GeniE User Manual
Code checking of beams
Implementation of AISC 360

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1. IMPLEMENTATION OF AISC 360

This implementation of AISC is according to “**ANSI/AISC 360-xx An American National Standard; Specification for Structural Steel Buildings**”.

1.1 Revisions supported

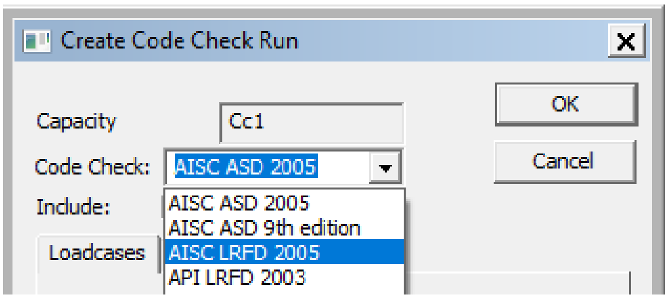
The implementation of this standard supports the following versions:

- 360-05, March 9, 2005, supported by **Steel Construction Manual 13th Edition**
- 360-10, June 22, 2010, supported by **Steel Construction Manual 14th Edition**
- 360-16, July 7, 2016, supported by **Steel Construction Manual 15th Edition**

The check covers design/utilisation of members according to the provisions for Load and Resistance Factor Design (LRFD) or to the provisions for Allowable Strength Design (ASD). Notice:

- Design is based on the principle that no applicable strength limit state shall be exceeded when the structure is subjected to all appropriate load combinations. The check covers checking of isolated members.
- Design of connections is not covered.
- Design for serviceability is not covered.
- Design wall thickness (chapter B3, item 12) is not handled automatically.
- Cross sections are classified according to TABLE B4.1, Limiting Width-Thickness Ratios for Compression Elements.
- To account for second-order effects in frames the first-order bending moments are amplified by the factor B1 (in 360-05: Chapter C2.1b, in 360-10 and later: Appendix 8.2)

Select AISC ASD 2005 (or AISC LRFD 2005) from the Create Code Check Run Dialog:

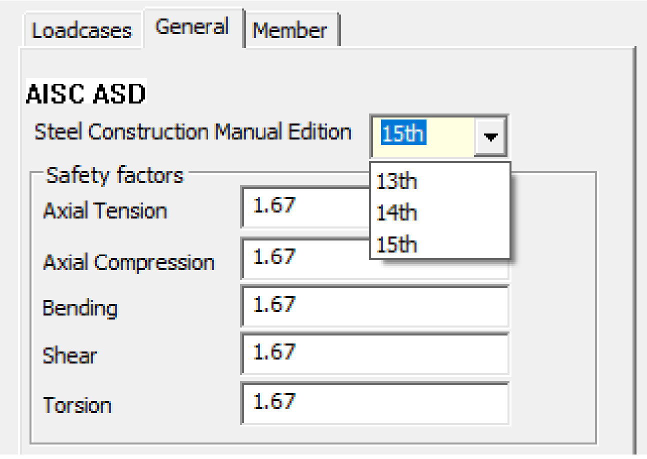


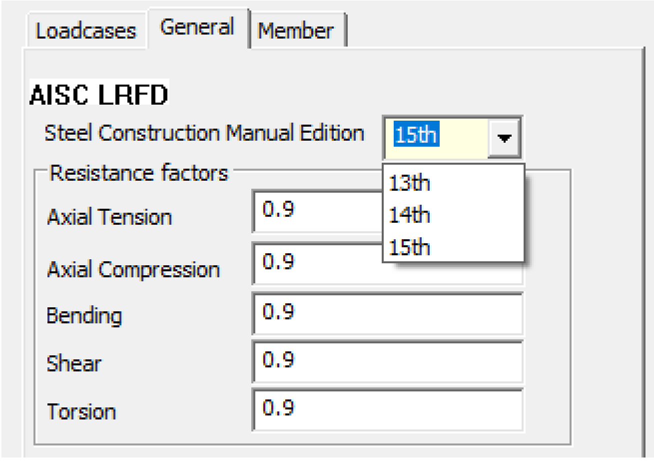
Define the general parameters:

Which data to be given is dependant of which provision selected, i.e. Load and Resistance Factor Design (LRFD) or Allowable Strength Design (ASD). Typically, for ASD the safety factors shall be given and for LRFD the resistance factors shall be given.

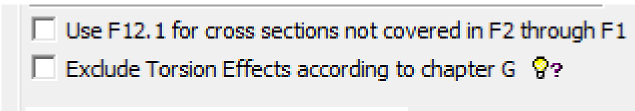
Select the version to be used, Steel Construction Manual 13th, 14th or 15th Edition.

The figures below show the General input to be given for ASD and LRFD. There are five safety/resistance factors that must be defined. The default values are according to the factors given in the standard.



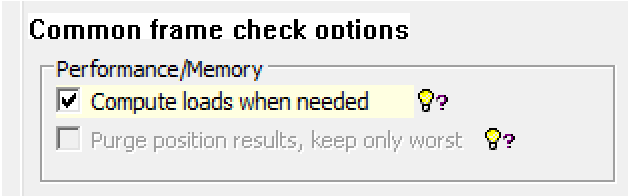


Decide if bending moment capacity shall be calculated according to chapter F12.1 for cross sections not covered in F2 through F11, and if effect of torsion shall be excluded from shear capacity check.



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.



1.2 Member code check

Member design is performed according to the chapters and sections referred to in the table below:

	Design consideration	Sections covered
D	Design of members for tension	**D1**. Slenderness Limitation **D2**. Tensile Strength
E	Design of members for compression See note 1)	**E1**. General Provisions **E2**. Slenderness Limitations and Effective Length **E3**. Compressive Strength for Flexural Buckling of Members without Slender Elements **E4**. Compressive Strength for Torsional and Flexural-Torsional Buckling of Members without Slender Elements **E5**. Single Angle Compression Members (parts (a) and (b) only) **E7**. Members with Slender Elements
F	Design of members for flexure (ref. Figure 1) See note 2) and 3)	**F1**. General Provisions **F2**. Doubly Symmetric Compact I-Shaped Members and Channels Bent about their Major Axis **F3**. Doubly Symmetric I-Shaped Members with Compact Webs and Noncompact or Slender Flanges Bent about Their Major Axis **F4**. Other I-Shaped Members with Compact or Noncompact Webs, Bent about Their Major Axis. **F5**. Doubly Symmetric and Singly Symmetric I-Shaped Members with Slender Webs Bent about Their Major Axis **F6**. I-Shaped Members and Channels Bent about Their Minor Axis **F7**. Square and Rectangular HSS and Box-Shaped Members **F8**. Round HSS **F9**. Tees and Double Angles Loaded in the Plane of Symmetry **F11**. Rectangular Bars and Rounds **F10**. Single Angles. **F12.1**. Unsymmetrical shapes (Note that the capacity M_n is calculated according to equation (F12-1) only, i.e. it is the yield moment that is calculated.) **F13**. Proportions of Beams and Girders (only part 2. Proportioning Limits for I-Shaped Members)
G	Design of members for shear See note 4) and 6)	**G1**. General Provisions **G2**. I-Shaped members and channels. ("Members with Unstiffened or Stiffened Webs" prior 360-10)

		G3. Single Angles (G4 prior 360-16) **G4**. Rectangular HSS and Box Members (G5 prior 360-16) **G5**. Round HSS (G6 prior 360-16) **G6**. Weak Axis Shear in Singly and Doubly Symmetric Shapes (G7 prior 360-16)
H	Design of members for combined forces and torsion See note 5) and 6)	**H1**. Doubly and Singly Symmetric Members Subject to Flexure and Axial Force **H1.1**. Doubly and Singly Symmetric Members in Flexure and Compression **H1.2**. Doubly and Singly Symmetric Members in Flexure and Tension **H2**. Un-symmetric and Other Members Subject to Flexure and Axial Force **H3**. Members Under Torsion and Combined Torsion, Flexure, Shear and/or Axial Force **H3.1**. Torsional Strength of Round and Rectangular HSS **H3.2**. HSS Subject to Combined Torsion, Shear, Flexure and Axial Force

Notes to table above:

1) Regarding section E7: From 360-16 the reduction factor Q is no longer used. However, for reporting purpose an equivalent Q = A_e/A is calculated.

2) Bending about major axis:

Members having cross section classification not covered by this section will not be given any nominal bending strength, e.g. a channel profile classified with non-compact or slender flange. Such members are given the usage factor 998, and the geometric check called “Out Of Bounds” will get the value of 2.

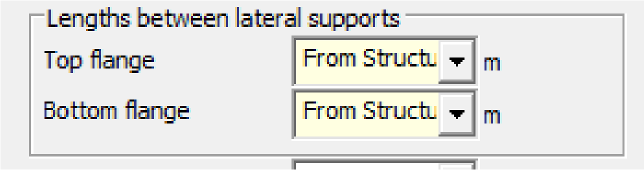
Prior 360-16, Box section with webs classified as slender was not covered. Such members are given the usage factor 997, and the geometric check called “Out Of Bounds” will get the value of 3.

Tubular (Pipe) sections: Pipe sections with (D/t) > (0.45*E/Fy) is not handled. Such members are given the usage factor 996, and the geometric check called “Out Of Bounds” will get the value of 4.

If the option “Use F12.1 for cross sections not covered in F2 through F11” is selected the yield moment capacity is calculated and hence usage factors are calculated and reported based on this.

3) Regarding section F10: For calculating the section property β_w used for unequal leg angles a close approximation explained in report: “Lateral Buckling Strengths of Steel Angle Section Beams, Research Report No R812, February 2002 from The University of Sydney Department of Civil Engineering” is used.

To determine if the beam has lateral-torsional restraint or not the smallest value given for “Length between lateral supports” of top or bottom flange is used as follows:



If not given (i.e. equal to beam length) → no lateral-torsional restraint

If given less than 10% of beam length → continuous lateral-torsional restraint assumed

If different from beam length and larger than 10% of beam length then assuming lateral-torsional restraint at the point of maximum moment only (and the value given is used as Lb). Used for equal leg angles only, ref. F10.2 (iii) (b), from 360-16 F10.2 (2) (ii).

4) For profiles of cross section types other than rectangular box and tubular the utilisation caused by shear is adjusted to also account for the shear stress flow caused by torsion.

LRFD: The given resistance factor φ_v (default set to 0.9) is automatically adjusted with a factor 1.11 for beams calculated according to G2.1.(a).

ASD: The given safety factor Ω_v (default set to 1.67) is automatically adjusted with a factor 0.9 for beams calculated according to G2.1.(a).

5) Members checked according to section H3 are also checked according to section H1.
For members in tension checked according to (H1-1b) where P_r/P_c alone gives a larger usage factor than (H1-1b), P_r/P_c is reported as the governing usage factor.

6) 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 $\alpha = 0.5$, Case 4 or Case 7).

Shear stress from pure torsion, in-plane shear stress and normal (longitudinal) stress due to warping are calculated. The contribution from these shear stresses is part of the reported shear utilization factor.

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

Reported warping normal stress, f_{rnw}:

- 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, f_{rvw}:

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

Also note the following:

- **Cross sections of type GENERAL**

Cross section defined without geometric shape is treated similar to rectangular BAR. The following formulas are used to simulate height, width and plastic section modulus:

Height	2.0 * I_y / S_y (S_y = elastic section modulus about major axis)
Width	2.0 * I_z / S_z (S_z = elastic section modulus about minor axis)
Z_y	2.0 * Static area moment about major axis
Z_z	2.0 * Static area moment about minor axis

Cross section local axes x (major axis) and y (minor axis) in AISC correspond to local axes y and z in the SESAM notations. In this document the SESAM notation is used.

- **AISC member check in context of API run**

When the AISC ASD member code check is executed in context of an API WSD run the safety factors are automatically modified (GeniE V6.5-04 and newer versions) based on the load case condition definition (or a manually defined stress increase factor). Ref. API RP 2A-WSD statement:” *Where stresses are due in part to the lateral and vertical forces imposed by design environmental conditions, the basic AISC allowable stresses may be increased by one-third*.”

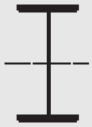
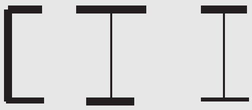
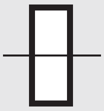
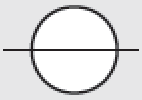
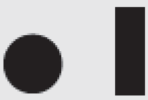
- **Profile type rolled vs. built-up**

All cross sections are as default set to fabrication status “Unknown”. Status “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”.

- **Un-symmtric I sections**

Un-symmetric I sections are in current implementation treated as single symmetric. Upper and lower flange thicknesses and width are kept, but symmetry about local Z axis is assumed.

TABLE USER NOTE E1.1
Selection Table for the Application of Chapter E Sections

Cross Section	Without Slender Elements		With Slender Elements	
	Sections in Chapter E	Limit States	Sections in Chapter E	Limit States
	E3 E4	FB TB	E7	LB FB TB
	E3 E4	FB FTB	E7	LB FB FTB
	E3	FB	E7	LB FB
	E3	FB	E7	LB FB
	E3 E4	FB FTB	E7	LB FB FTB
	E6 E3 E4	FB FTB	E6 E7	LB FB FTB
	E5		E5	
	E3	FB	N/A	N/A
Unsymmetrical shapes other than single angles	E4	FTB	E7	LB FTB

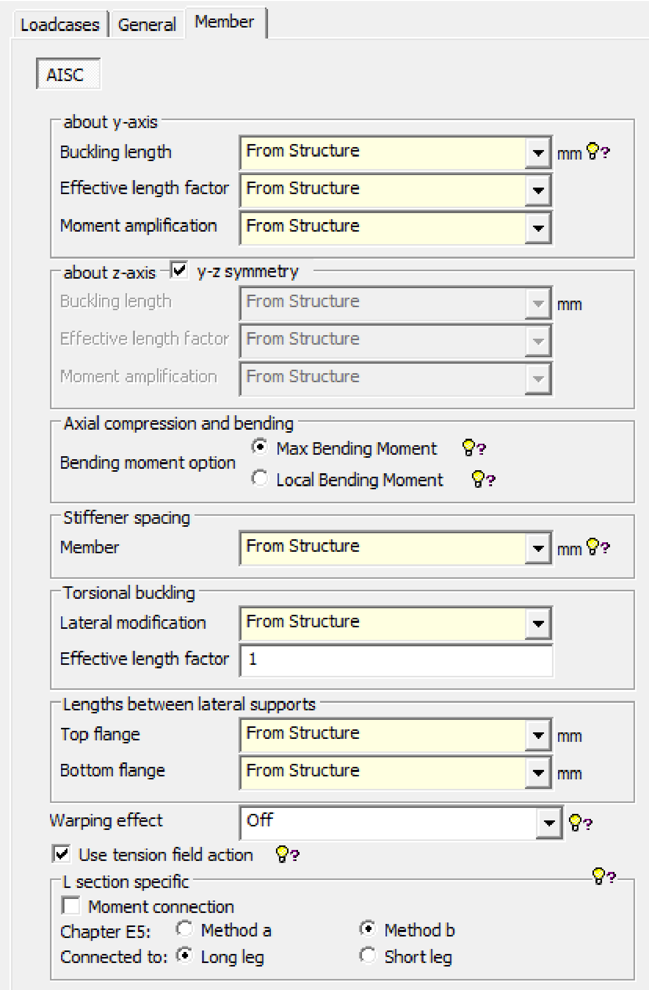
FB = flexural buckling, TB = torsional buckling, FTB = flexural-torsional buckling, LB = local buckling

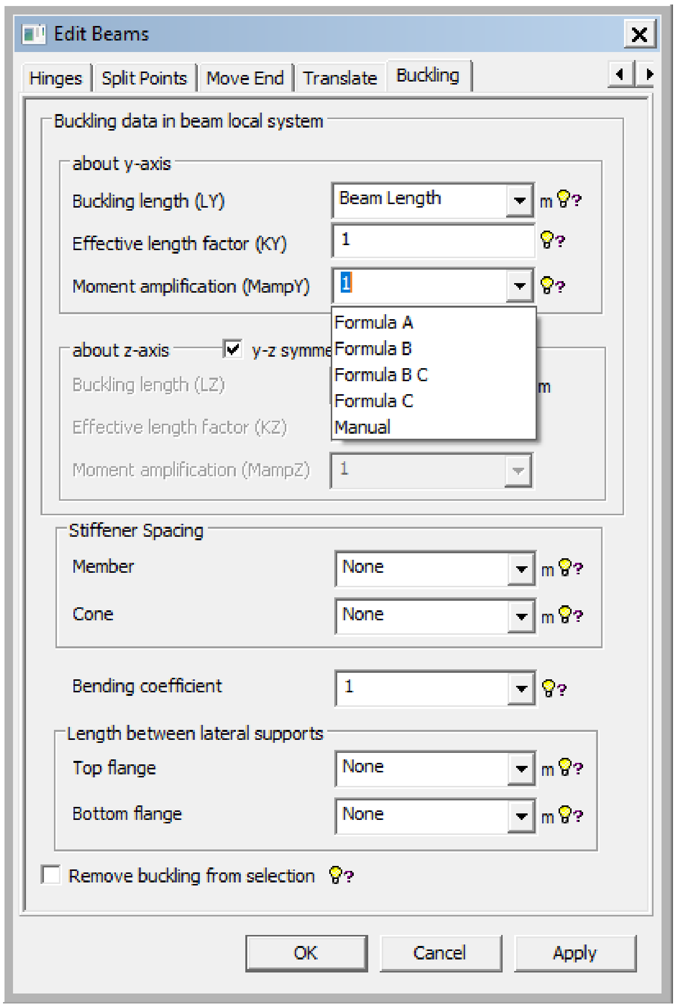
Figure 1. (360-16)

1.3 Definition of member specific parameters (both ASD and LRFD)

For 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).

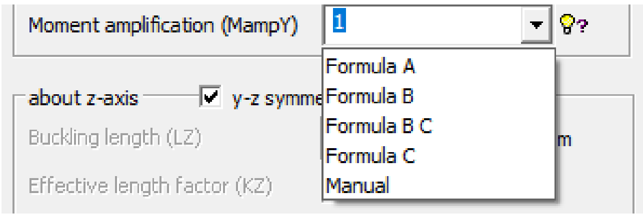
The “From Structure” alternative is only accepted in cases with one-to-one mapping between modelled beam and member, else the default value/option will be used.

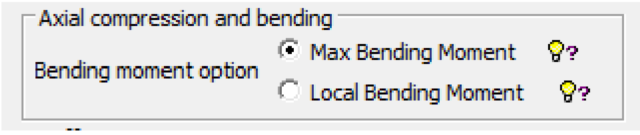




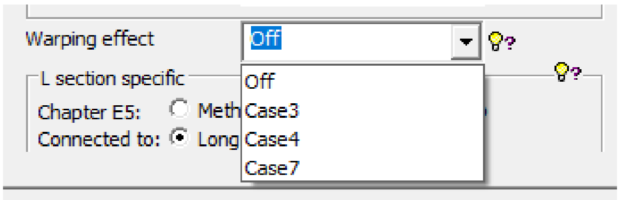
Options:

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 amplification	**Aisc** = use rule/expression given in the standard

<table>
<tr><td></td><td> From Structure = use value/option assigned to the beam concept, ref. Edit Beam dialog


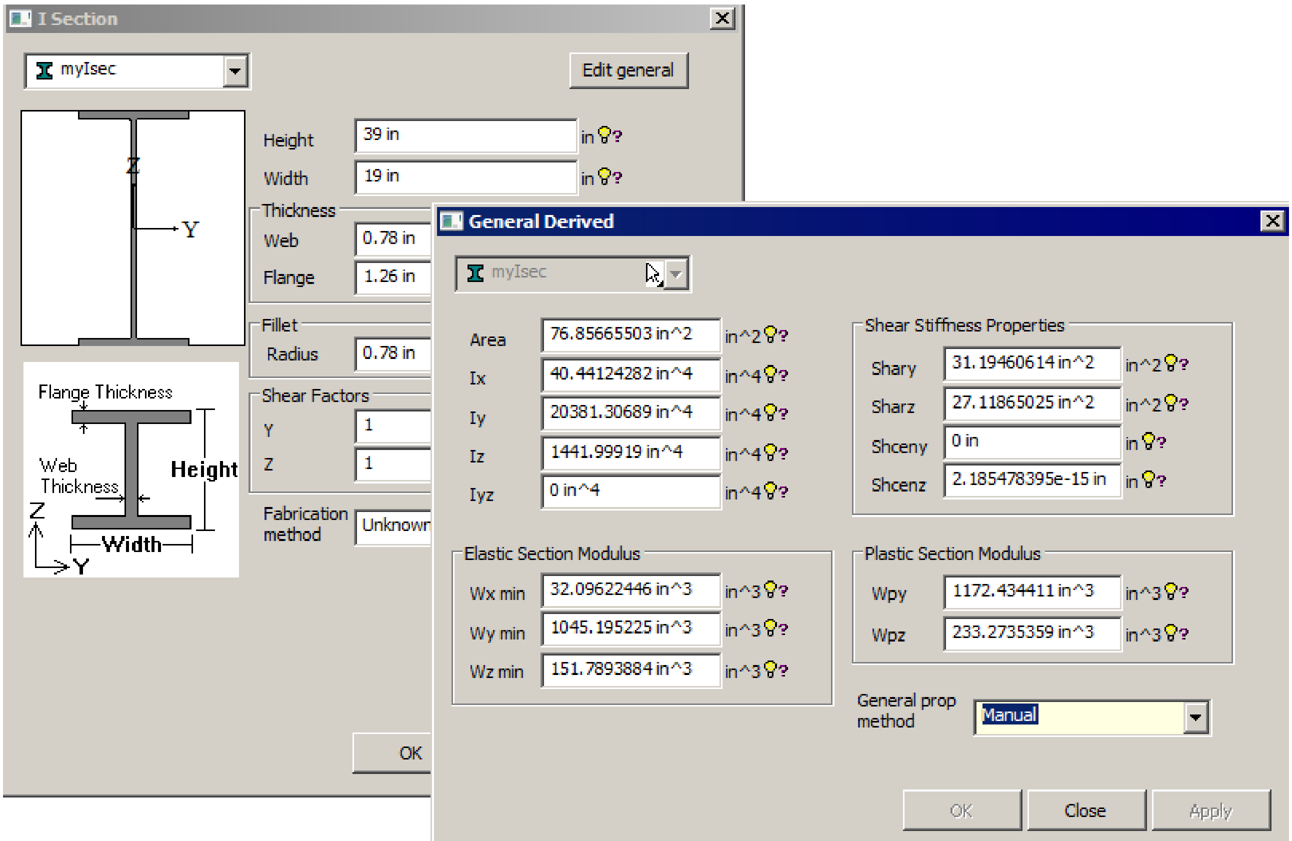
For this code check all dialog Formula options are mapped to Aisc rulebased.
Manual = specify the factor to be used </td></tr>
<tr><td>Axial compression and bending.</td><td>

Max Bending Moment
This option selects the maximum bending moments along a capacity member derived by the effect of moment gradient, Cm.
Local Bending Moment
This option uses the local bending moments at every code check positions. Use of local bending moment could be non-conservative. </td></tr>
<tr><td>Stiffener spacing</td><td> None = no web stiffeners given (stiffener spacing = member length). Set spacing to zero for “true” unstiffened.
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) </td></tr>
<tr><td>Lateral torsional buckling modification</td><td> Aisc = use rule/expression given in the standard
From Structure = use the assignment given to the Beam concept, ref. Edit Beam dialog option Bending coefficient
Manual = specify the value to be used </td></tr>
<tr><td>Effective length factor for torsional buckling</td><td>Specify the value to be used for effective length factor for torsional buckling, K_z</td></tr>
<tr><td>Length between lateral supports, top and bottom flange</td><td> 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) </td></tr>
<tr><td>Warping effect</td><td> Select how to handle warping:
Off = no effect from warping included
Case3, 4 or 7 = include warping, see note 6) on page 6 </td></tr>
</table>

	
Use tension field action	When selected increased shear capacity due to tension field action will be accounted for. (Ref. 360-16 section G2.2. Implemented when selecting 15th or later only). Switch off if in doubt that tension field can be developed.
L section specific data	**Moment connection**: User given buckling lengths and factors will be used together with principal axis in the column buckling calculations. **Chapter E5 (Connected to)**: Axial capacity according to E5.(a) or E5.(b): Method a = use E5.(a), Method b = use E5.(b), and select connected to long leg or short leg.

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 AISC

The print of all available results inclusive intermediate data from the AISC check will report the following:

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 AISC member check
GeomCheck	Status regarding any violation of geometric limitations: - slenderness L/r < 300 (member in tension) - slenderness L/r < 200 (member in compression) - D/t < 273 (pipe section only) - 0.1 < Izc/Iz < 0.9 (I section only) - h/tw ratio according to Section F13.2. Reported relative to variable limit. - Aweb/Acf < 10 (according to Section F13.2) - Leg length ratio < 1.7 (L section only)
ufShear	Usage factor caused by shear force (inclusive effect of torsion for non-HSS sections)
ufH1	Usage factor according to section H1
ufH1ax	Axial contribution to usage factor according to section H1
ufH1mo	Moment contribution to usage factor according to section H1
ufH2	Usage factor according to section H2
ufH2ax	Axial contribution to usage factor according to section H2
ufH2mo	Moment contribution to usage factor according to section H2
ufH3	Usage factor according to section H3
sldTens	member slenderness, member in tension
sldComp	member slenderness, member in compression
D/t	Outer diameter / wall thickness ratio for tubular member
Izc/Iz	Ratio between moment of inertia of compression flange and complete section about minor axis (Valid for I section only. Note that for other cross section types 0.5 is reported)
h/tw(rel.)	Ratio between web height and web thickness (I section only). Reported rel. to variable limit.
web/Afc	Ratio between web area and area of compression flange (I section only)

bl/bs	Ratio between lengths for long and short leg of L section
OutOfBounds	Warning flag that the cross section is outside what is covered in the standard (or implementation)
relpos	Relative position along member longitudinal axis (start = 0, end = 1)
Fy	Yield strength
E	Young's modulus of elasticity
KLy	Buckling length for buckling about major axis
KLz	Buckling length for buckling about minor axis
a	Length between stiffeners
L	Length of capacity model
Kz	Length factor for torsional buckling
Lb	Length between point for lateral support of flange
Cmy	Bending moment amplification coefficient for bending about major axis
Cmz	Bending moment amplification coefficient for bending about minor axis
Pr	Acting axial force (negative when compression)
Mry	Acting bending moment about major axis. (Effect of amplifier included.) For single angle profile according to principal axis design this is wrt. principal major axis.
Mrz	Acting bending moment about minor axis. (Effect of amplifier included.) For single angle profile according to principal axis design this is wrt. principal minor axis.
Mrymax	Maximum acting bending moment about major axis in case of compression. If tension then Mrymax is always zero. (Effect of amplifier included.) For single angle profile according to principal axis design this is wrt. principal major axis.
Mrzmax	Maximum acting bending moment about minor axis in case of compression. If tension then Mrzmax is always zero. (Effect of amplifier included.) For single angle profile according to principal axis design this is wrt. principal minor axis.
B1y	Bending moment amplifier to account for second order effects regarding bending about major axis
B1z	Bending moment amplifier to account for second order effects regarding bending about minor axis
Pey	Elastic critical buckling resistance when bending about major axis
Pez	Elastic critical buckling resistance when bending about minor axis
PnD2	Nominal axial strength for member in tension, ref. section D.2
FlSldC	Slenderness class. of flange, axial compression (0=compact, 1=non-compact, 2=slender)
WebSldC	Web classification of flange, axial compression (0=compact, 1=non-compact, 2=slender)
PnE3	Nominal compression strength based on limit state of flexural buckling, ref. section E.3
FcrE3	Flexural buckling stress of members without slender elements, ref. section E.3
PnE4	Nominal compression strength based on limit state of flexural-torsional buckling, ref. section E.4
FcrE4	Flexural buckling stress of members without slender elements, ref. section E.4
Q	Reduction factor due to slender elements (From 360-16 the reduction factor Q is no longer

	used. However, for reporting purpose an equivalent Q = Ae/A is calculated)
PnE	Nominal compressive strength
FcrAxial	Flexural buckling stress for members in compression
Cb	Lateral torsional buckling modification factor
FlSldF	Slenderness classification of flange, flexure (0=compact, 1=non-compact, 2=slender)
WebSldF	Web classification of flange, flexure (0=compact, 1=non-compact, 2=slender)
Mny	Nominal flexural strength for bending about major axis
Sect. F.	Reference to section in chapter F for calculation of Mny
Mnz	Nominal flexural strength for bending about minor axis
Vnz	Nominal shear strength for shear in local z direction
Cv	Web shear coefficient
kv	Web plate buckling coefficient
Vny	Nominal shear strength for shear in local y direction
Pc	Design axial strength
Pr/Pc	Ratio between required axial strength and design strength
Mcy	Design flexural strength for bending about major axis
Mcz	Design flexural strength for bending about minor axis
J	Torsional constant
Cw	Warping constant
frnw	Calculated normal stress (maximum) due to warping
frvw	Calculated shear stress (maximum) due to warping

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