SDC VERIFIER

Tutorial
AISC 360-10 & Eurocode3
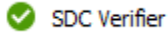
ANSYS®

25 Nov 2020
version 2020.0.2

Content

▸ In this tutorial, AISC 360-10 & Eurocode3 Beam Design Checks are reviewed in details.

▸ A beam model structure has been used as a start FEM model.

▸ Beam member finder was used to recognize beam member dimensions.

▸ Report was automatically generated in SDC Verifier Report to represent beam checks results according AISC 360-10 & Eurocode3 standards.
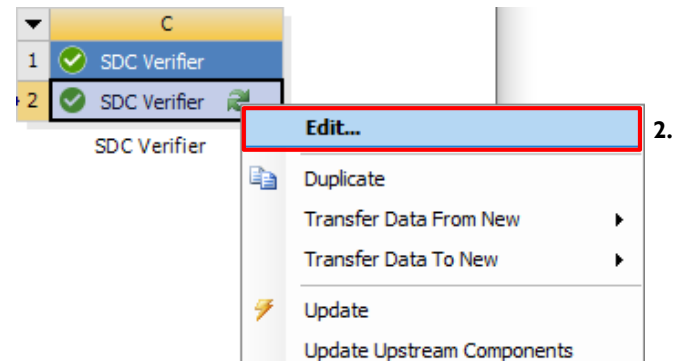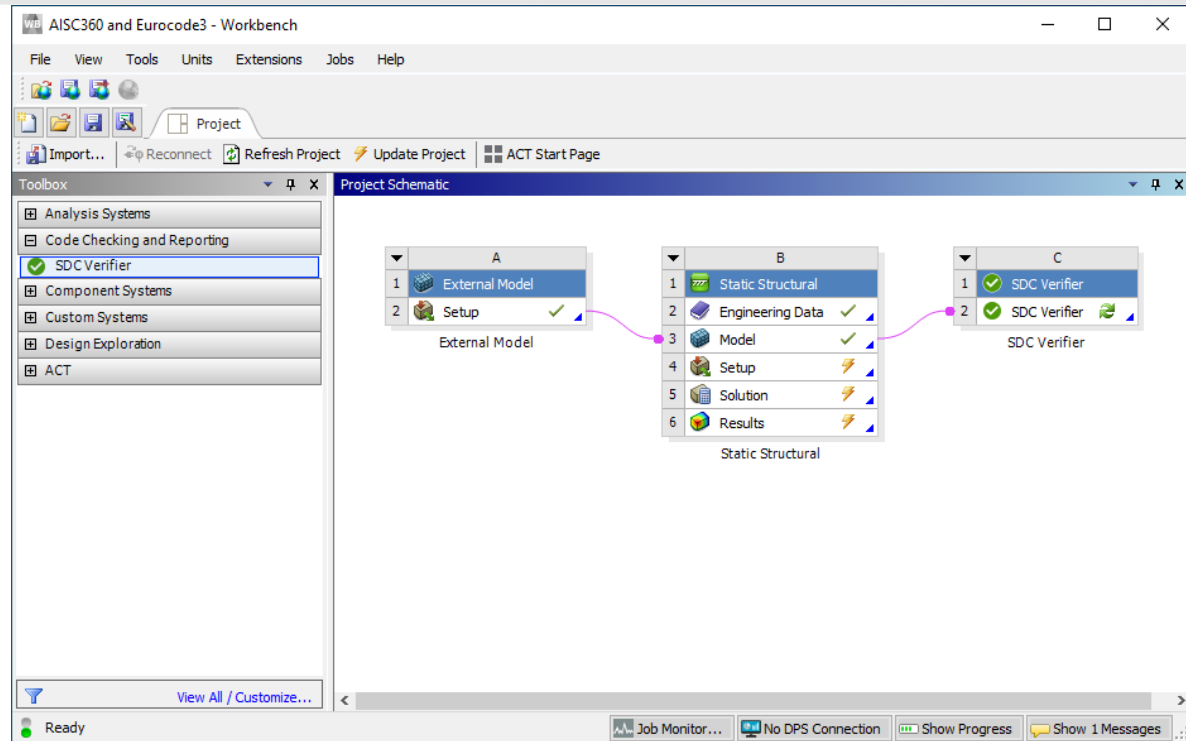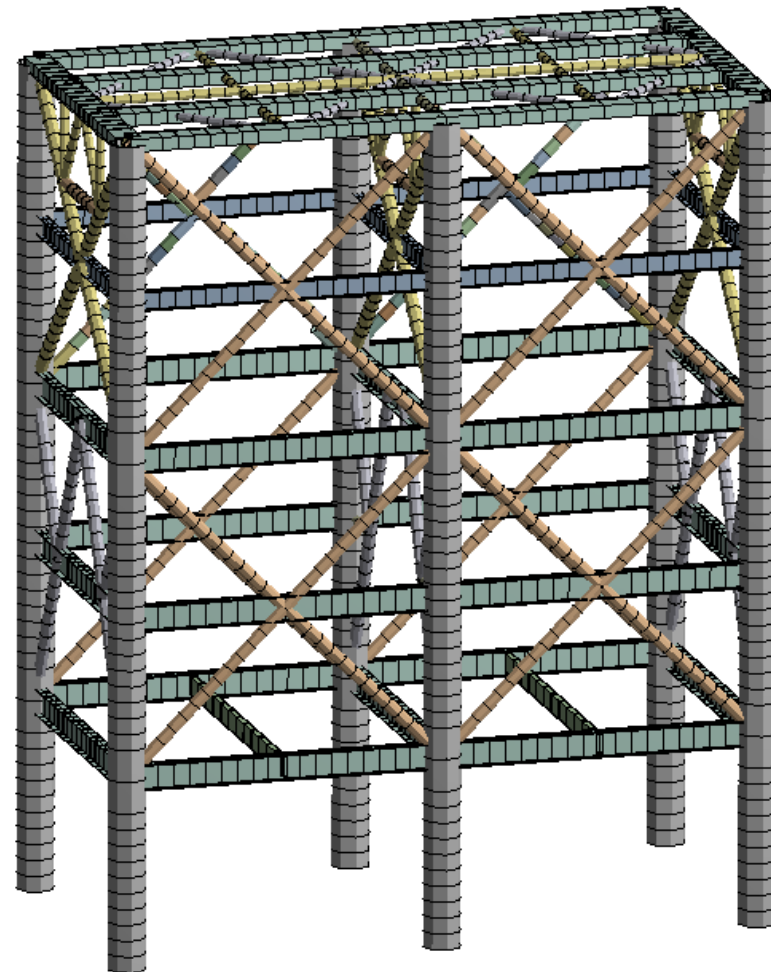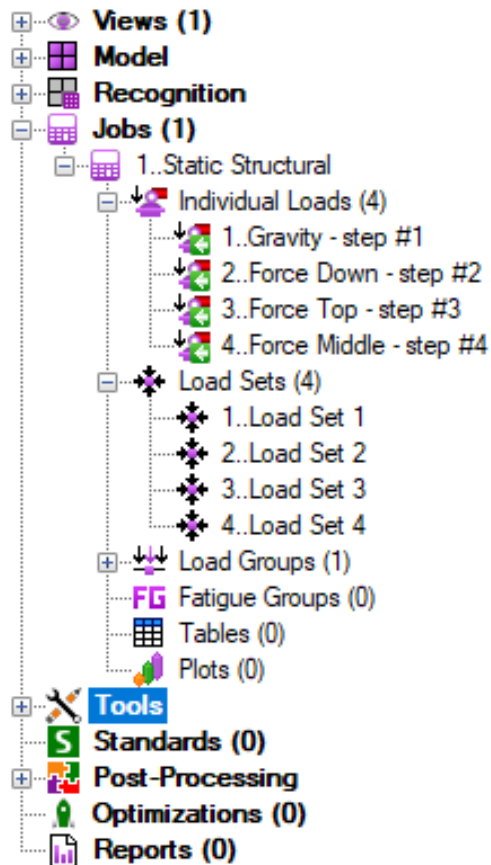
Launch SDC Verifier

1 Open in **Ansys Workbench** ⛰️
AISC360 and Eurocode3.wbpj

2 Double Click on ▸2 ✅ SDC Verifier ♻️◣
or in context menu click **Edit**

2.

Predefined project

- Views (1)
- Model
- Recognition
- Jobs (1)
  - 1..Static Structural
    - Individual Loads (4)
      - 1..Gravity - step #1
      - 2..Force Down - step #2
      - 3..Force Top - step #3
      - 4..Force Middle - step #4
    - Load Sets (4)
      - 1..Load Set 1
      - 2..Load Set 2
      - 3..Load Set 3
      - 4..Load Set 4
    - Load Groups (1)
    - Fatigue Groups (0)
    - Tables (0)
    - Plots (0)
- Tools
- Standards (0)
- Post-Processing
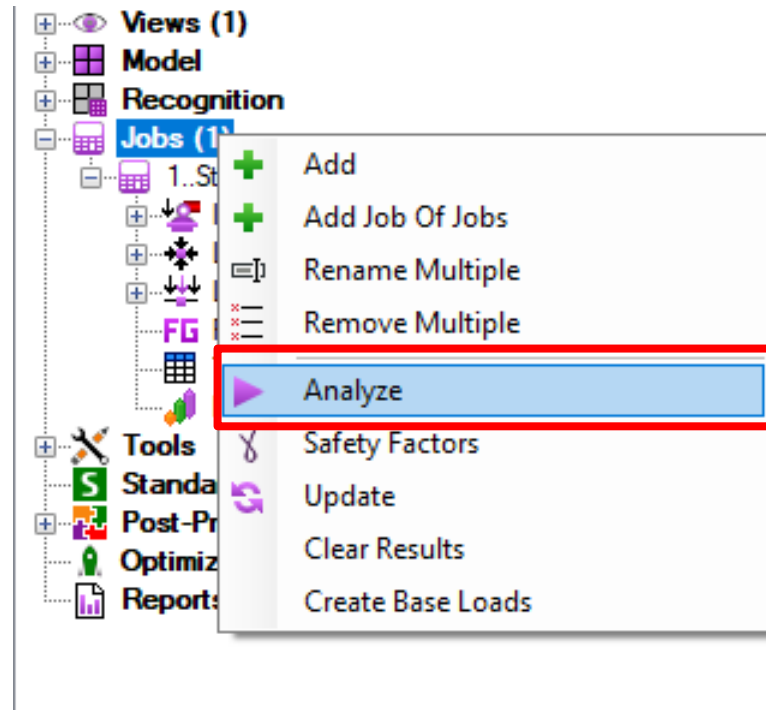- Optimizations (0)
- Reports (0)

This tutorial uses project with predefined boundary condition, load combinations and load group.
The model contains only beam elements of the following types: I-Beam, Circular and Rectangular Tubes

Analyze Job

1 Execute ▶ **Analyze** from *Static Structural* context menu

Joint – location where different beam members connect. They are used to recognize beam member length by Beam Member Finder Tool.

There are 6 types of Joints:
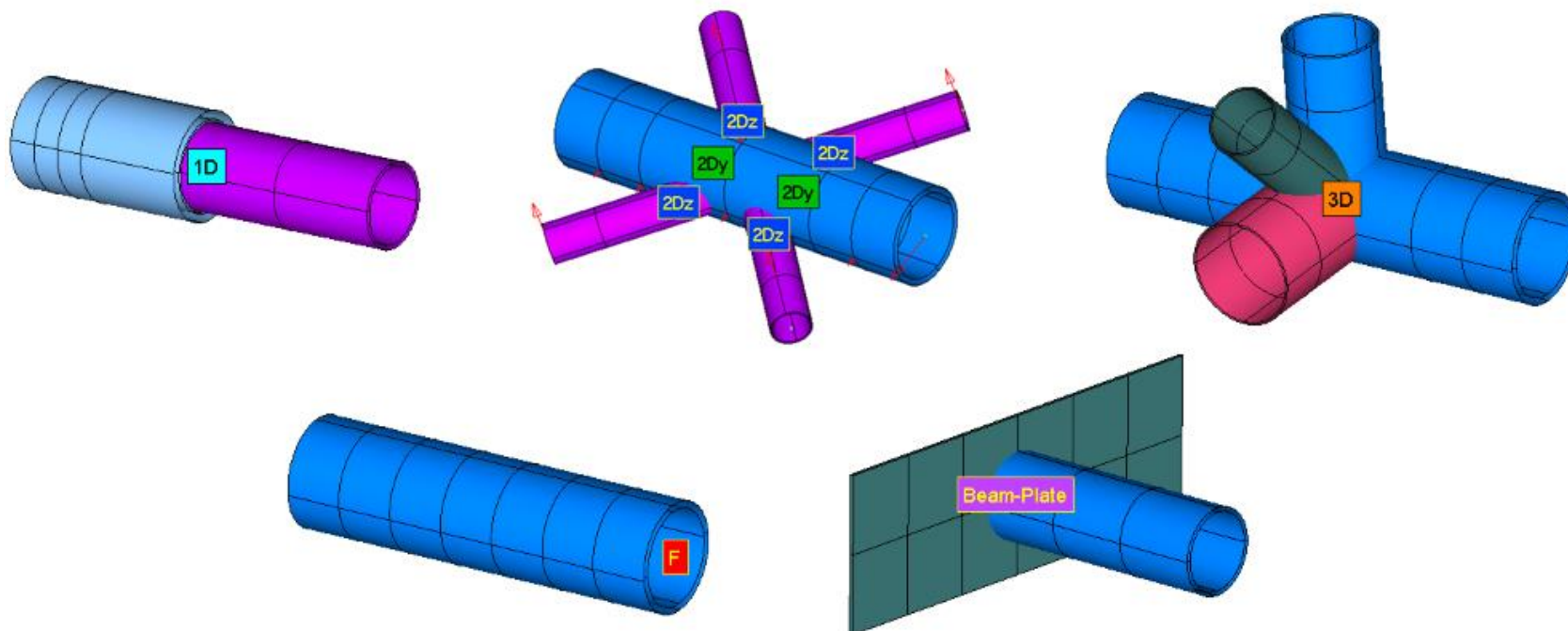1D Joint – 2 beam members that lie on the curve but with different properties;
2D Joint – beam members connected in one plane;
3D Joint – beam members connected in space;
Free Joint – node which belongs only to one element (free);
Beam-Plate Joint – beam member connected to plates (perpendicularly);
User Defined;

Joint Recognition

| 1 | Execute *Edit* from *Joint Finder* context menu |

| 2 | Press *Find*. |

Joints Plot

1	Select All Joints (Ctrl+A).
2	Press 📦 and Execute 📦 Plot Joint Type in colors
3	Press *OK*

Joint Finder

Change Type for selected Joints

Type: None   Set

Plot all joints

Show Labels: None

Show 2D joint axes: Relevant

- ☑ 1D   ☑ Free   All
- ☑ 2Dy   ☑ Plate 2Dy   2D only
- ☑ 2Dz   ☑ Plate 2Dz   None
- ☑ 2D Und. ☑ Plate 2D Und.
- ☑ 3D   ☑ Plate 3D
- ☑ User   ☑ Beam-Plate

☐ Show only joint elements   Plot

Id	Type	Property
Node ID = 1	F	
Node ID = 2	F	
Node ID = 3	3D	
Node ID = 4	3D	
Node ID = 5	3D	
Node ID = 6	3D	
Node ID = 7	3D	
Node ID = 22	3D	
Node ID = 23	3D	
Node ID = 24	3D	
Node ID = 68	2Dy	
Node ID = 117	3D	
Node ID = 136	3D	
Node ID = 155	3D	
Node ID = 165	3D	
Node ID = 201	3D	
Node ID = 202	3D	
Node ID = 231	2Dy	
Node ID = 237	2Dy	
Node ID = 243	2Dy	

Plot Joint Type Labels
Plot Joint Type in colors

2.

Settings   Find   **3.** OK   Cancel

Modify Joint Type:

Change Type for selected Joints

Type: None   Set

Beam Member Finder recognizes beam members and (buckling) lengths for different directions (Y, Z and Torsional).
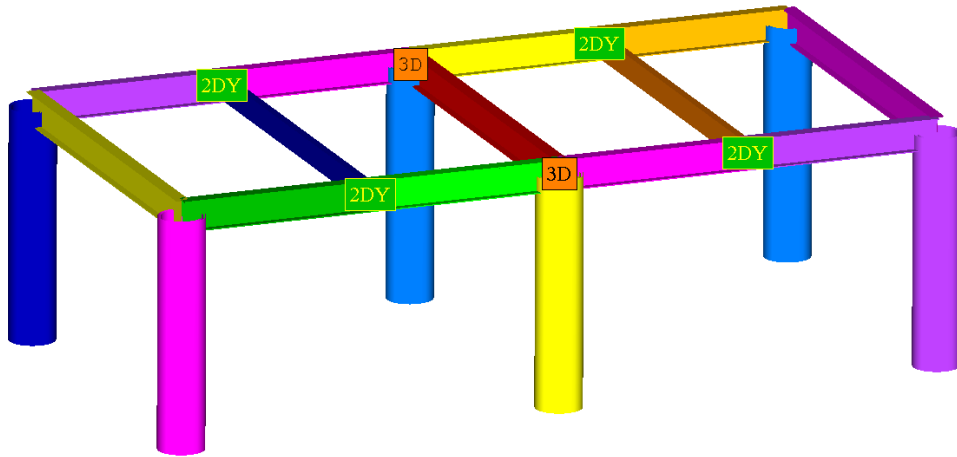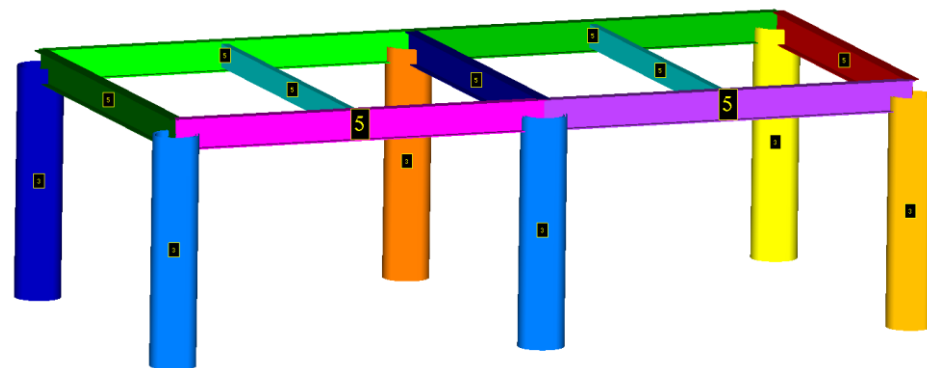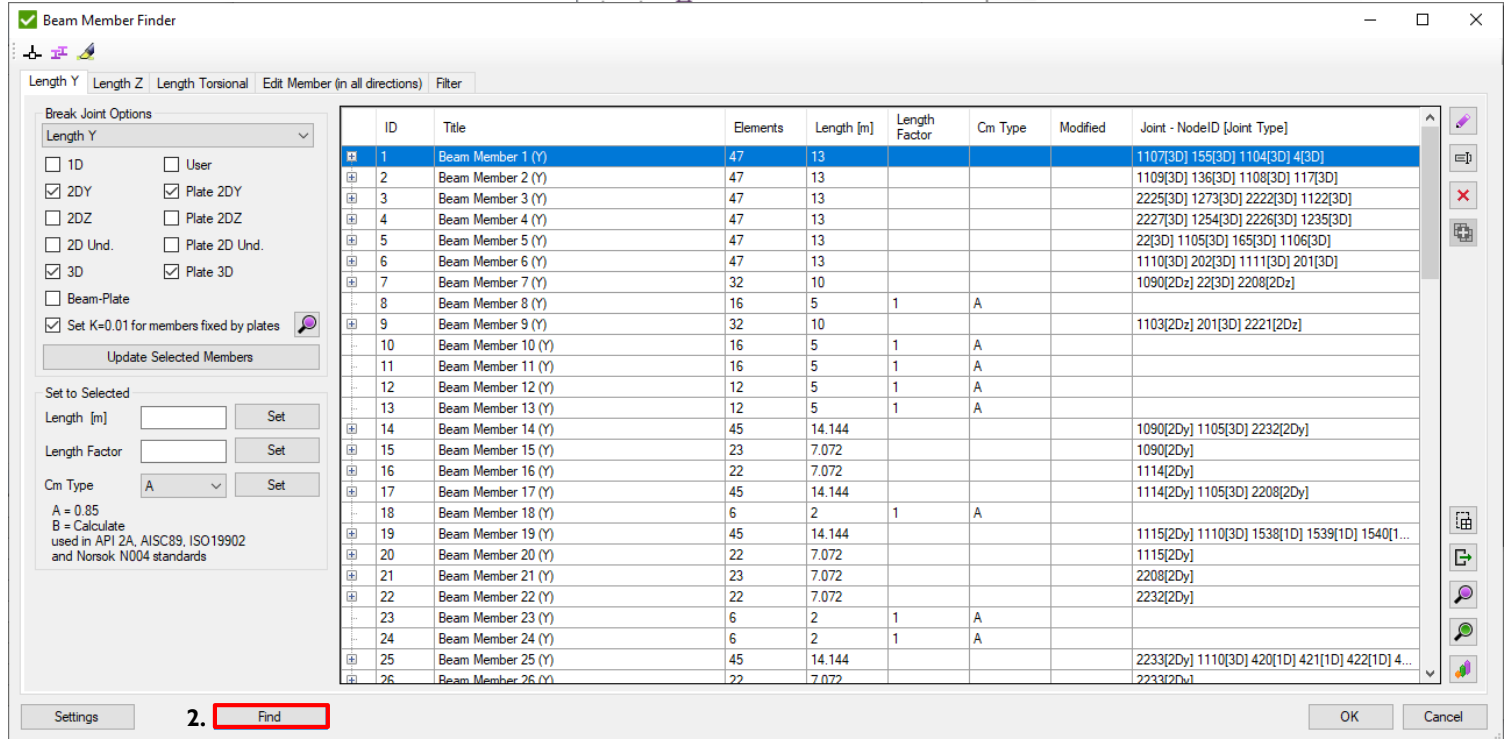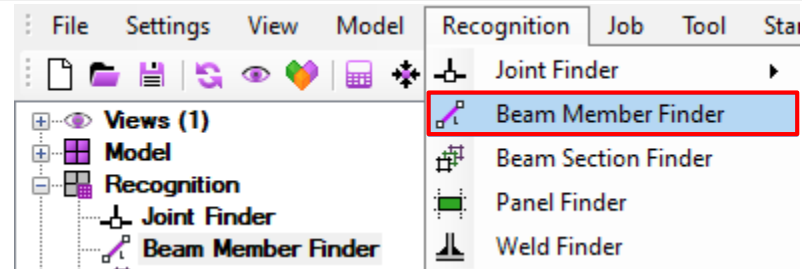

2DY Joint
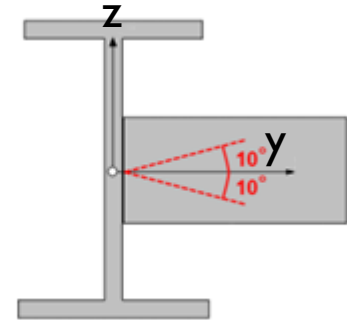
Length Y – 4 Beam Members with L = 2.5
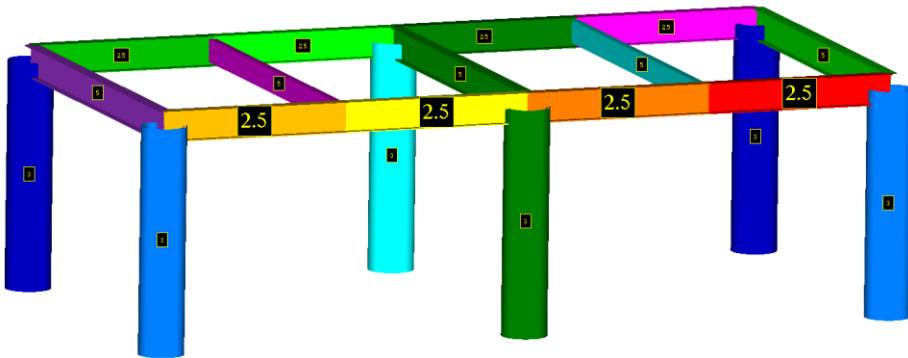
Length Z – 2 Beam Members with L = 5

Recognize Length

1 Execute *Recognition – Beam Member Finder*

2 Press *Find*.

Default *Break Joint Options* for Tabs:
Length Y: **2DY, 3D, Plate 2DY, Plate 3D**
Length Z: **2DZ, 3D, Plate 2DZ, Plate 3D**
Length Torsional: **2DY, 2DZ, 2D Und, 3D**

Beam Member Finder interface

Break Options define what joints are used to split beam members

Change Length/Factor for selected beam members

Cm Type is used in API 2A, ISO 19902 and Norsok N004 standards

Colored Plot of members with labels (ID, Length, Factor or Cm Type).

Beam Member – straight line. If it contains joints it is split on sub members

14	Beam Member 14 (Y)	45	14.144				1090[2Dy] 1105[3D] 2232[2Dy]
14.1	Beam Member 14.1 (Y)	12	3.536	1	A		
14.2	Beam Member 14.2 (Y)	11	3.536	1	A		
14.3	Beam Member 14.3 (Y)	11	3.536	1	A		
14.4	Beam Member 14.4 (Y)	11	3.536	1	A		
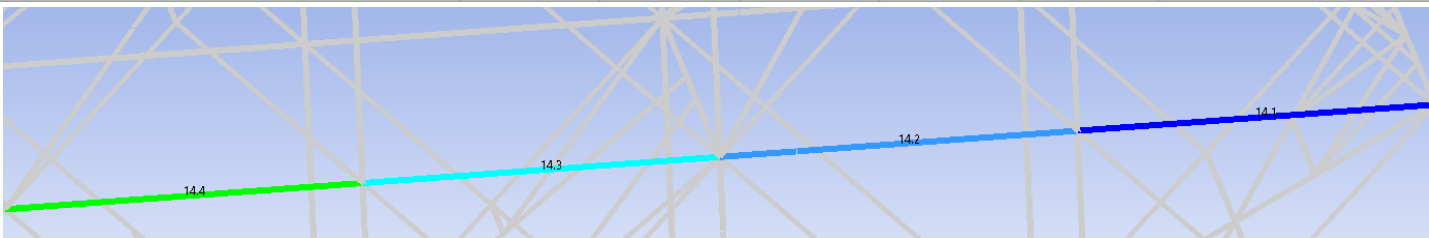
Beam Member's Length Plot

1 Select All Beam Members (Ctrl+A)

2 Press 🔧 and 📊 Plot Length labels to display Length Plot

3 Press *OK*

Also it is possible to display beam members IDs by pressing 🔧 and 📊 Plot Members ID labels

AISC 360-10

STEEL CONSTRUCTION

AISC

MANUAL

AMERICAN INSTITUTE
OF
STEEL CONSTRUCTION
INC.

THIRTEENTH EDITION

ANSI/AISC 360-10 - an American national standard "Specification for Structural Steel Buildings", released on June 22, 2010. Checks are performed according to the provisions for load and resistance factor design (LRFD) and allowable strength design (ASD).
The standard implements checks for design of members for tension, compression, bending, shear and combined.

Specification
for Structural Steel Buildings

March 9, 2005

Supersedes the *Load and Resistance Factor Design Specification for Structural Steel Buildings* dated December 27, 1999, the *Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design* dated June 1, 1989, including Supplement No. 1, the *Specification for Allowable Stress Design of Single-Angle Members* dated June 1, 1989, the *Load and Resistance Factor Design Specification for Single-Angle Members* dated November 10, 2000, and the *Load and Resistance Factor Design Specification for the Design of Steel Hollow Structural Sections* dated November 10, 2000, and all previous versions of these specifications.

Approved by the AISC Committee on Specifications and issued by the
AISC Board of Directors

AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.
One East Wacker Drive, Suite 700
Chicago, Illinois 60601-1802

LRFD vs ASD

It is possible to check a design according to load and resistance factor design (LRFD) or allowable strength design (ASD). The difference between 2 designs is in load combinations and resistance factors:

Resistance Factors

	LRFD ⦿	ASD ○
Tension (F_t)		0.9
Tensile Rupture (F_tr)		0.75
Compression (F_c)		0.9
Shear (F_v)		0.9
Bending (F_b)		0.9
Torsion (F_tor)		0.9

Resistance Factors

	LRFD ○	ASD ⦿
Tension (F_t)		0.6
Tensile Rupture (F_tr)		0.5
Compression (F_c)		0.6
Shear (F_v)		0.6
Bending (F_b)		0.6
Torsion (F_tor)		0.6

Design for Strength Using Load and Resistance Factor Design (LRFD)
Design will be performed in accordance with Equation B3-1:
$Ru \leq \phi Rn$ (B3-1),
where:
Ru = required strength using LRFD load combinations;
Rn = nominal strength, specified in Chapters B through K;
ϕ = resistance factor, specified in Chapters B through K;
ϕRn = design strength.

Design for Strength Using Allowable Strength Design (ASD)
Design will be performed in accordance with Equation B3-2:
$Ra \leq Rn/\Omega$ (B3-2),
where:
Ra = required strength using ASD load combinations;
Rn = nominal strength, specified in Chapters B through K;
Ω = safety factor, specified in Chapters B through K;
Rn/Ω = allowable strength.

According to the standard Design Strength is multiplied by LRFD factor and divided by ASD factor.
For tensile yielding in the gross section:

$$P_n = F_y A_g \qquad (D2\text{-}1)$$
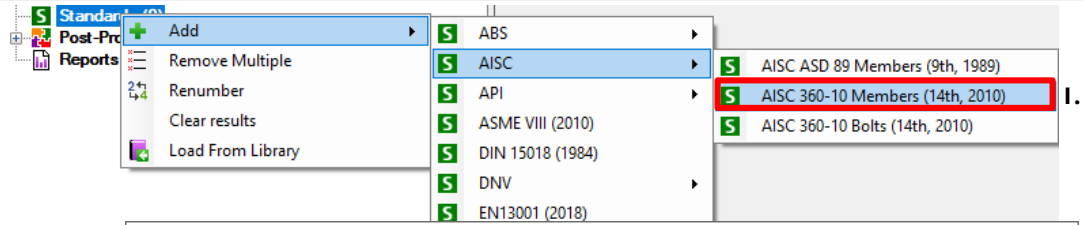
$$\phi_t = 0.90 \text{ (LRFD)} \qquad \Omega_t = 1.67 \text{ (ASD)}$$

In SDC Verifier multiplication is always used ASD factor is converted to 1 / Sf (ASD). For example: tensile resistance factor (F_t) = 1/1.67 = 0.6.

Add AISC360-10 standard

1 Execute **Standards => Add => AISC => AISC 360-10 Members** from context menu

2 Resistance Factors: **LRFD**

Section Build Type

1 Press ⏹ for Section Build Type

2 Build Type: **Rolled**

3 Select *To All*

4 Press *OK*

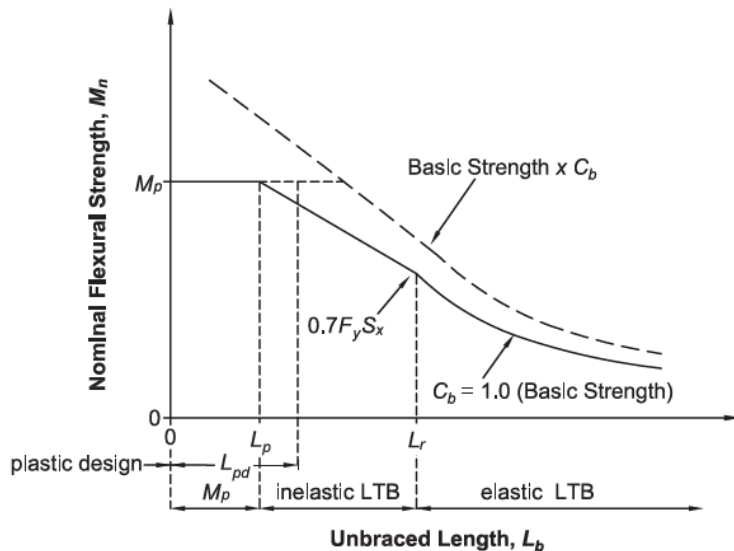Go to the next slide to Continue

Lateral-torsional buckling factor (Cb)

1 Select – *Calculate Cb*

Go to the next slide to Continue

SDC Verifier follows conservative approach and uses Cb = 1.0.
Cb is implemented as a characteristic which can be modified.
For the details see Chapter F "Design of members for Flexure",
F1 General Provisions

AISC 360-10 Members (14th, 2010)

ID	1	Title	AISC 360-10 Members (14th, 2010)
Alias	Standard1
Description	

Settings

Resistance Factors	LRFD
Section Build Type	Defined

1. ⦿ Calculate Cb (based on moment diagram, Chapter F1)
○ User defined Cb — Defined

Stiffener Distance (Chapter G2.1)	Defined
Net Area (Chapter D2.2)	Defined
Shear Lag Factor (Table D3.1)	Defined

☐ Calculate asymmetric shapes as symmetric

Selection

+ 6 Shapes

Elements — 1856

☐ Use API 2A RP for tubular shapes — Materials with Yield and Tensile = 0 — 1

Second order effects (APPENDIX 8)
☐ Take into account second-order effects (B1 multiplier)
○ Use Cm = 1 (conservative)
⦿ Calculate Cm: case a = 0.6 - 0.4 * M1 / M2, case b = 1.0
Not subject to transverse loading (case a) when Shear Force < 0.1 Percent of Axial Force

Torsion
☐ Include Torsion check
Warping is neglected for the torsion check. Additional assessment is therefore required for open sections flagged with a UC=1234. SDC returns this error UC code for open sections with an UF.torsion exceeding: 0.3

Preview Not Supported Elements — OK — Cancel

Define Material Characteristics

1. Press [icon] to set the material yield stress and tensile strength

2. Select All Materials (Ctrl+A)

3. Tensile Strength: **360e+6**

4. Yield Stress: **240e+6**

5. Press *Set*

6. Press *OK*

7. Press *OK*

Standard is created

It is possible to modify Safety Factors in Constants section.

Standard contains 16 checks:
1 - Beam member characteristics;
2-6 - calculation dimensions and factors for 5 different shapes;
7-11 – strength for different shapes ;
12 – tension and compression check;
13 – additional shear check;
14 – additional bending check;
15 – torsion check;
16 - All Checks together with combined.

Standards (1)
- 1..AISC 360-10 Members (14th, 2010)
  - Input
    - π Constants (22)
    - Types (2)
    - Characteristic (5)
    - Classifications (0)
    - Standard Tables (0)
  - Checks (16)
    - 1..Beam Characteristics
    - 2..Circular Tube
    - 3..Rectangular Tube
    - 4..Bars
    - 5..Section C
    - 6..Section I
    - 7..Axial Strength
    - 8..Shear Strength
    - 9..Bending Strength Bars
    - 10..Bending Strength I-beams
    - 11..Bending Strength Channels
    - 12..Axial
    - 13..Shear
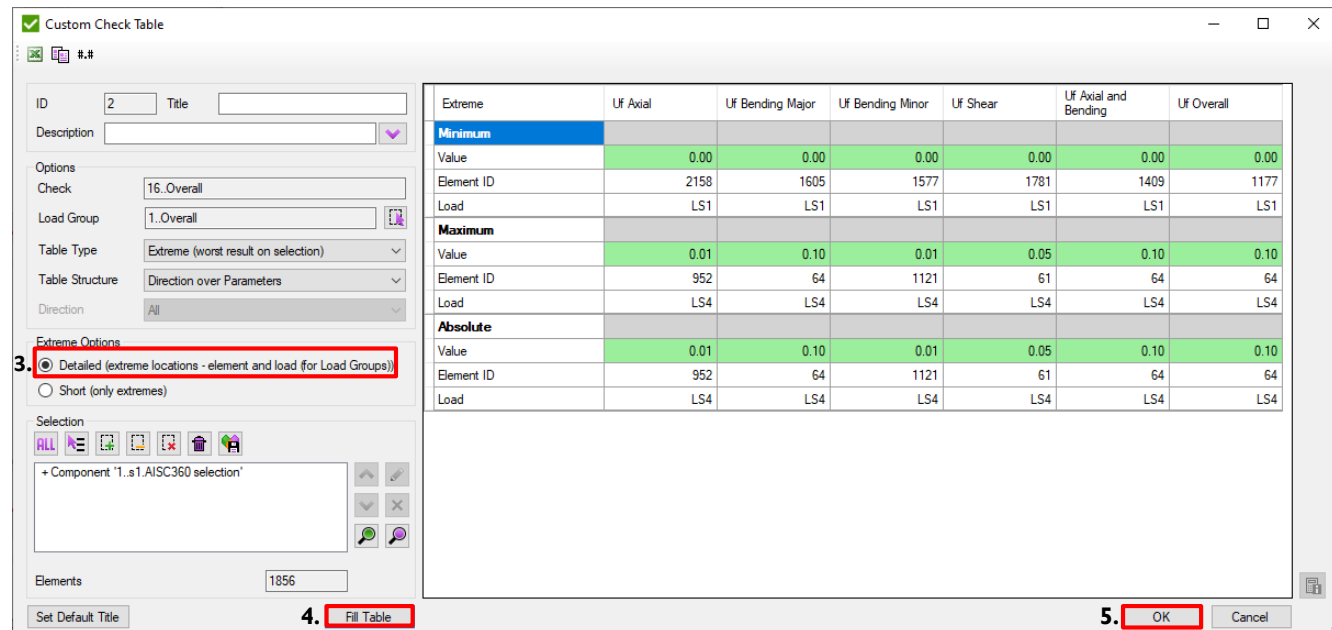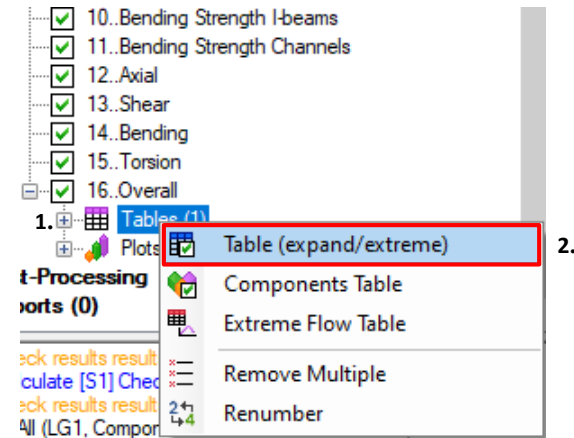   - 14..Bending
    - 15..Torsion
    - 16..Overall

Standards (1)
- 1..AISC 360-10 Members (14th, 2010)
  - Input
    - Constants
    - Types
    - Charac...
    - Classifi...
    - Standar...
  - Checks (16)

Edit

Constants

Id	Title (Alias)	Value	Description
1	CalculateCb	1	Set 1 to calculate Cb based on formula (F1-1). Set 0 to use n
2	SecondOrderEffect	0	Set 1 to take into account second order analysis effect (App
3	PercentOfAxial	0.1	if shear force is lower than percent of axial force than memb
4	CalculateCm	1	Cm will be calculated only when second analysis order effec
5	IncludeTorsionCheck	0	Include torsion check with neglected warping?
6	F_t	0.9	Tension Resistance Factor
7	F_c	0.9	Compression Resistance Factor
8	F_v	0.9	Shear Resistance Factor
9	F_b	0.9	Shear Resistance Factor
10	F_tr	0.75	Tensile Rupture Resistance Factor
11	F_vl	1	Shear rolled IBeam Resistance Factor
12	F_tor	0.9	Torsional Resistance Factor
13	Alpha	1	LRFD force level adjustment factor. Used in (A-8-1)
14	UFTorsionLimit	0.3	Additional assessment on torsion is required for open sectio
15	UFTorsionCode	1234	Code is used for Torsional Utilization Factor when it is highe
16	rolled	1	
17	built_up	2	
18	nonslender	3	
19	slender	4	
20	NotSupported	12345678	
21	compact	5	
22	noncompact	6	

OK   Cancel

Preview Table Results

1 Select *Tables*

2 Execute *Table (expand/extreme)* in context menu

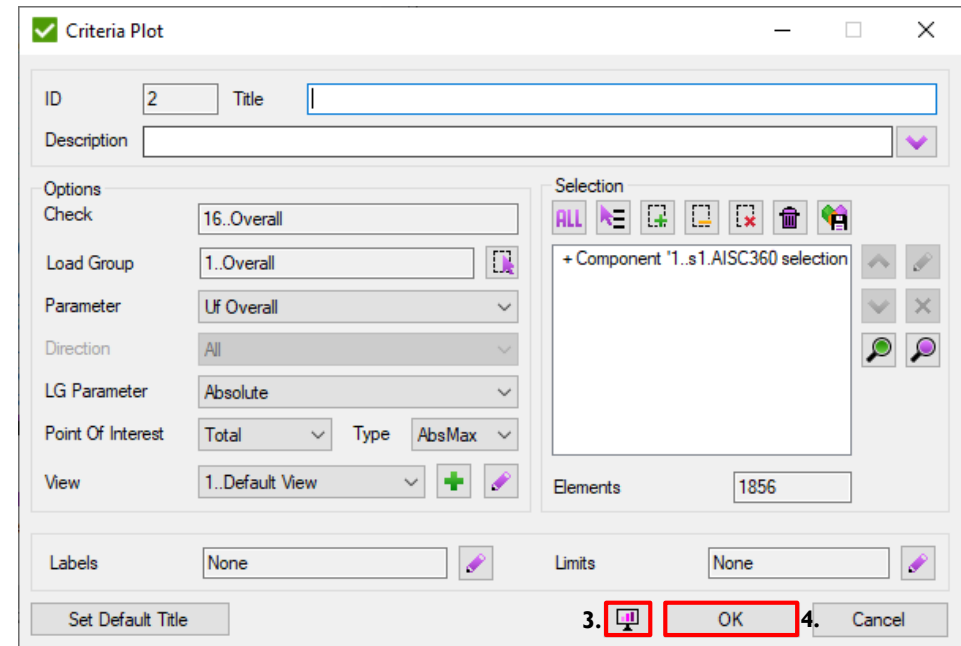**3** Select Extreme Options - *Detailed*
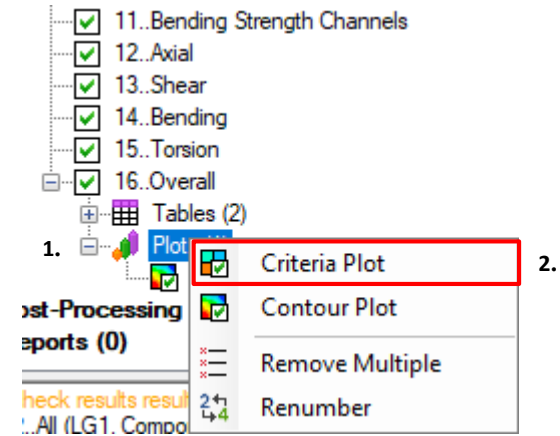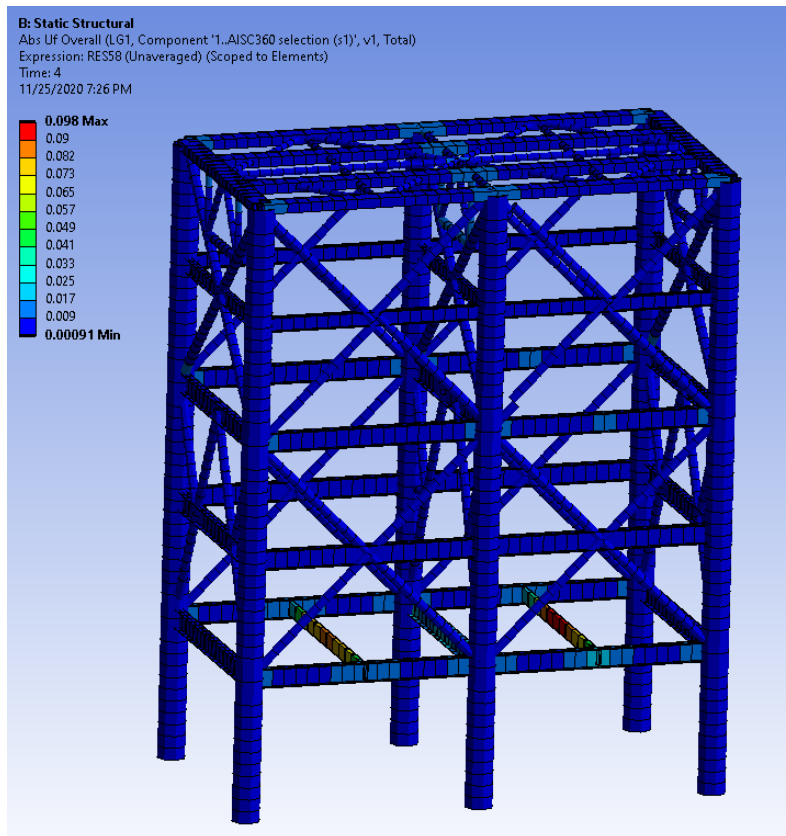
4 Press *Fill Table*

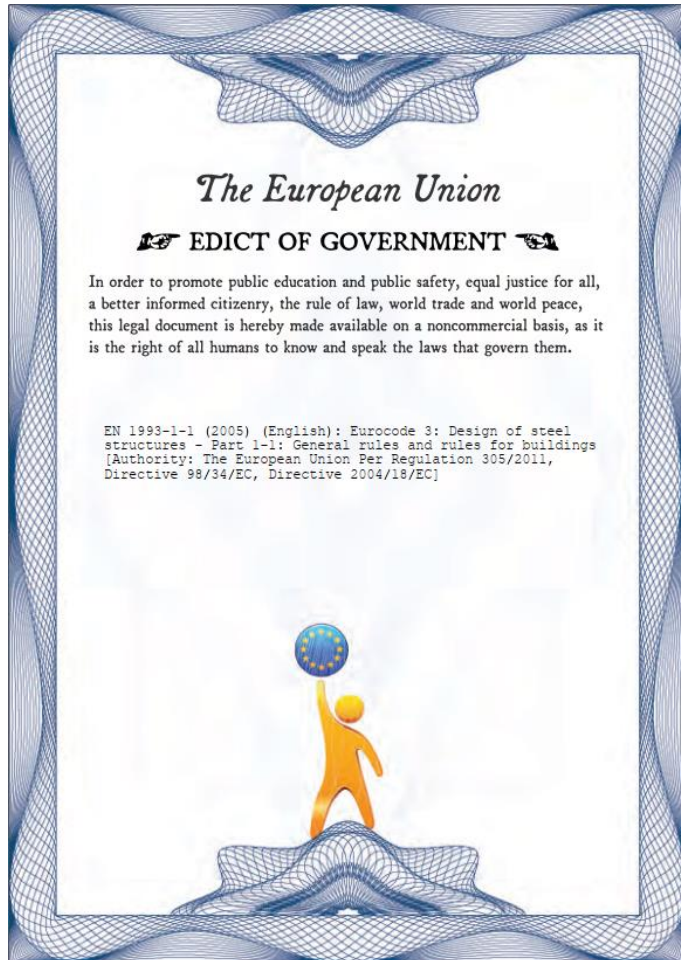**5** Press *Ok*

Utilization Factor Plot

1	Select *Plots*

3	Press 🖥 to preview Plot

2	Execute *Criteria Plot* in context menu

4	Press *Ok*

B: Static Structural
Abs Uf Overall (LG1, Component '1..AISC360 selection (s1)', v1, Total)
Expression: RES58 (Unaveraged) (Scoped to Elements)
Time: 4
11/25/2020 7:26 PM

```
0.098 Max
0.09
0.082
0.073
0.065
0.057
0.049
0.041
0.033
0.025
0.017
0.009
0.00091 Min
```

11..Bending Strength Channels
12..Axial
13..Shear
14..Bending
15..Torsion
16..Overall
    Tables (2)
1. Plot

    Criteria Plot   2.
    Contour Plot
    Remove Multiple
    Renumber

ost-Processing
eports (0)

heck results resul
..All (LG1, Compo

Criteria Plot

ID	2	Title	
Description			▼

Options

Check	16..Overall
Load Group	1..Overall
Parameter	Uf Overall
Direction	All
LG Parameter	Absolute
Point Of Interest	Total	Type	AbsMax
View	1..Default View

Selection

ALL

+ Component '1..s1.AISC360 selection

Elements   1856

| Labels | None | | Limits | None | |

Set Default Title   3. 🖥   OK   4. Cancel

Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings

Description of Eurocode3 (EN1993-1-1, 2005)

Gm0 - resistance of cross-sections whatever the class is;
Gm1 - resistance of members to instability assessed by member checks;
Gm2 - resistance of cross-sections in tension to fracture.
λLT,0 – plateau length of the lateral torsional buckling curves for rolled sections;
β - correction factor for the lateral torsional buckling curves for rolled sections;
η - is used in the shear area calculations.

Note: All parameters may be taken from the National Annex

Fabrication Type: Rolled/Welded;
Manufacture Type: Hot Finished/Cold Formed
Fillets has to be defined in the characteristic (they are missing in the model);
Section Net Area - for fasteners with holes net area has to be defined;
Material Type - the buckling curve (Table 6.2) depends on the material type.

It is possible to choose the calculation method for Lateral Torsional Buckling: General Case (chapter 6.3.2.2), For rolled sections or equivalent welded sections (chapter 6.3.2.3) or the worst of two (min reduction factor is used from 2 methods):

A correction Factor Kc can be calculated using the Cm Tool for each member. Also it is possible to set the Kc equal to 1.

Table 6.6: The Correction Factor:

Moment distribution	k_c
$\psi = 1$	1,0
$-1 \leq \psi \leq 1$	$\dfrac{1}{1,33 - 0,33\psi}$
	0,94
	0,90
	0,91

The following cases are NOT recognized and are skipped:

	0,86
	0,77
	0,82

Member Length for Torsional and Torsional-Flexural Buckling Check (LT) by default is max among Ly and Lz lengths. For lateral torsional buckling (L LT) is length in strong axis.

It is possible to use Torsional Length from Beam Member Finder. In this case it can be modified manually by user.

Eurocode3. Fabrication Type

1 Execute *Standards-Add-Eurocode3-Eurocode3 Members*

2 Press 🔧 to set *Fabrication Type*

3 Execute - **Rolled**

4 Press *To All*

5 Press *Ok*

Go to the next slide to Continue
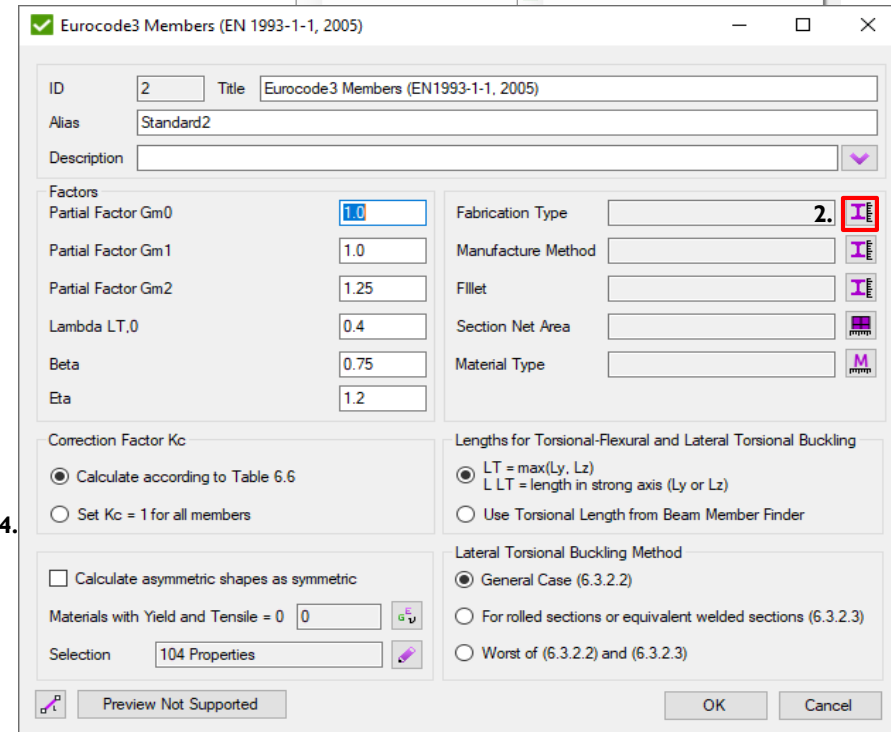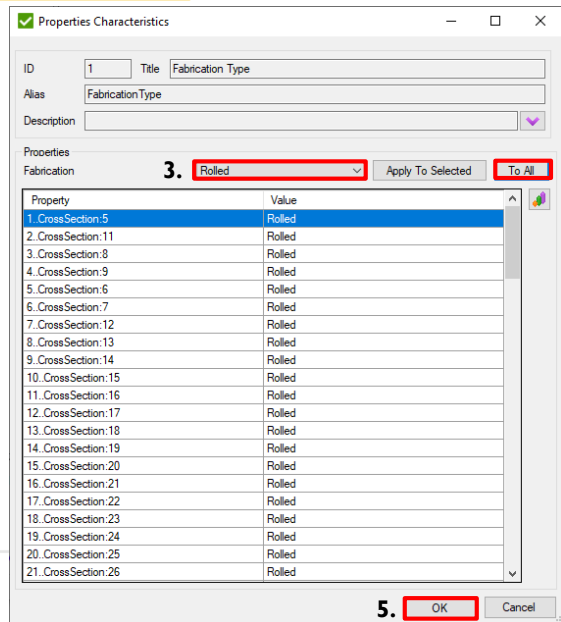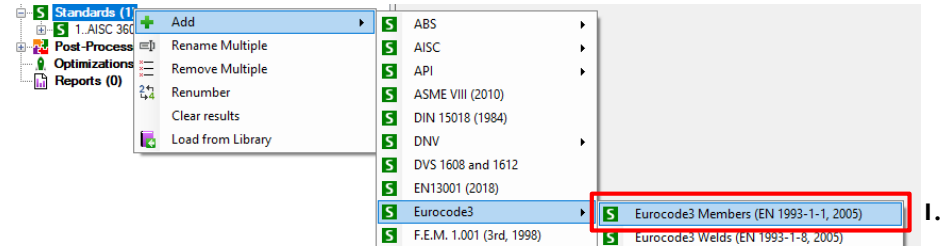
1 Press [icon] to set *Manufacture Method*

2 Execute – ***Hot Finished***

3 Press *To All*

4 Press *Ok*

Go to the next slide to Continue

Eurocode3. Fillet

1   Press ▮ to set *Fillet*
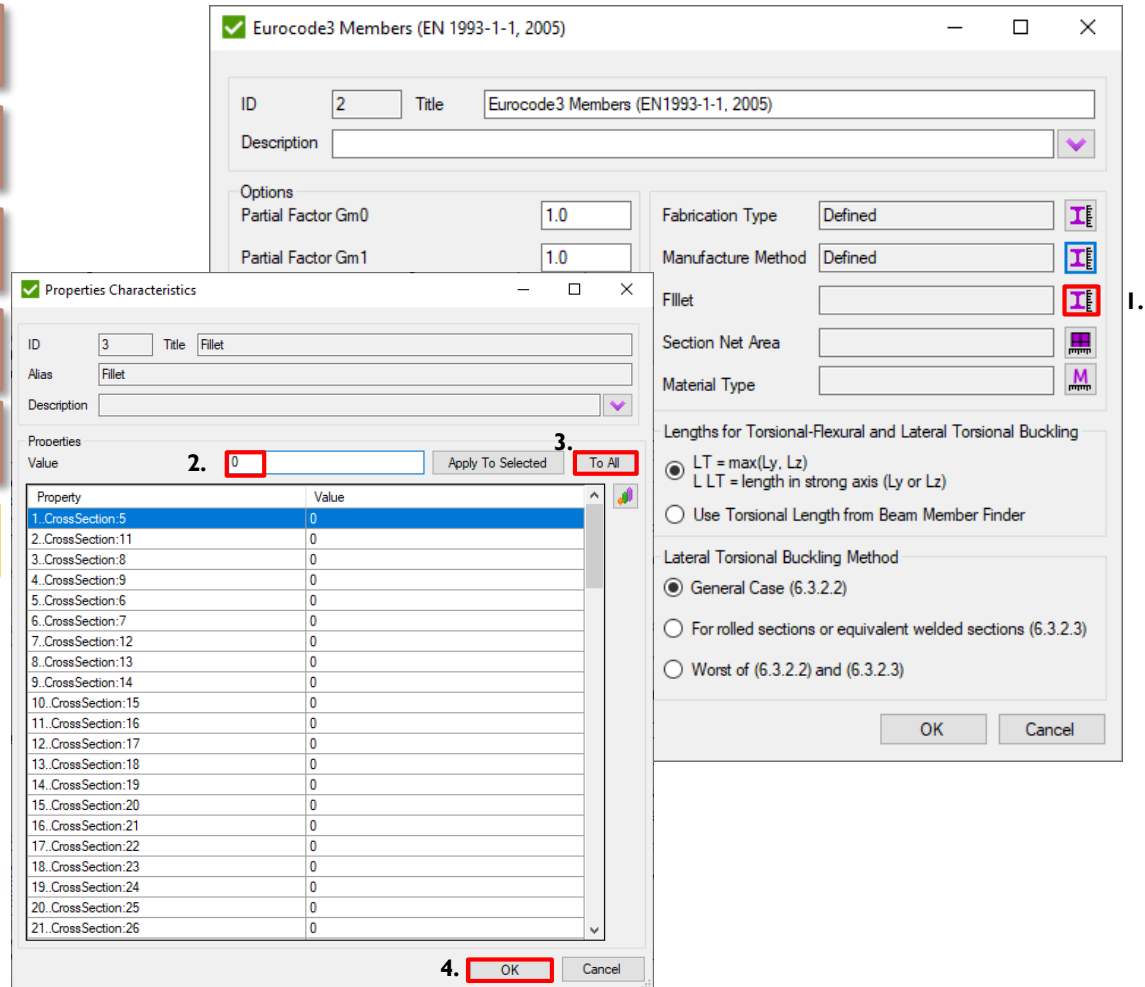
2   Properties Value - *0*

3   Press *To All*

4   Press *Ok*

Repeat Steps 1-4 for *Section Net Area*

Go to the next slide to Continue

Eurocode3. Material Type

1 Press ⬛ to set *Material Type*

2 Execute – *S235_S275_S355_S420*

3 Press *To All*

4 Press *Ok*

5 Press *Ok*

Standard is created
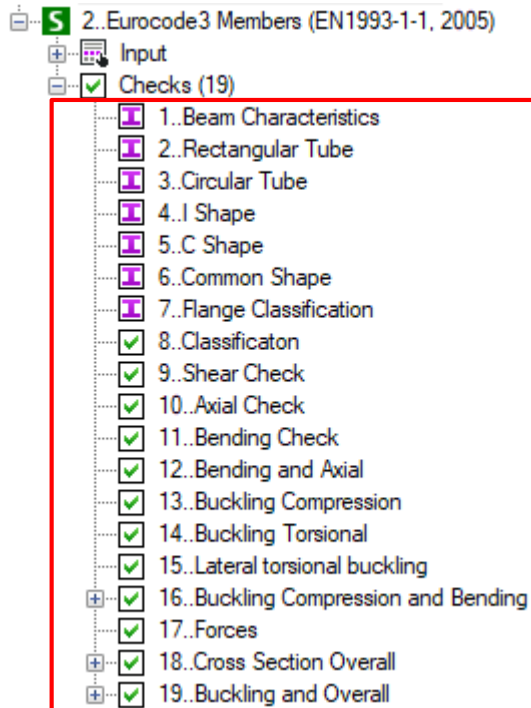
Standard contains 19 checks:
1 - Beam member characteristics;
2-7 - calculation dimensions and factors for 5 different shapes;
8 – cross section resistance;
9 – shear strength check;
10 – tension and compression strength check;
11 – bending strength check;
12 – bending, tension and compression strength check;
13-15 – buckling strength checks ;
16 – additional buckling compression and bending check;
17 – forces;
18 - cross section overall strength check;
19 – buckling and overall strength check.

Preview Table Results

1 Select *Tables*

2 Execute *Table (expand/extreme)* in context menu

3 Select Extreme Options - *Detailed*

4 Press *Fill Table*
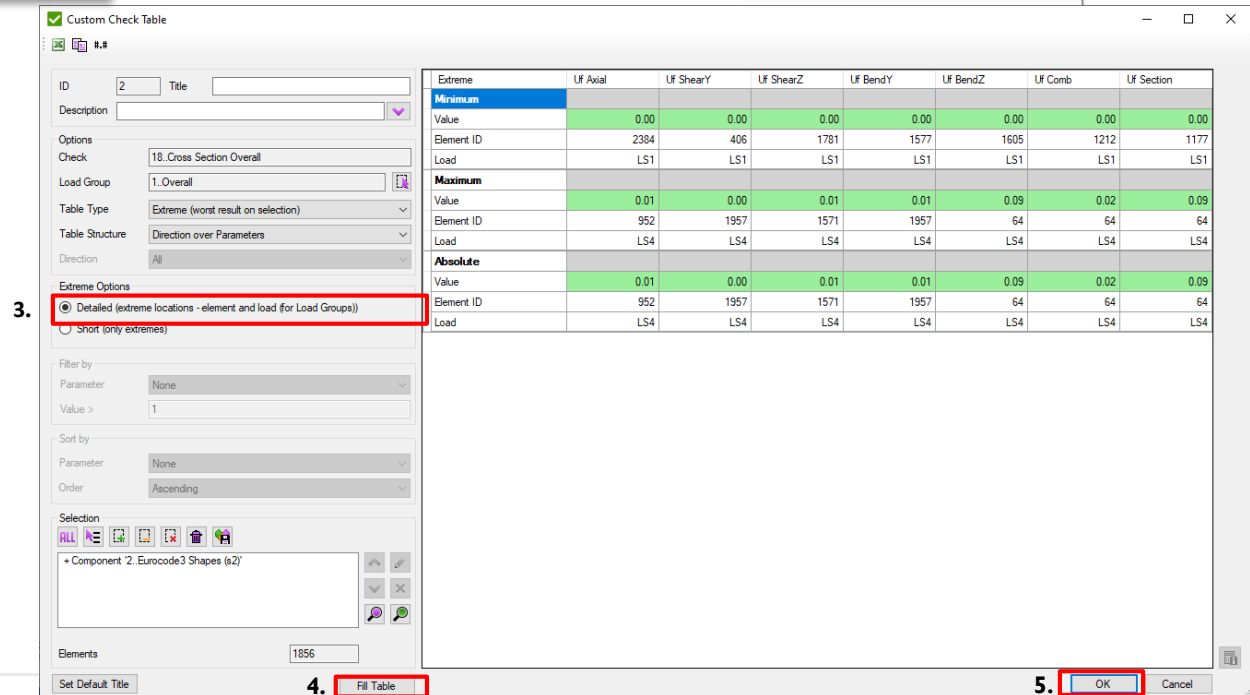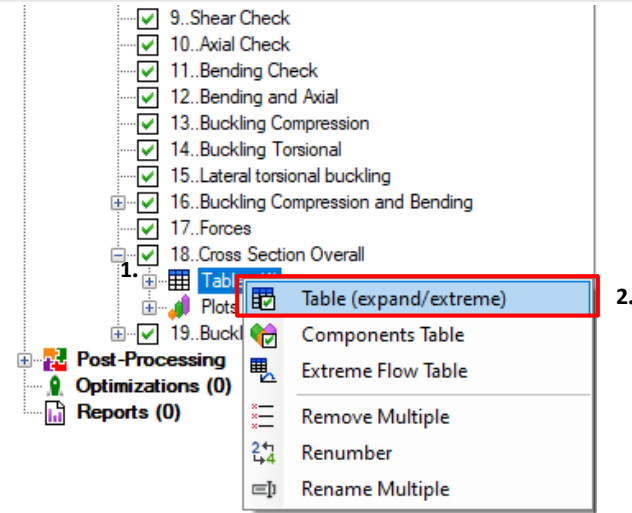
5 Press *Ok*

Utilization Factor Plot

1	Select *Plots*

3	Press 🖥️ to preview Plot

2	Execute *Criteria Plot* in context menu

4	Press *Ok*
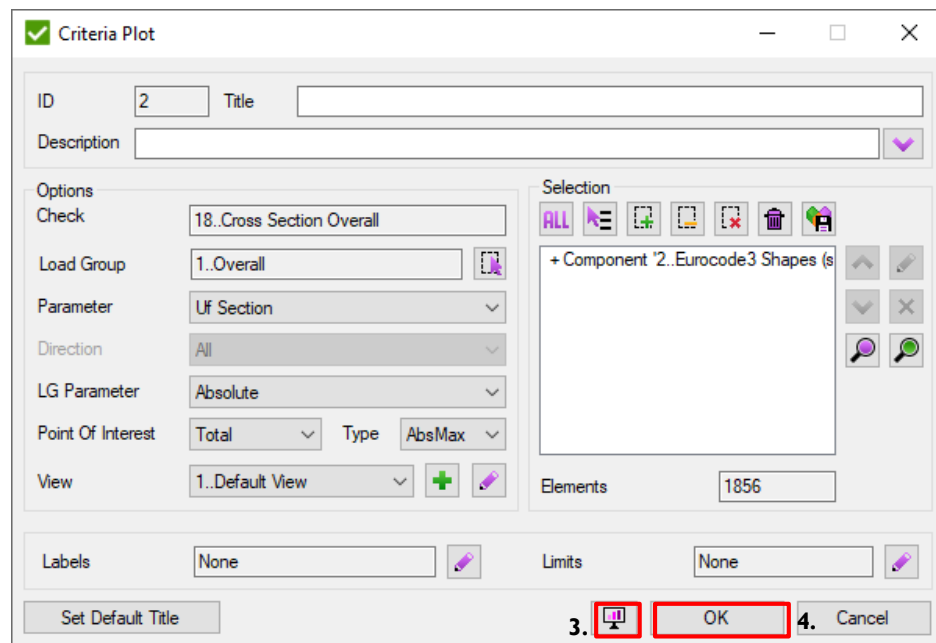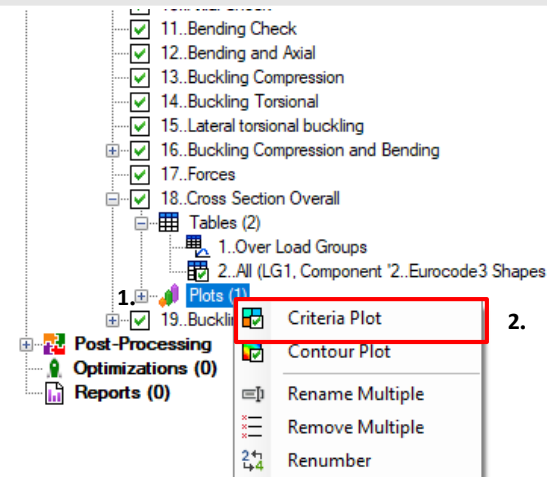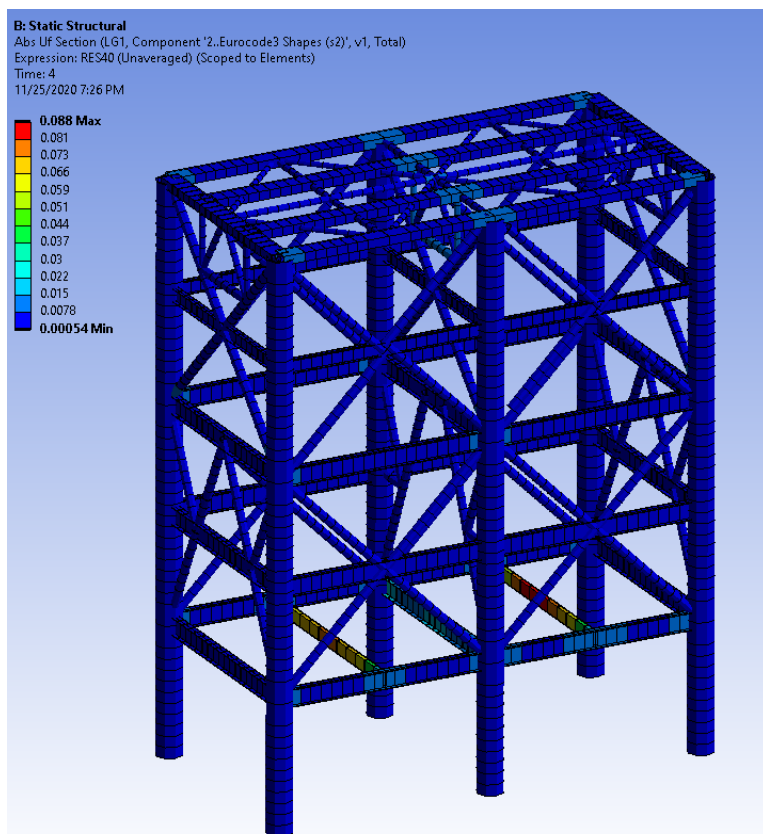
Create Predefined Report

1 Execute *Reports - Add - Designer-Results.*
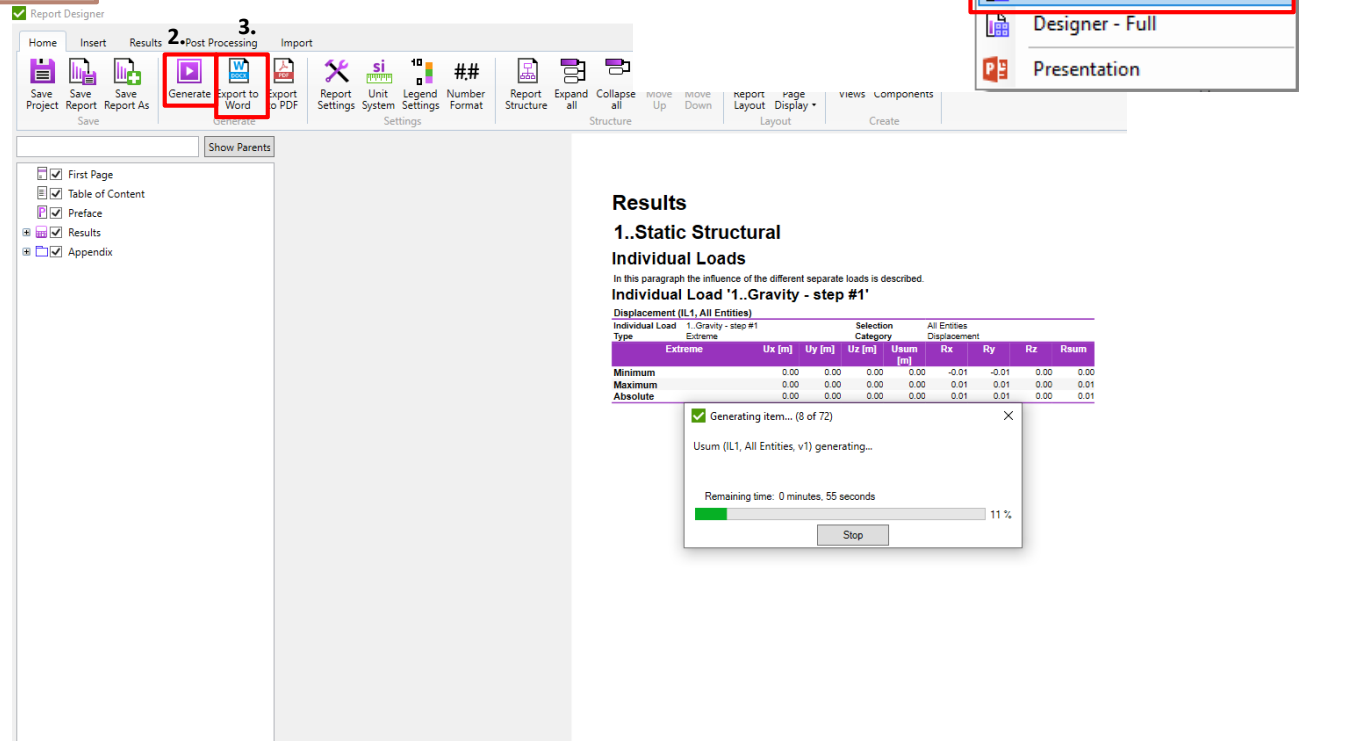
2 Press ▶ to generate report

3 When report is generated press 📄

Results report includes an overview of the displacements and stresses for all loads and standards with all predefined tables and plots

Generated Report

AISC 360 - 10

Eurocode3