GeniE User Manual
Code checking of beams
Implementation of EUROCODE – 1993-1-1

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1. IMPLEMENTATION OF EUROCODE 3

The implementation of Eurocode 3, EN 1993-1-1 is according to:

Eurocode 3: Design of steel structures – EN 1993 Part 1-1: General rules and rules for buildings, 2005

1.1 Revisions supported

The implementation is based on the revision from 2005. It is also an option to select the preferences according to the Norwegian and Danish National Annex.

Due to the updates done to the Eurocode 1993-1-1, the following corrigendas are now supported by GeniE:

NS-EN 1993-1-1:2005/AC:2009

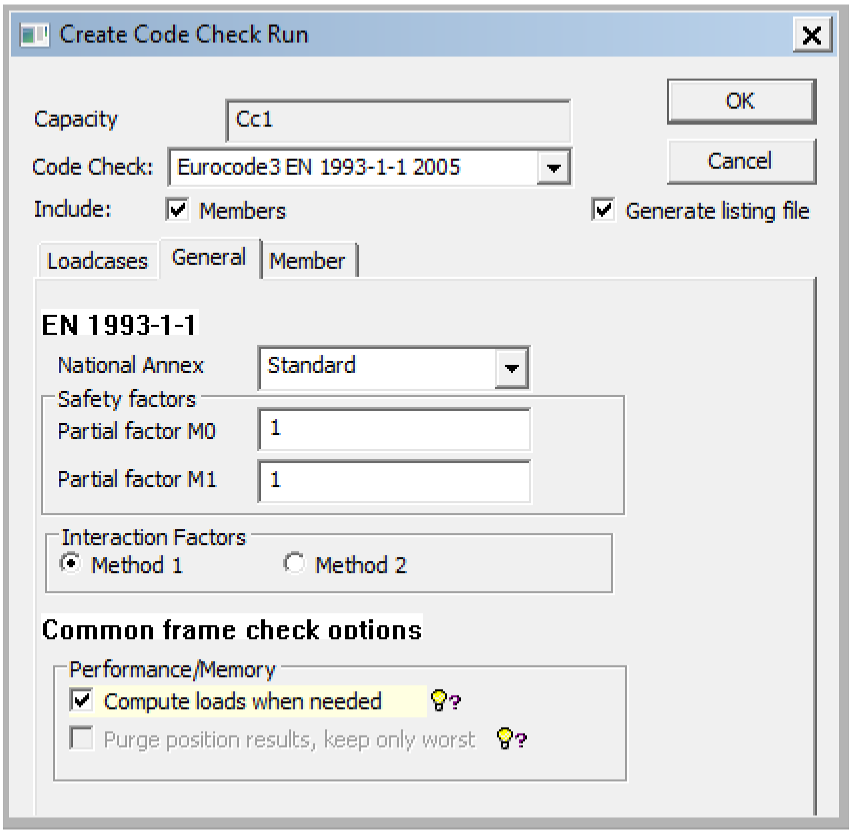
NS-EN 1993-1-1:2005/NA:2008/AC:2010

NS-EN 1993-1-1:2005+A1:2014+NA:2015

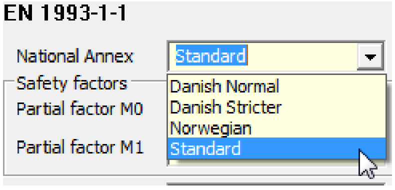
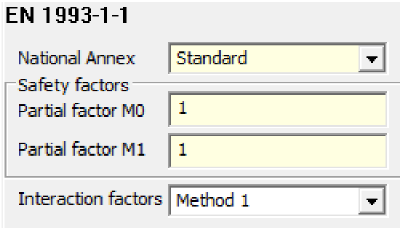
The check covers cross-section and buckling resistance check of isolated members.

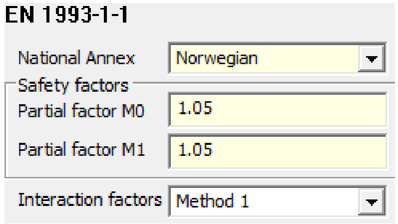
Select EN-1993-1-1 from the Create Code Check Run dialog

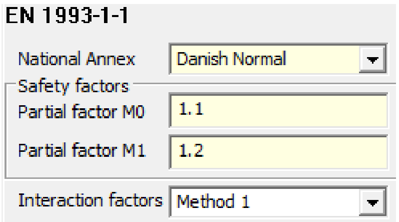
Define the global parameters:

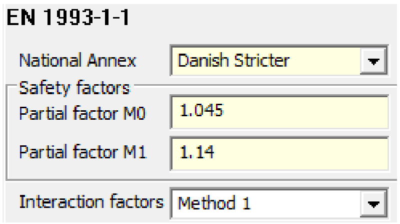


Options:

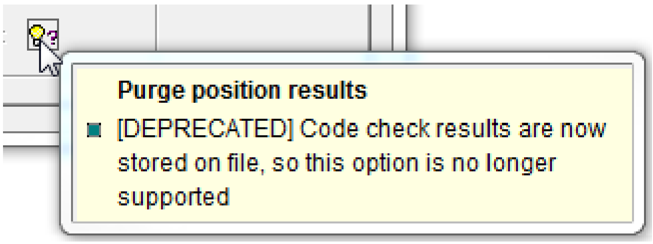
<table>
<tr><td>National Annex

</td><td>Select Standard to use the “neutral” version of EN 1993-1-1, or select a preferred National Annex or select from list:
- Norwegian
- Danish (normal or sticter control class)
When selecting a National Annex the dialogs will be updated to reflect the preferred settings defined in the annex, as shown below</td></tr>
<tr><td colspan="2">The Standard annex uses factors M0 and M1:


The Norwegian annex uses factors M0 and M1:


The Danish annex Control Extent Normal uses factors M0 and M1:


The Danish annex Control Extent Stricter uses factors M0 and M1:

</td></tr>
<tr><td>Safety factors</td><td>Define the partial factors γ_{M0} and γ_{M1} (will automatically update dependant of National Annex)</td></tr>
<tr><td>Interaction factors</td><td>Interaction factors for use in equations (6.61) and (6.62) may be calculated according to method1 (Annex A) or method 2 (Annex B). Select method to be used, default selection is method 1.

</td></tr>
</table>

Compute loads when needed	• To reduce use of database memory, you can compute temporary loads (during code check execution). These loads will be deleted immediately when no longer needed. • This option can affect performance on redesign, as loads must be recalculated locally every time you change member/joint settings. • With this option checked, you will always use the latest FEM loads. When unchecked, you will use the FEM loads retrieved the last time you used “Generate Code Check Loads”. • Note that with option checked member loads will not be available in the report nor in object properties.
Purge position results, keep only worst	

1.2 Member code check

The member code check is performed according to the chapters and sections referred to in the table below:

	Design consideration	Sections covered
5	Structural analysis	**5.5** Classification of cross section 5.5.2 Classification 1) 2)
6	Ultimate limit state	**6.1** General **6.2** Resistance of cross-section 3) 6.2.2 Section properties 6.2.2.1 Gross cross-section 6.2.2.5 Effective cross-section properties of Class 4 cross-sections 6.2.3 Tension 6.2.4 Compression

		6.2.5 Bending moment 6.2.6 Shear 6.2.7 Torsion 9) 6.2.8 Bending and shear 8) 6.2.9 Bending and axial force 6.2.9.1 Class 1 and 2 cross-sections 4) 6.2.9.2 Class 3 cross-sections 6.2.9.3 Class 4 cross-sections 6.2.10 Bending shear and axial force **6.3** Buckling resistance of members 6.3.1 Uniform members in compression 6.3.1.1 Buckling resistance 6.3.1.2 Buckling curves 5) 6.3.1.4 Slenderness for torsional and torsional-flexural buckling 6.3.2 Uniform members in bending 6.3.2.1 Buckling resistance 6.3.2.2 Lateral torsional buckling curves – General case 6) 6.3.2.3 Lateral torsional buckling curves for rolled sections or equivalent welded sections 6.3.3. Uniform members in bending and axial compression
	Annex A	Method 1: Interaction factors k_{ij} for interaction formula in 6.3.3 Table A.1: Interaction factors Table A.2: Equivalent uniform moment factors 7)
	Annex B	Method 2: Interaction factors k_{ij} for interaction formula in 6.3.3 Table B.1: Interaction factors k_{ij} for members not susceptible to torsional deformations Table B.2: Interaction factors k_{ij} for members susceptible to torsional

		deformations Table B.3: Equivalent uniform moment factors 7)

Notes to the table above:

1) The classification of flanges and web(s) are done for axial compression and bending about strong and weak axes for pure axial compression and bending moment actions respectively. I.e. flanges are classified as “part subjected to compression” for load action axial compression and bending about strong axis. Webs are given two classifications, i.e. as “part subjected to compression” and “part subjected to bending”.

One exception from above is that for double-symmetric I/H sections the web is classified as “part subjected to compression and bending”, hence one web classification only. The α value for use in Table 2.1 (sheet 1 of 3) as given in the standard is according to proposal by Gardner and Nethercot (2005). With reference to nomenclature in the standard, the α value is:

$\alpha = (1/c) * ((h/2) + (N_{Ed}/(2*t_w*f_y)) – (t_f-r)) \leq 1$

The allowable capacities for use in the various beam utilization equations are based on the section part classifications for axial compression and bending separately.

2) - Pipe sections: Class 4 is not supported. Treated as class 3 only in "Elastic" classification. If manually set to class 4, class 3 will be used.
- T sections (degenerated I/H): Treated as class 3 only. (Independent of selected "Section classification" option.)
- Box sections: Classification with respect to weak axis is based on webs in uniform compression. Flanges are assumed fully effective.
- Flat bar sections: Treated as class 3 only in "Elastic" classification. If manually set to class 4, class 3 will be used.
- Channel sections: Classification with respect to weak axis bending supports class 1, 2 and 3 only.
- L sections: Treated as class 3 only. (Independent of selected "Section classification" option.)

3) General section is treated similar to the flat bar section but is limited to class 3 behaviour. The following values are used in the calculations:

height = 2*Iy / Wy

width = 2*Iz / Wz

4) For pipe sections $M_{N,Rd} = M_{pl,Rd}(1 – (N_{ed}/N_{pl,Rd}))$ is used. For channel sections equations (6.36) – (6.38) are used.

5) Ref. 6.3.1.2 (4): The paragraph in the standard says “may be”. In this implementation buckling effects are always checked.

6) Ref. 6.3.2.2 (4): The paragraph in the standard says “may be”. In this implementation lateral torsional buckling effects are always checked.

7) For both Method 1 and 2 the bending moment distribution is regarded as linear if, at check point closest to mid-span, the difference between the actual bending moment and calculated linear distribution based on moment at beam start and end is less than 1% of the maximum value at start or

end. The maximum member displacement to be used in Method 1 is a simplified calculation based on the bending moment distribution and stiffness. To distinguish the two cases shown below (Method 1) the bending moment at quarter-point and mid-span is used (with the same approach as explained above) to check if the distribution is linear or not.

	$C_{mi,0} = 1 - 0{,}18\dfrac{N_{Ed}}{N_{cr,i}}$
	$C_{mi,0} = 1 + 0{,}03\dfrac{N_{Ed}}{N_{cr,i}}$

8) Ref 6.2.8 item (2): For members with I/H and Box cross sections where shear buckling reduces the section resistance the section is also checked according to EN 1993-1-5 section 7.1. This check is reported as the shear usage factor (ufShearz) when governing.

9) Implementation of warping effect is according to theory description and expressions given in: AISC, Steel Design Guide Series 9, Torsional Analysis of Structural Steel Members, Seaburg and Carter, 1997 (2nd print 2003).

Implemented for double symmetric I/H shaped profiles and channel profiles.

Maximum torsional moment reported along the member is regarded as the design torsional moment (applied torque) to be used in connection with the selected warping calculation method (Case 3 with α=0.5, Case 4 or Case 7).

Shear stress from pure torsion, in-plane shear stress and normal (longitudinal) stress due to warping are calculated. These stresses ($\tau_{t,Ed}$ and $\tau_{w,Ed}$) are used as defined in 1993-1-1 section 6.2.7 Torsion.

The effect from warping normal stress is added to bending about weak axis when calculating the utilization factor.

Maximum torsional moment reported along the member is regarded as the design torsional moment (applied torque) to be used in connection with the selected warping calculation method (Case 3, 4 or 7).

Reported warping normal stress, sigmawEd:

- for I/H: normal (bending) stress in flange tip
- for channel: maximum normal (bending) stress from flange tip and transition flange/web

Reported warping shear stress, tauwEd:

- for I/H: shear stress in flange
- for channel: maximum shear stress from flange and web

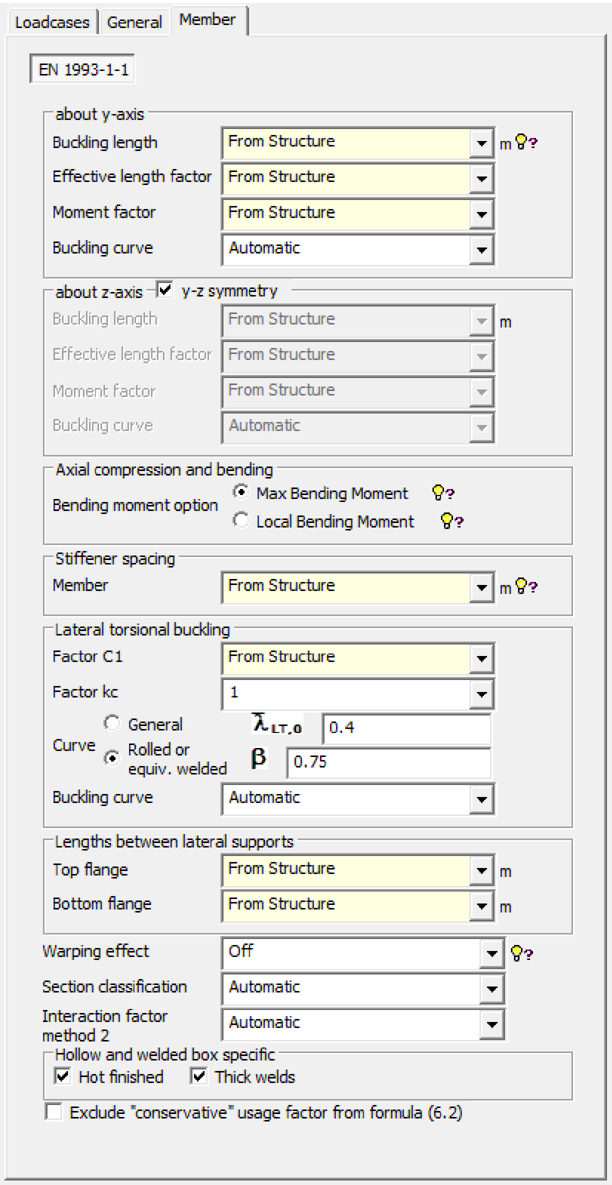
Also note the following:

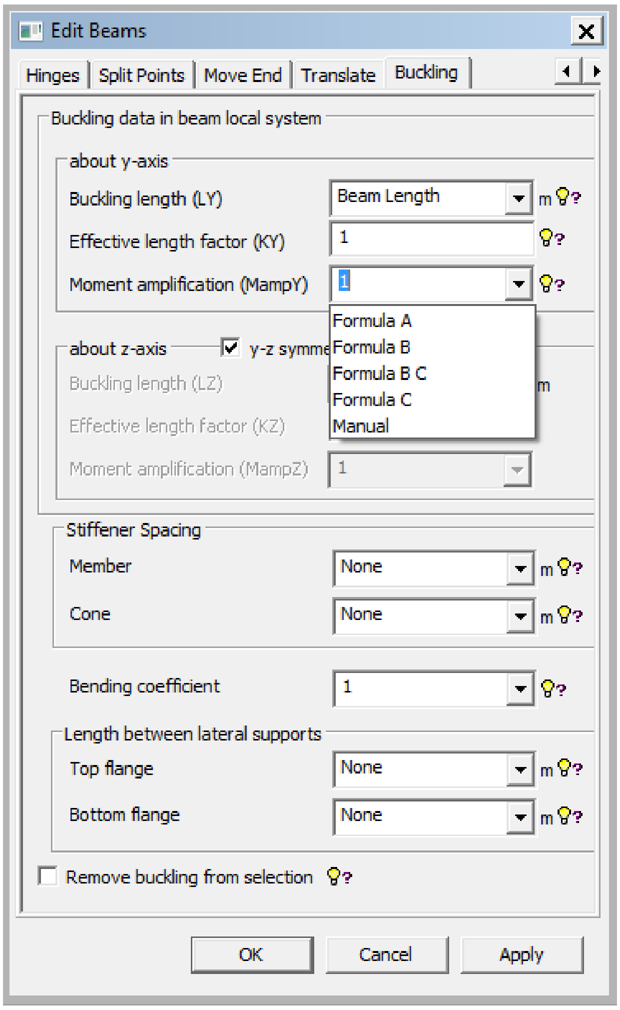
- Un-symmetric I sections are in current implementation treated as single symmetric.
- Code check of L sections is based on principal axes (u and v axes).
- All cross sections are as default set to fabrication status “Unknown”. Unkown is in the code check treated as Built-up (Welded). Note that sections read from the section libraries are also set to status “Unknown”.
- This code check is used by NORSOK N004 and ISO 19902 for non-tubular profiles.

1.3 Definition of member specific parameters:

For the Member specific parameters shown below (to the left) set to From Structure the values will be inherited from the assignments done to the Beam concept (dialog to the right).

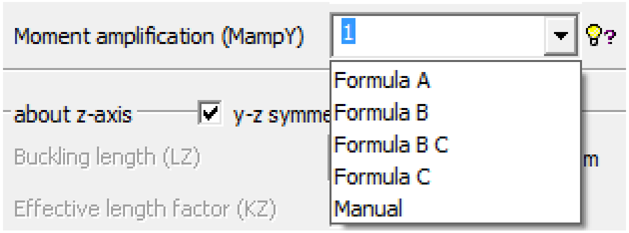
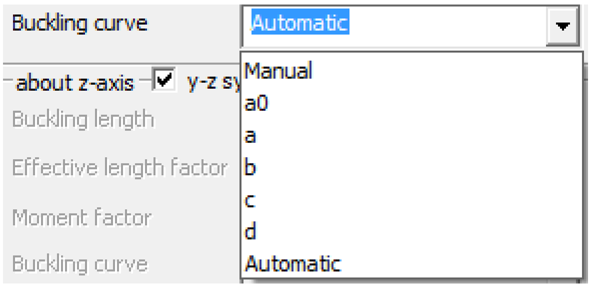
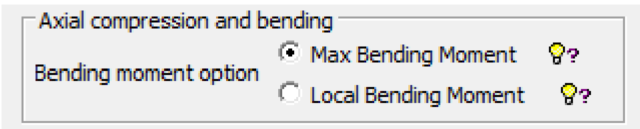
The From Structure alternative is only accepted in cases with one-to-one mapping between modelled beam and member, else the default value/option will be used.

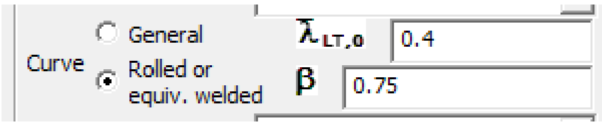
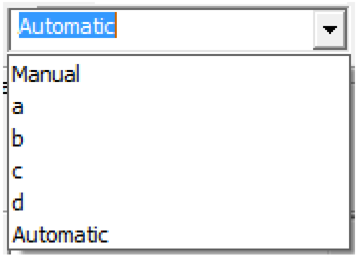


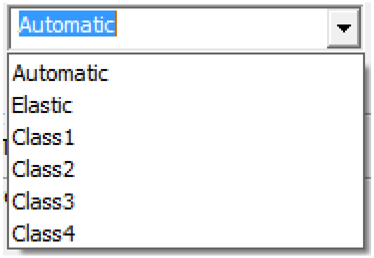
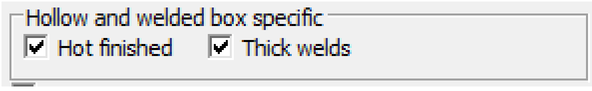
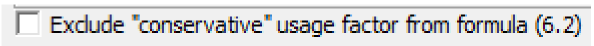


Options:

Buckling length	**From Structure** = use value/option assigned to the beam concept, ref. Edit Beam dialog **Member Length** = use the geometric length of the member (capacity model) **Manual** = specify the length to be used

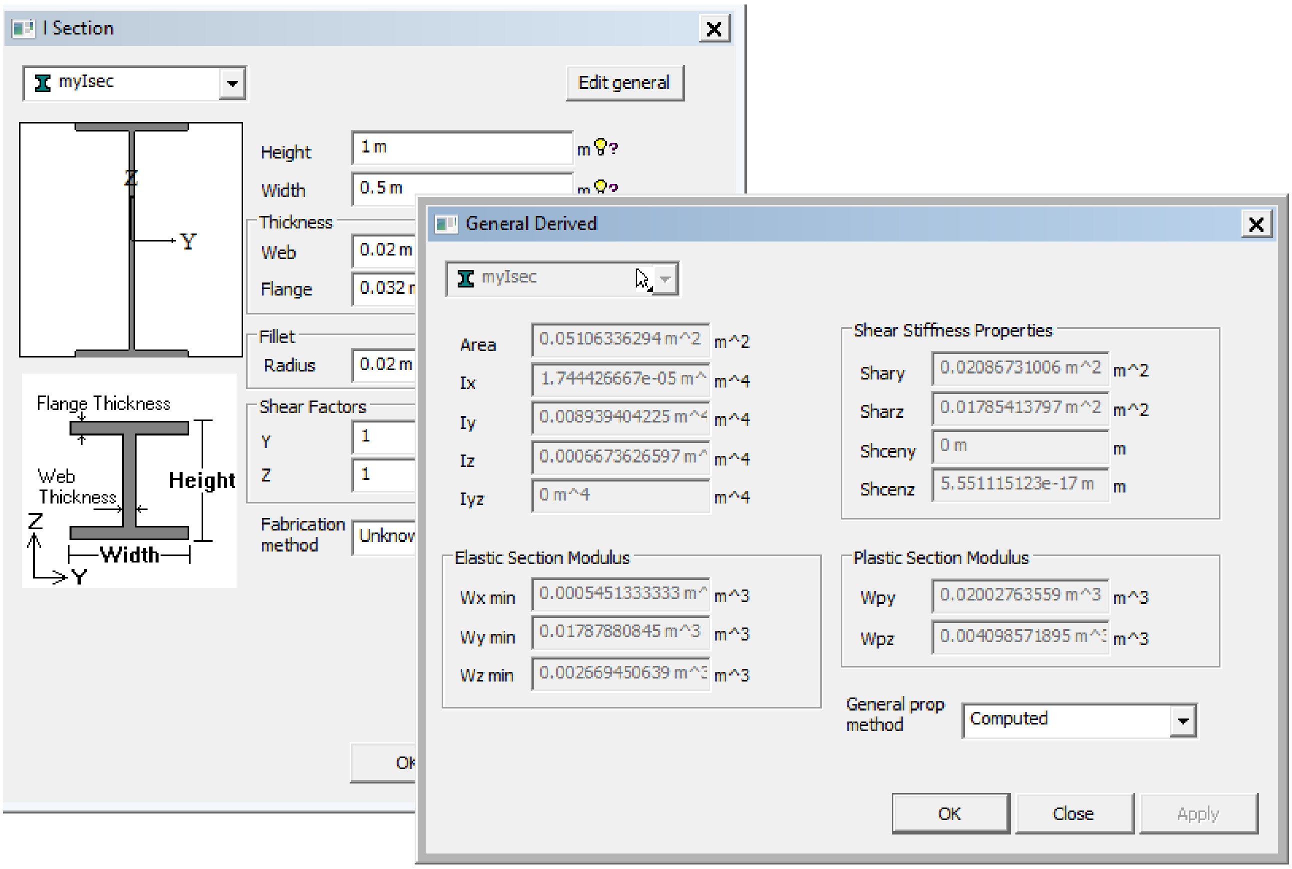
Effective length factor	**From Structure** = use value/option assigned to the beam concept, ref. Edit Beam dialog **Manual** = specify the factor to be used
Moment factor	**EN199311** = use rule/expression given in the standard **From Structure** = use value/option assigned to the beam concept, ref. Edit Beam dialog  For this code check all dialog Formula options are mapped to **EN 1993-1-1** rulebased. **Manual** = specify the factor to be used
Buckling curve	Specify the imperfection factor α to be used or select between the options: Curves a, a0, b, c. d or Automatic selection of curve according to Table 6.2 “Selection of buckling curve for cross-section” 
Axial compression and bending	 **Max Bending Moment** This option selects the maximum bending moments along a capacity member. **Local Bending Moment** This option uses the local bending moments at every code check positions. (Effect of “Moment factor” is taken into account, hence 1.0 should probably be used for this alternative.)
Stiffener spacing	**None** = no web stiffeners given (stiffener spacing = member length) **From Structure** = option will use the assignment given to the Beam concept, ref. Edit Beam dialog **Manual** = specify the length between stiffeners. (The spacing given may be larger than the length of the member concept)

Lateral torsional buckling	<u>Factor C_1:</u> **EN1993_1_1** = use rule/expression given in the standard. Note that rulebased calculation of C1 only supports "simple linear moment distribution", i.e. C_1=1.77-1.04ψ+0.27ψ^2 **From Structure** = use the assignment given to the Beam concept, ref. Edit Beam dialog option **Bending coefficient** **Manual** = specify the value to be used <u>Factor kc:</u> **EN1993_1_1** = use rule/expression given in the standard **Manual** = specify the value to be used <u>Reduction factor χ_{LT} :</u> The alternative for calculating χ_{LT} (based on buckling curve) for lateral torsional buckling must also be selected, i.e. the 'General case' (6.3.2.2) or 'Rolled sections or equivalent welded sections' (6.3.2.3)  <u>Buckling curve:</u> Manually specify the imperfection factor α_{LT} to be used or select between the curves a, b, c, or d according to Table 6.3 "Recommended values for imperfection factors for lateral torsional buckling curves", or Automatic selection of curve according to Tables 6.4 and 6.5. 
Length between lateral supports, top and bottom flange	**None** = no lateral supports given **From Structure** = use the assignment given to the Beam concept, ref. Edit Beam dialog **Manual** = specify the length between lateral supports (unbraced length)
Warping effect	Select how to handle warping: **Off**, or **Case**3, 4 or 7 (see note 9) on page 7) 

Section classification	Select how to handle the cross-section classification; - manually give the class - automatic classification - elastic = automatic classification, but limited to 3 or 4 
Interaction factor method 2	Selection regarding alternatives for interaction factors, Annex B (method 2) Table B1. vs. Table B.2. 
Hollow and welded box specific	Select hot finished (vs. cold formed) and thick welds (vs. generally) with respect to automatic definition of buckling curves, see Table 6.2. 
Formula (6.2)	Conservative approximation for all cross section classes a linear summation of the utilization ratios for each stress resultant may be used. This feature can be disabled by the user on the member tab. 

1.4 Cross section properties for manually updated profiles

From GeniE v7.5 it is possible to manually modify/update the computed cross section properties.



When any of the stiffness properties have been modified by use of “Edit general”, the values sent to the code check routines will be used as is. Dependent of profile type and check different stiffness properties are in use. It is strongly recommended to always update related values, e.g. if modifying Iy also update Wymin and Wpy accordingly.

Also note that when the code check routines get information that something has been modified the slenderness classification (width/thickness ratios) will still be determined, but no cross section reduction will be calculated even if flange or web are defined as slender. Shear capacity (area) will also be re-calculated according to specific formulas given in the standard.

1.5 Nomenclature – EUROCODE 3

The print of all available results inclusive intermediate data from the member check will report the following data.

Member	Capacity model name (name of Beam(s) or part of beam representing the member)
Loadcase	Name of load case/combination under consideration
Position	Relative position along member longitudinal axis (start = 0, end = 1)
Status	Status regarding outcome of code check (OK or Failed)
UfTot	Value of governing usage factor
Formula	Reference to formula/check type causing the governing usage factor
SubCheck	Which check causes this result, here Eurocode EN 1993-1-1 member check
GeomCheck	Status regarding any violation of geometric limitations
ufEuler	Usage factor equal ratio for axial compression / Euler capacity
ufAxial	Usage factor equal ratio for axial load / design resistance for axial loading
ufTorsion	Usage factor due to torsion
ufShearz	Usage factor due to shear in local z direction
ufSheary	Usage factor due to shear in local y direction
ufXSection	Cross section usage factor according to section 6.2.9 and 6.2.10
uf646	Usage factor according to equation (6.46)
uf654	Usage factor according to equation (6.54)
uf661	Usage factor according to equation (6.61)
uf661ax	Axial contribution to usage factor according to equation (6.61)
uf661mo	Moment contribution to usage factor according to equation (6.61)
uf661my	Moment contribution (about local y axis) to usage factor according to equation (6.61)
uf661mz	Moment contribution (about local z axis) to usage factor according to equation (6.61)
uf662	Usage factor according to equation (6.62)
uf662ax	Axial contribution to usage factor according to equation (6.62)
uf662mo	Moment contribution to usage factor according to equation (6.62)
uf662my	Moment contribution (about local y axis) to usage factor according to equation (6.62)
uf662mz	Moment contribution (about local z axis) to usage factor according to equation (6.62)
uf62	Usage factor according to equation (6.2)
uf62ax	Axial contribution to usage factor according to equation (6.2)
uf62mo	Moment contribution to usage factor according to equation (6.2)
uf62my	Moment contribution (about local y axis) to usage factor according to equation (6.2)
uf62mz	Moment contribution (about local z axis) to usage factor according to equation (6.2)

sldComp	slenderness ratio (beam in compression)
relpos	Relative position along member longitudinal axis (start = 0, end = 1)
fy	Yield strength
E	Young's modulus of elasticity
gammaM0	Partial factor M0
gammaM1	Partial factor M1
NEd	Design value of axial force (positive when tension)
MyEd	Design value of moment about local y axis (strong axis)
MzEd	Design value of moment about local z axis (weak axis)
MyMax	Maximum moment along member about local y axis
MzEd	Maximum moment along member about local z axis
TEd	Design value of torsional moment
VyEd	Design value of shear force in local y direction
VzEd	Design value of shear force in local z direction
KLy	System length for buckling about local y axis
KLz	System length for buckling about local z axis
L	Length of member (length of the capacity model)
Ncry	Elastic flexural buckling force about local y axis
Ncrz	Elastic flexural buckling force about local z axis
NtRd	Design value of the resistance to tension force
classF	Cross section classification, flange, uniform compression
classWeak	Cross section classification, bending about weak axis
classWaxi	Cross section classification, web, uniform compression
classWbend	Cross section classification, web, bending
NcRd	Design resistance to normal force for uniform compression
MycRd	Design resistance for bending about local y axis
MzcRd	Design resistance for bending about local z axis
alphay	The imperfection factor according to buckling curve for buckling about local y axis
alphaz	The imperfection factor according to buckling curve for buckling about local z axis
chiy	Reduction factor for buckling resistance about local y axis
chiz	Reduction factor for buckling resistance about local z axis
Aeff	Effective area of the cross section
NbRd	Design buckling resistance of a compression member
NcrTF	The elastic torsional-flexural buckling force
C1	Modification factor for moment distribution
Mcr	Elastic critical moment for lateral-torsional buckling

alphaLT	Imperfection factor for lateral torsional buckling
chiLT	Reduction factor for lateral-torsional buckling
MbRd	Design buckling resistance moment
Cmy	Equivalent uniform moment factor, bending about local y axis
Cmz	Equivalent uniform moment factor, bending about local z axis
CmLT	Equivalent uniform moment factor, lateral-torsional bending
kyy	Interaction factor kyy calculated based on method 1 or method 2
kyz	Interaction factor kyz calculated based on method 1 or method 2
kzy	Interaction factor kzy calculated based on method 1 or method 2
kzz	Interaction factor kzz calculated based on method 1 or method 2
It	Torsional constant
Iw	Warping constant
sigmawEd	Calculated normal stress (maximum) due to warping
tauwEd	Calculated shear stress (maximum) due to warping

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