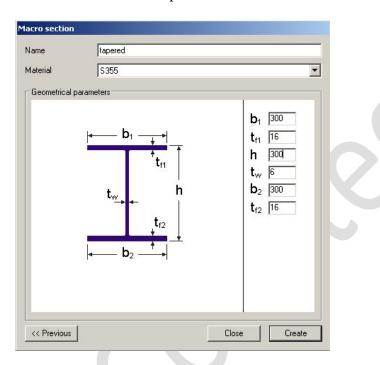


<u>1. Cross section model</u>

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

Macro section	
Macro section types Steel Welded from plates Cold formed	

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



Image: standard resistance Image: standar			ses) - Section module	pered (Thin-walled section / Plate classe	🖅 tapere
Image: Sector module					
Image: Standard resistance Ether Compression Image: Standard resistance Image: Standard resistance Image: Im					-0 L
8 3 9 3 9 3 9 9 a 9 a 9 a 9 a 9 a 9 a 1 a 3		1 3 2 3 3 0 4 0 5 1 6 0			
Itapered_higher (Thin-walled section / Plate classes) - Section module IF. Model Properties Standard resistance Image: Standard resistance Image: Standard resistance Image: Standard resistance		8 3	3	3	
Plate Pure compression 1 3 2 3			umentation	pered_higher (Thin-walled section / Plate of Model Properties Standard resistance Docum	tapered le Model
4 0 5 4 6 0 7 0 8 3		1 3 2 3 3 0 4 0 5 4 6 0 7 0 8 3		∟ ⊨ } =2	
	l	9 3		۳	

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!).

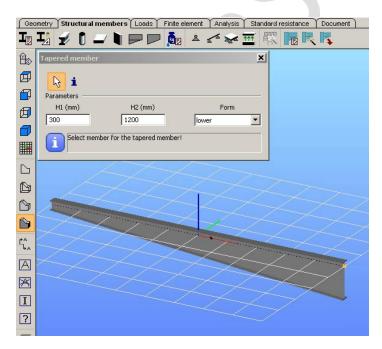
2. Tapered member model

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



Geo	metry Structural members Loads Finite element Analysis Standard resistance Docume
T	≠ 0 - ↓
⊞⊘	Beam
	🖳 🗟 🖬 🌅 🕑
	Parameters
Ø	Element type Section Direction of section Beam-column with twist tapered Normal
	Eccentricity (y, z, rotation) 0 mm 0 degree
	Release (start, end) Folytonos Folytonos
ß	Initial crookedness 0 L/y 0 L/z
1 4 A	Element group Number of finite
	Set the start point
С <u></u> ,	
A	
×	
Ι	
?	
(FFR	

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

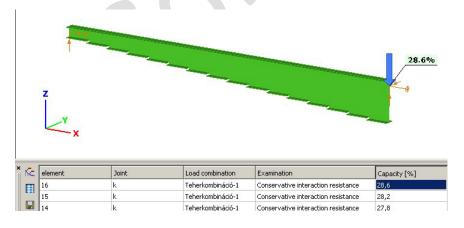
4



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):

Geo	ometry Y Structural members Y Loads Y Finite element Y Analysis Y Standard resistan
Ð	$\square \square $
Ĥx	Point load
	💶 i 🌐 🛩 🏤
	Parameters
Ø	Load (X, Y, Z) 0 kN 0 kN 0 kN
	Moment (X, Y, Z) 0 kNm 600 kNm 0 kNm
	Local eccentricity (y, z) 0 mm 0 mm
	Select the action point of load!
¢л Цл	
A	600.00KNm
×	
Ι	
?	
3. C	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:



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



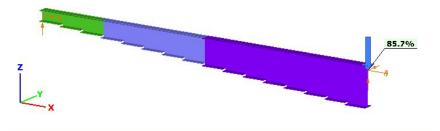
💋 Section_19 (Thin-walled section / EN 1993-1-1) - Section module			
Ris Model Properties Standard resistance I I I I II II III III IIII IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII			
	1		
Z,		Summary	
		2000-00-00-00-00-0 0	Adequate!
		Rmax	
			Conservative interaction resistance
			Conservative interaction resistance - class 4
			Teherkombináció-1 (first order)
	Đ	General elastic resista	ince
	Đ	Pure resistances	
		Conservative interact	ion resistance (Dominant)
1		Warning	The effect of shear and/or torsion is exluded!
Z			
			6.2.9.3 - (6.44) formula
			Second room
			600,0 kNm
	Capacity 28,6 % Section class 4 Applied part of standard 6.2.9.3 NEa 0,0 kN My,Ed 600,0 k MaEd 0,0 kN Aver 14 643 eNy 0,0 mm		
la de la companya de		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	14 643,3 mm ²
			-32,6 mm
Ĭ		W eff,y,min	5 913 164,4 mm ³
		Weff,z,min	480 000,0 mm ³
JW P		Guit,k	3,499
i de la companya de l	Ŧ	Web buckling resistan	ce
12 11 18 10 10 z			-
	-		

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):



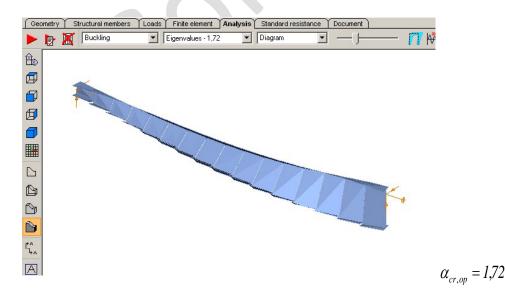
element	Joint	Load combination	Examination	Capacity [%]
16	k	Teherkombináció-1	Global stability resistance	85,7
15	k	Teherkombináció-1	Global stability resistance	85,5
14	k	Teherkombináció-1	Global stability resistance	85,3
13	k	Teherkombináció-1	Global stability resistance	84,8
12	L	Teberkombináció-1	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	n
General elastic resista	ance
Pure resistances	
Conservative interact	ion resistance
Web buckling resistar	ice
Global stability resista	ance (Dominant)
Capacity	85,7 %
Applied part of standard	6.3.4 (2)-(3), (4)b - (6.63, 6.64, 6.66) form
Cluit,k	3,499
Ø.cr.op	1,720
λορ	1,426
α	0,490
Φ	1,817
χ	0,340
α.lt	0,760
ФІТ	1,983
χιτ	0,298
Nea	0,0 kN
My,Ed	600,0 kNm
Ma,Ed	0,0 kNm
NBk	5 198,4 kN
My,Bk	2 353,3 kNm
Ma,Bk	170,4 kNm
γM1	1,0

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





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