SDC VERIFIER

Tutorial
Joint Check

ANSYS®

27.11.2020
version 2020.0.2

Content

- In this tutorial, Joint Check is reviewed in details
- General Info
- Connection Types
- Connection design
- Joint Checks according to standards
- The report was generated with the help of report designer.

General Info

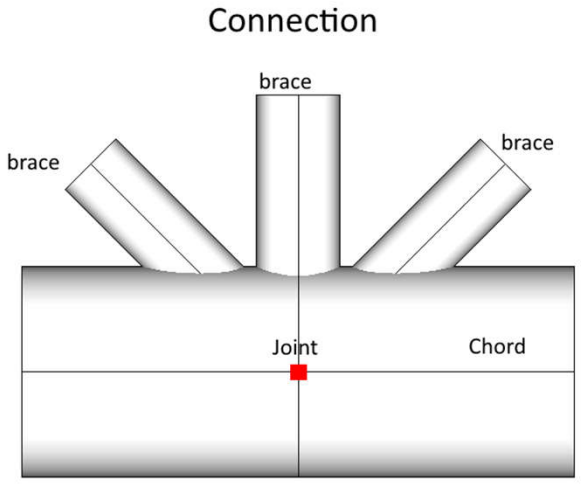
Joint Check – offshore check that verifies strength of tubular structure under tension or compression members according to the standards.

Joint is a node where two or more incline elements are connected.

Connection is a set of elements of the same plane around a joint node.

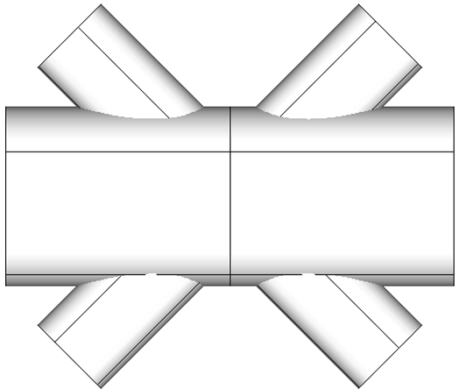
Chord is a set of non-welded elements that form straight line.

Brace is a welded to a chord element.

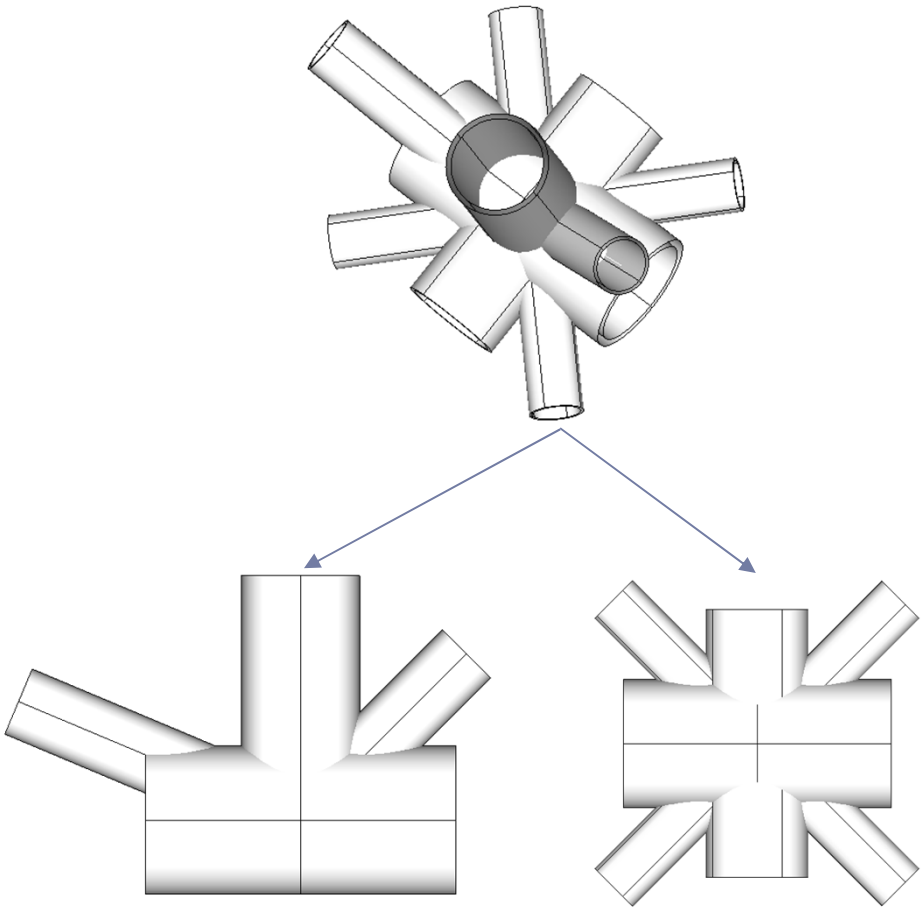


Connection Types

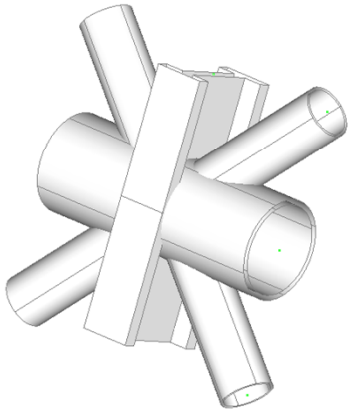
2D Connection. Set of elements of one plane



3D Connection. Will be split on 2D Connections



Connection can include only circular tube shape elements. Otherwise connection will not be recognized. Example of not recognized connection:

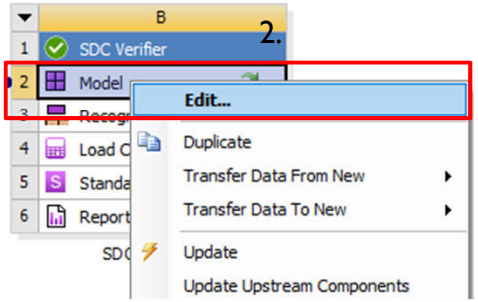


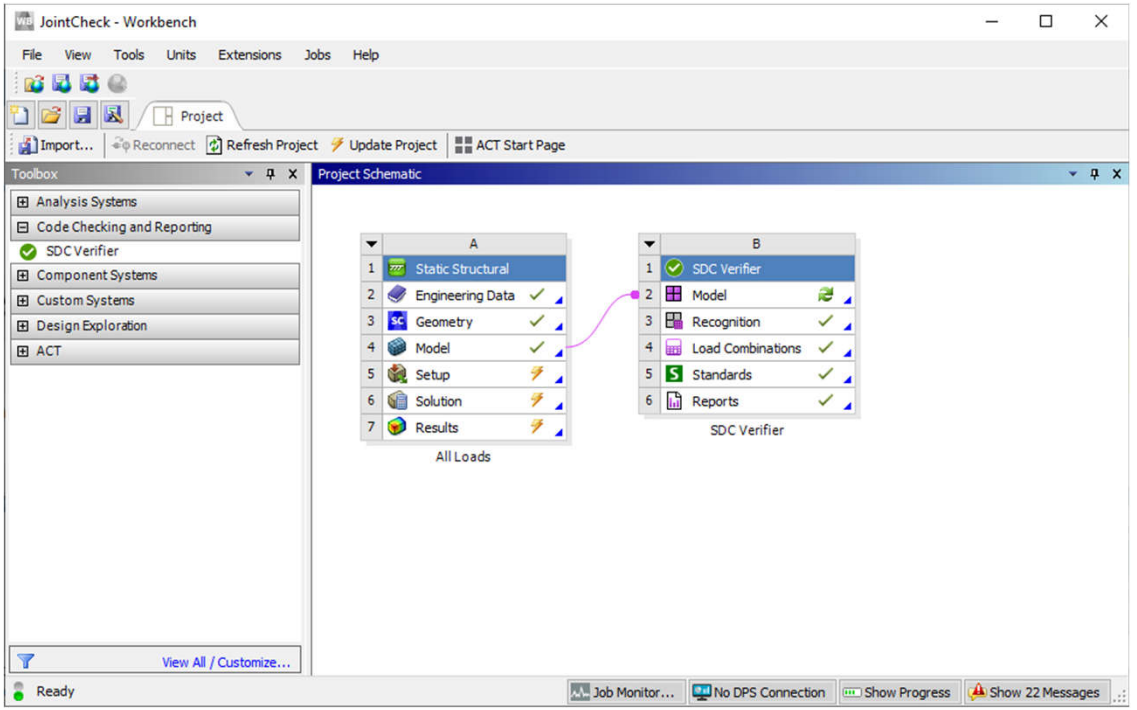
Launch SDC Verifier

1. Open in **Ansys Workbench** **JointCheck.wbpj**

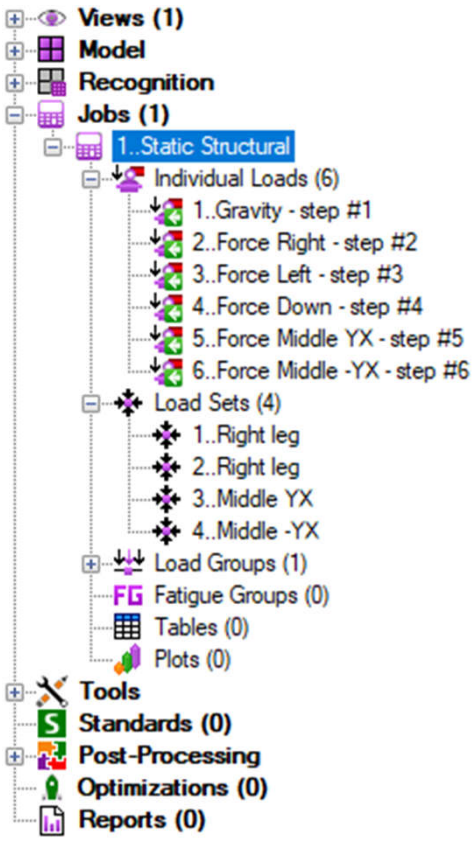
2. Double Click on 

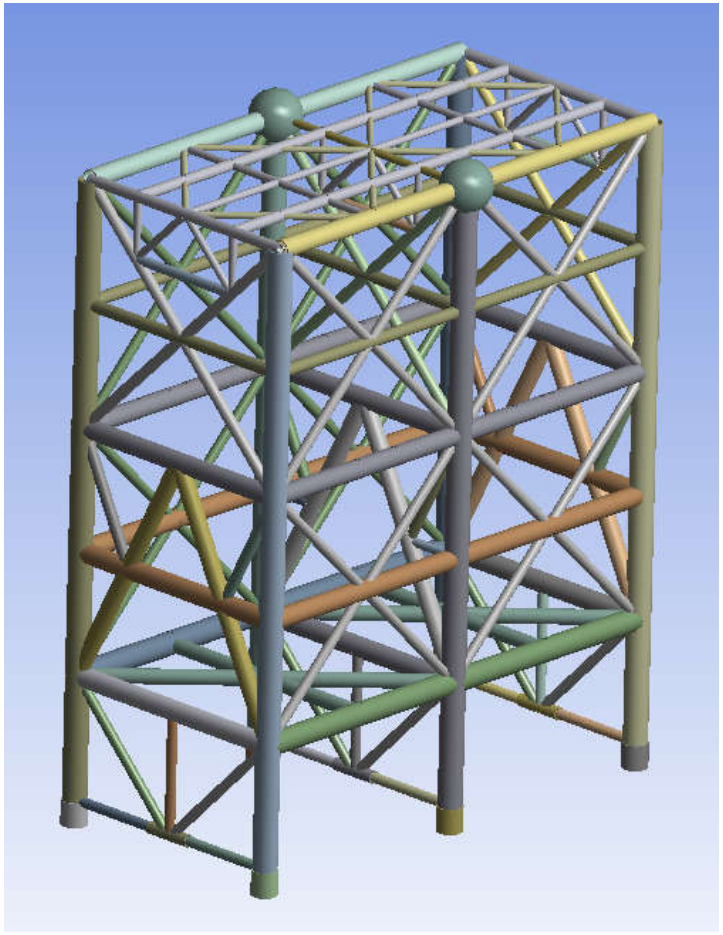
or in context menu click *Edit*





Predefined Project

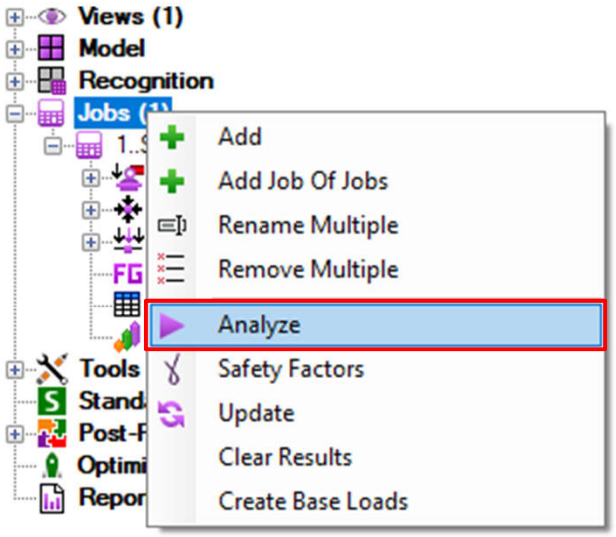




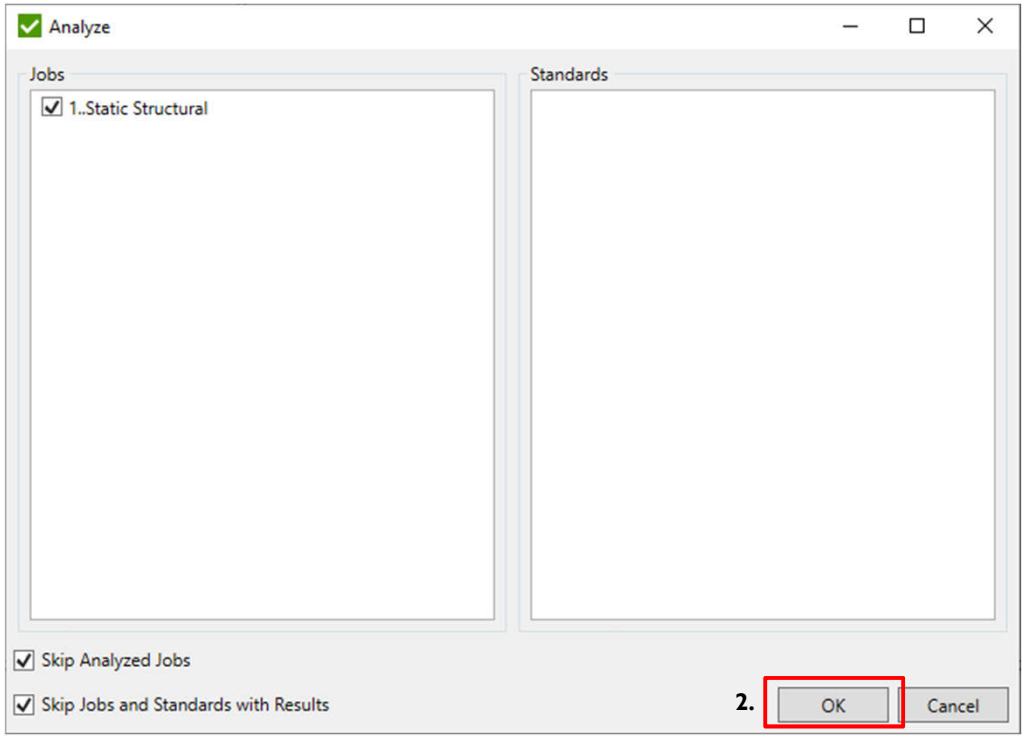
This tutorial uses project with predefined boundary conditions. The model contains only circular tube beams

Analyze Job

1. Execute ▶ **Analyze** from *Static Structural* context menu
2. Press **Ok**



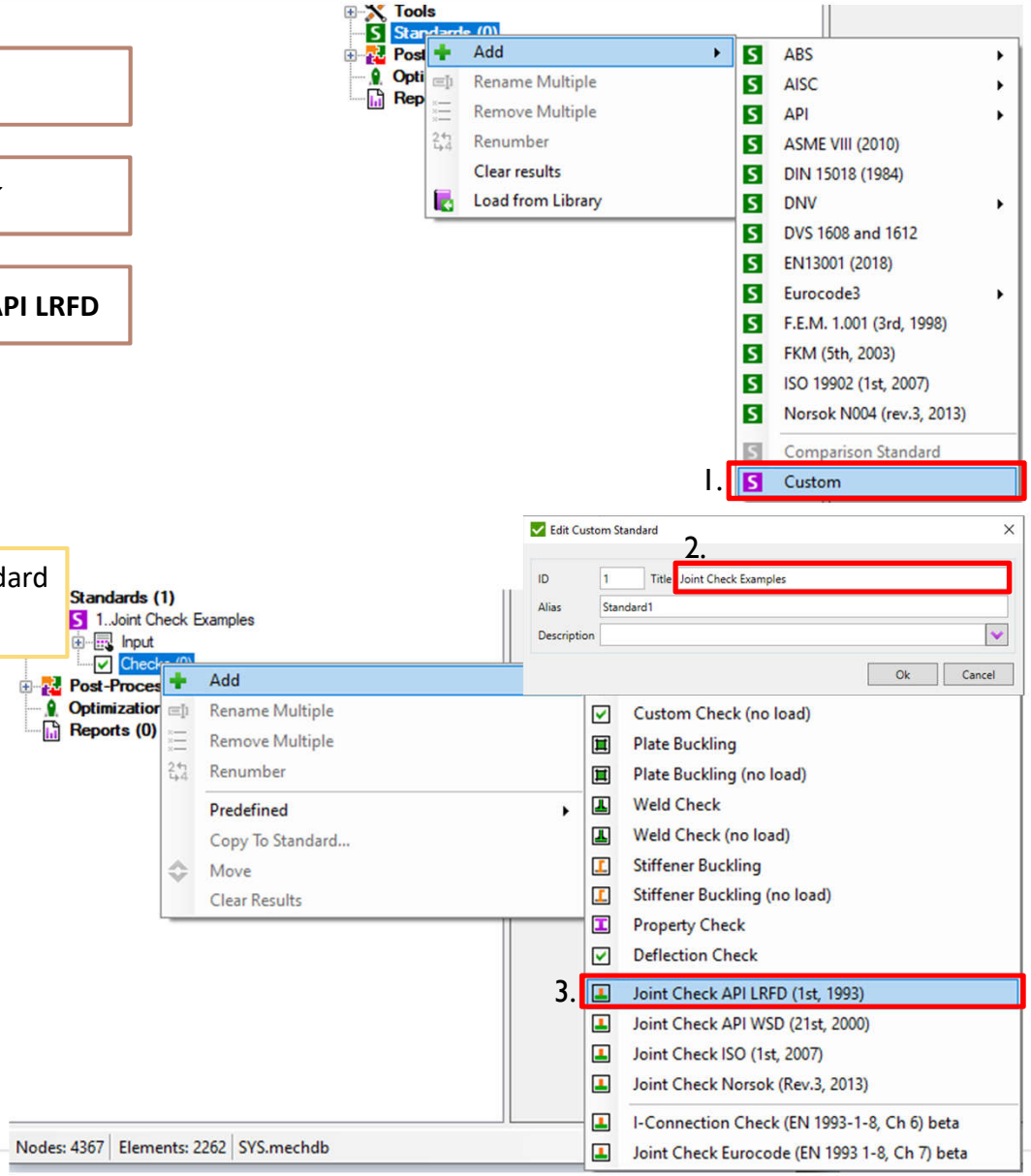
1.



Joint Check API LRFD

1. Execute **Standards->Add->Custom**
2. **Title**: Joint Check Examples. Press *OK*
3. Execute **Checks->Add->Joint Check API LRFD**

Joint Check API LRFD is a part of the standard **API RP 2A LRFD (1st, Jul 1993)**



Joint Check Settings

1. **Joint nodes to be checked.** Part of the model can be checked by selecting required joints.

2. **Maximum distance between joint nodes of one connection.** Include connections that are formed by multiple joints. Recommended distance is D/4. It is possible to set custom distance.

3. **Angle between braces treated as in one plane**. Braces that are located in different planes of one connection with an angle *A* to each other will be treat as in-plane connection.

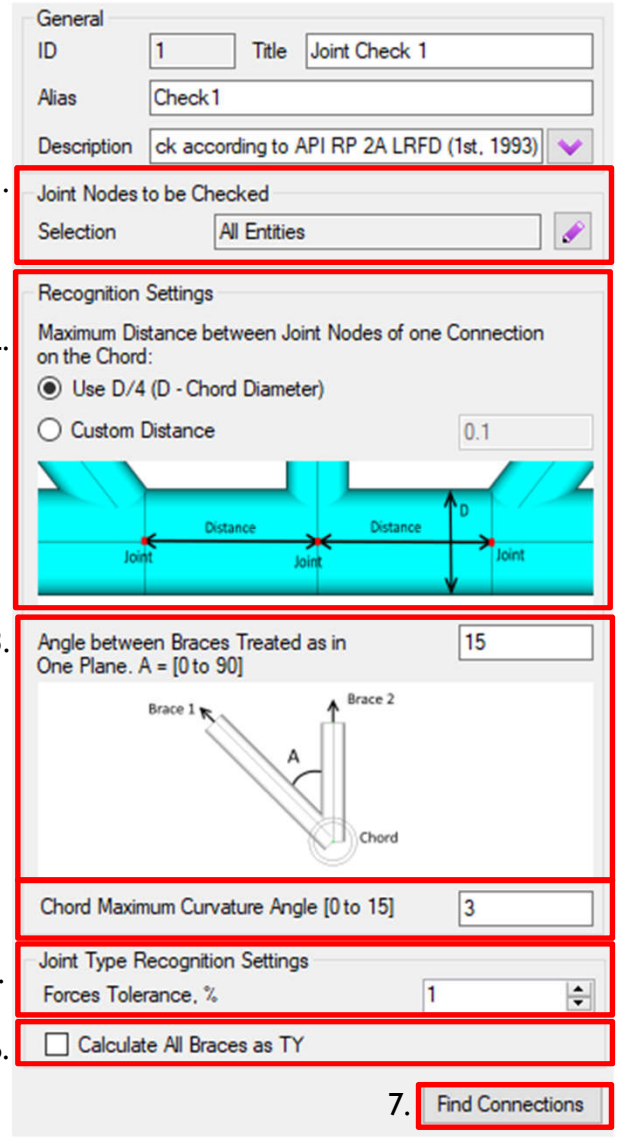
4. **Chord maximum curvature angle** – defines the maximum allowable straightness of the chord. Default angle is 3 degrees.

5. **Forces tolerance**. Maximum allowable difference between axial tension and compression forces that are perpendicular to the chord from the one side of the connection. If forces are balanced, all braces are considered to be K joint.

6. **Calculate all braces as TY**. Ignore all loading conditions and set all brace types to TY if turned on.

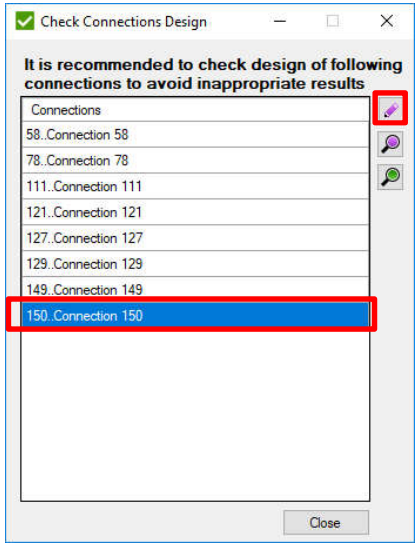
7. Press *Find Connections* to perform recognition.

Joint Check Settings are common for all available types of joint checks: API, ISO and Norsok.

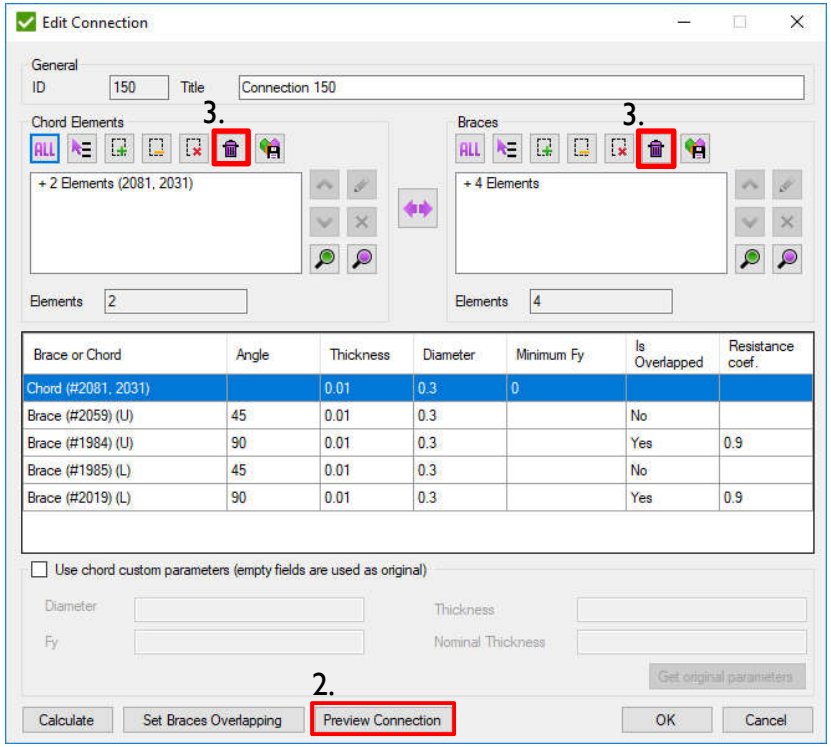


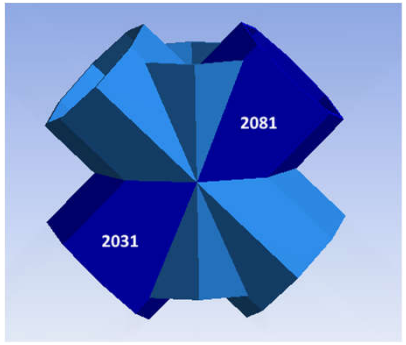
Connections design

List of connections that are recommended to be checked:



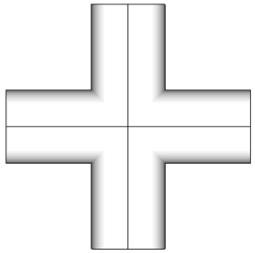
All connections in the list are recommended to be checked as all elements of each connection are of the same diameters and thicknesses. Depending on the welding process it is possible to modify connection and set chord and braces manually.





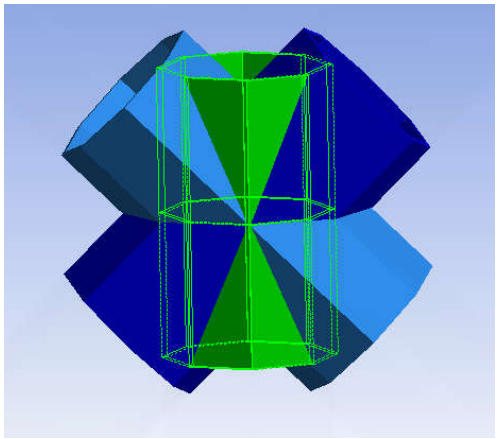
1. Select *Connection 150* and press *Edit* button.
2. Press *Preview Connection*
3. Press *Remove all conditions in chord and braces selection*

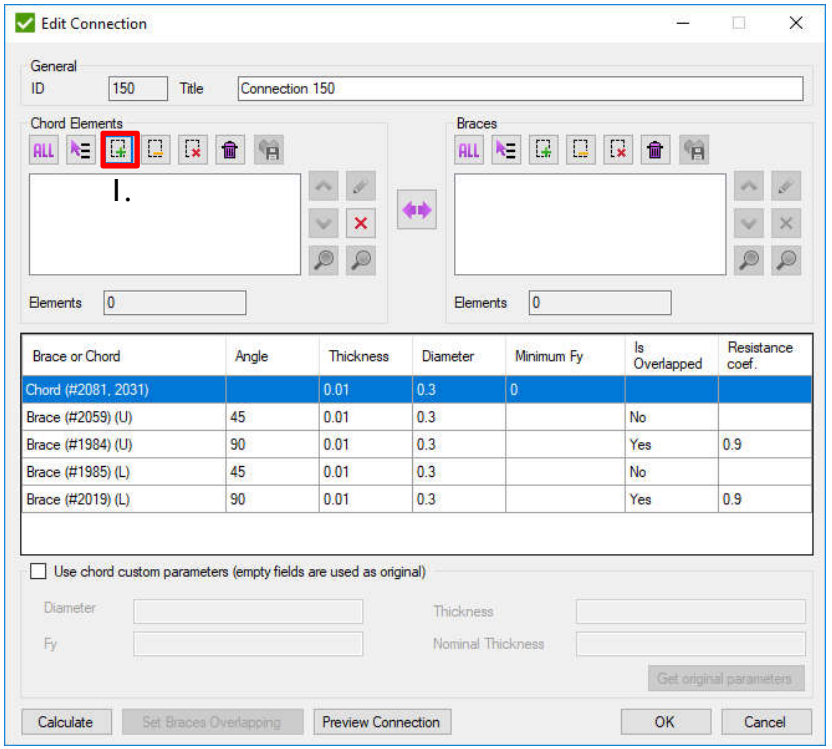
Two separate connections will be created automatically for cross type of joint with equal dimensions. With chord parallel and perpendicular.

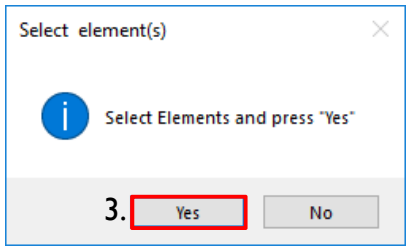


Connections design

1. Press *Add entities using Ansys*
2. Select *Mesh elements ID 2510, 2497.*
3. Press *Yes*





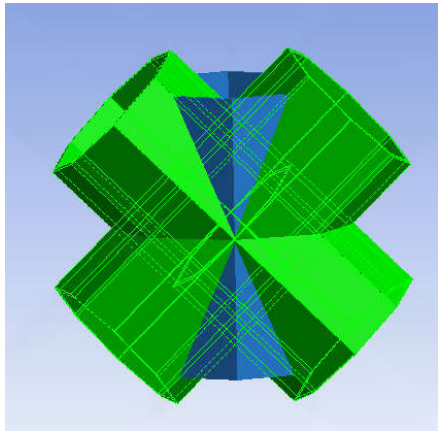


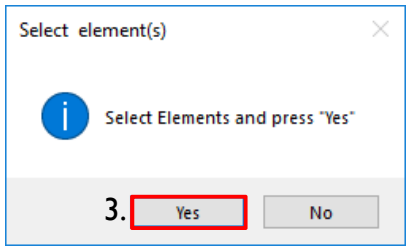
2.

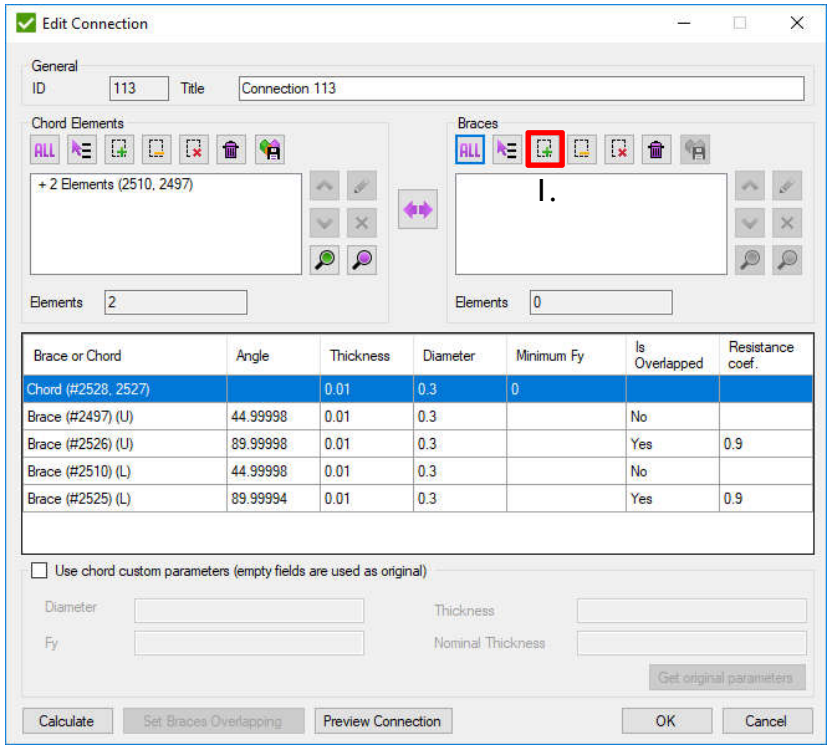
Entity	Element ID	Element Type	Body
2 Mesh Elements, Summary			
Mesh Element 1	2081	Low Order Beam	Beam (Pipe D300x10)
Mesh Element 2	2031	Low Order Beam	Beam (Pipe D300x10)

Connections design

1. Press *Add entities using Ansys*
2. Select *Mesh elements ID 2526, 2528, 2525, 2527.*
3. Press *Yes*





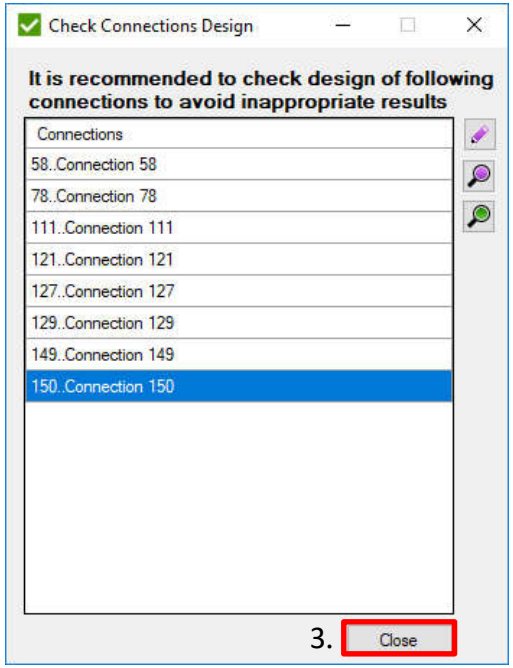


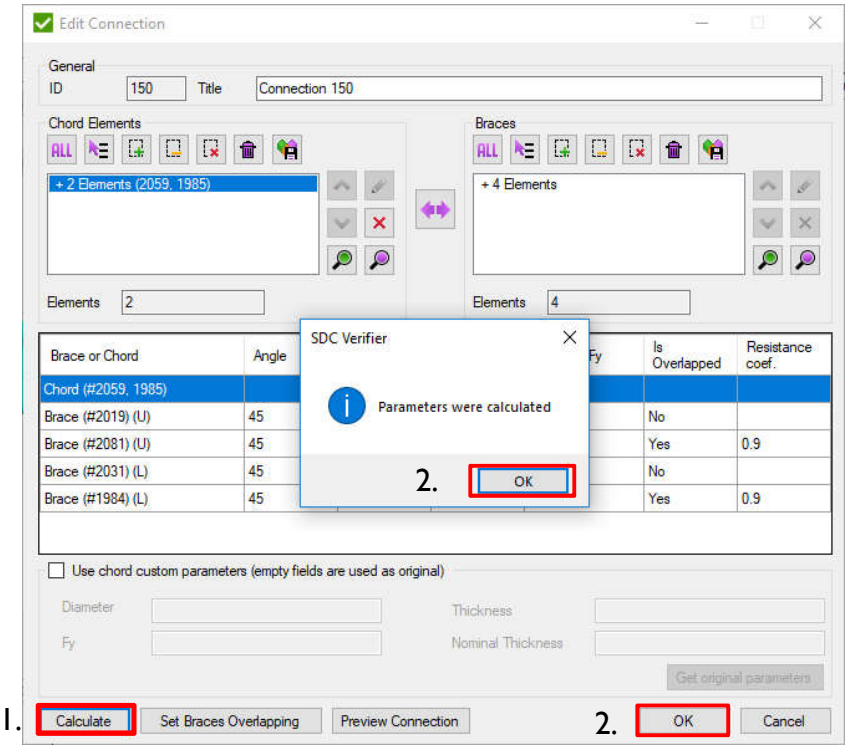
2.

Entity	Element ID	Element Type	Body
4 Mesh Elements, Summary			
Mesh Element 1	2019	Low Order Beam	Beam (Pipe D300x10)
Mesh Element 2	1985	Low Order Beam	Beam (Pipe D300x10)
Mesh Element 3	1984	Low Order Beam	Beam (Pipe D300x10)
Mesh Element 4	2059	Low Order Beam	Beam (Pipe D300x10)

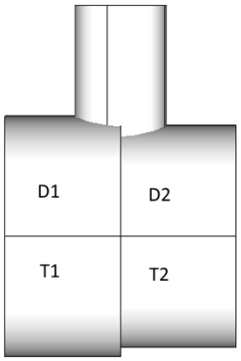
Connections design

1. Press *Calculate*
2. Select *Ok twice.*
3. Press *Close*

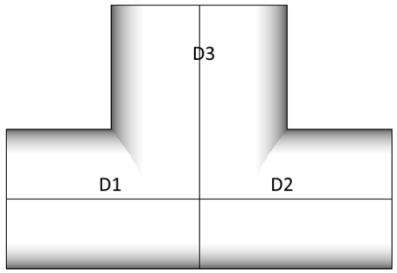




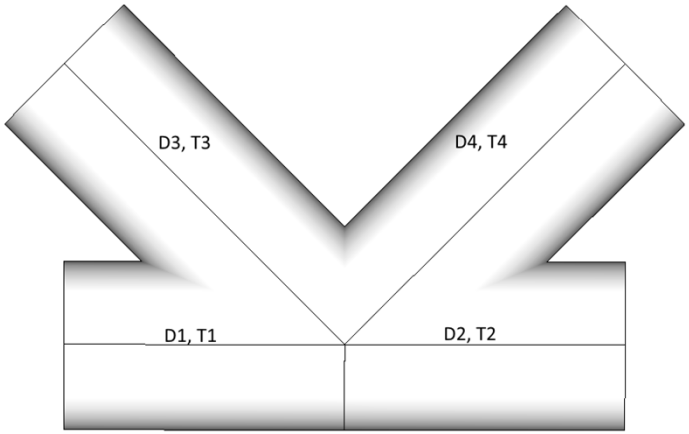
Connections design



When Chord is formed by elements with different properties around the joint node and D1<>D2, D = min(D1, D2); T = min(T1, T2) are considered for calculations.



D1 = D2, D1 < D3. For such case D3 is recognized as chord as it has bigger diameter. Naturally pipe of bigger diameter cannot be welded to smaller. Such connections are recommended to be checked.



D1 = D2 = D3 = D4;
T1 = T2 = T3; T4 > T1;
When all diameters of connection are equal, thicknesses are compared. Element with thickness = T4 is recognized as chord.

In case when:
D1 = D2 = D3 = D4;
T1 = T2 = T3 = T4;
When all elements of connection are of the same dimensions, chord is recognized as pair of elements that form straight line. If any pair that match condition is found, random element will be recognized as chord.

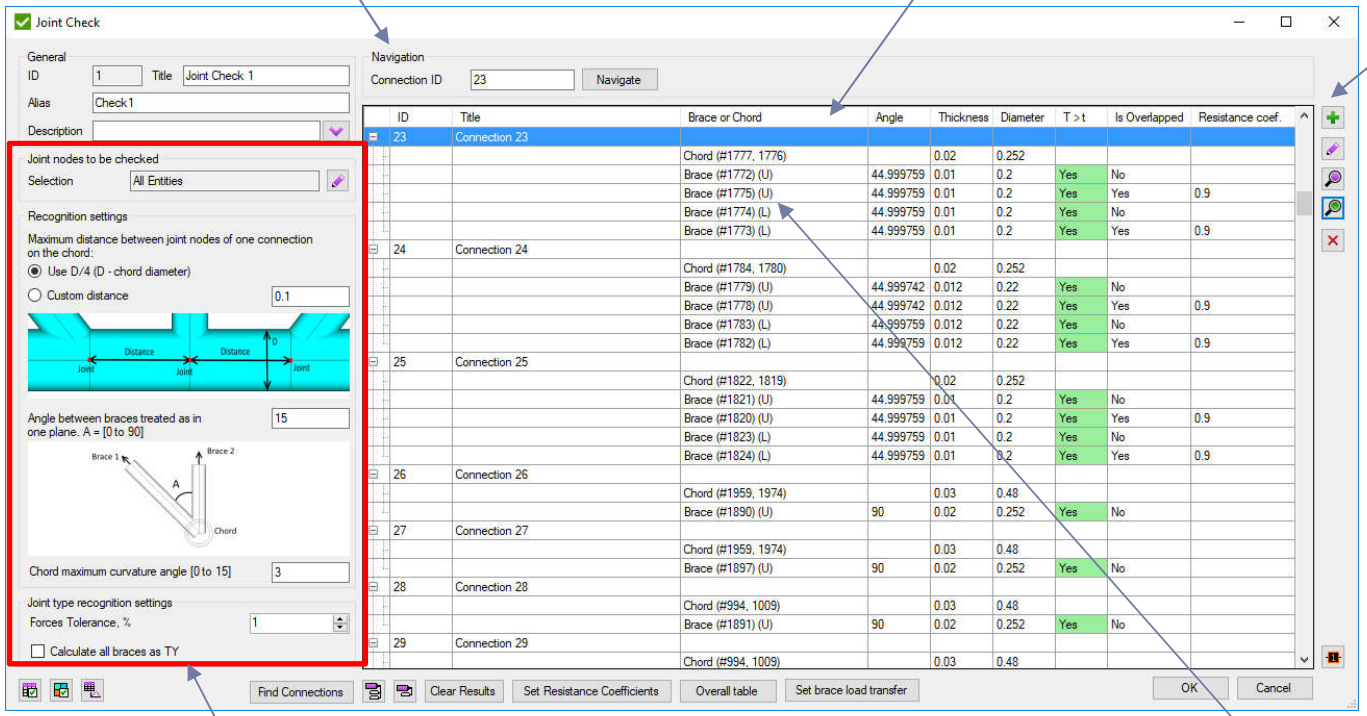
In both cases such types of connections are recommended to be checked.

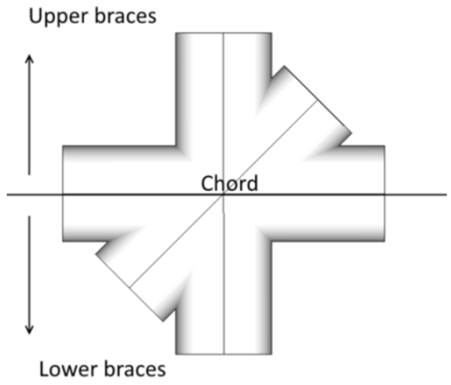
Joint Check API LRFD

Navigation. Fill *Connection ID* and Press *Navigate* to find connection in the table

Connection info. Chord, Braces and their properties

Add, Edit, Preview and Remove selected connections.



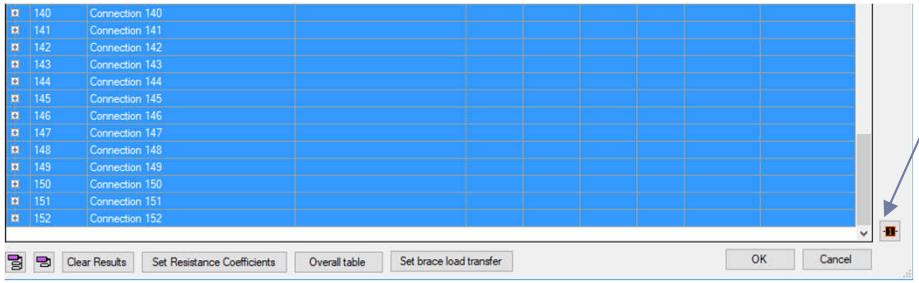


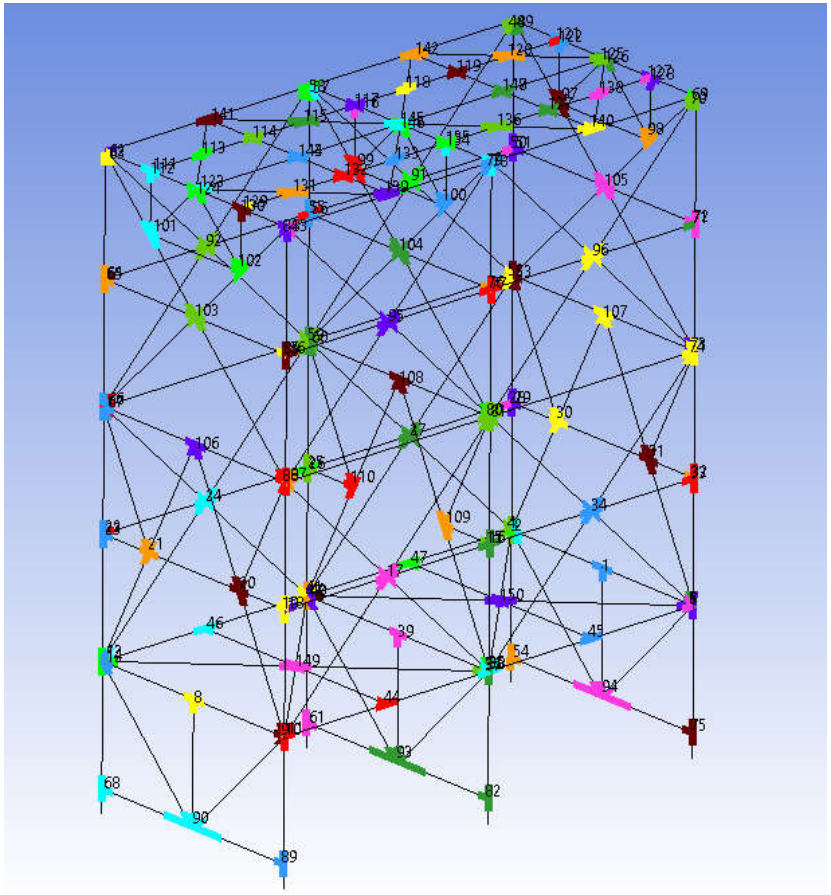
Selection and recognition settings

#1777,1776 – IDs of related elements in the model.
(U) – Upper (0°-180°) braces
(L) – Lower (180°-360°) braces

Joint Check API LRFD

Select all connections in the list (Ctrl + A) and press *Plot* to display all connections with labels of IDs.



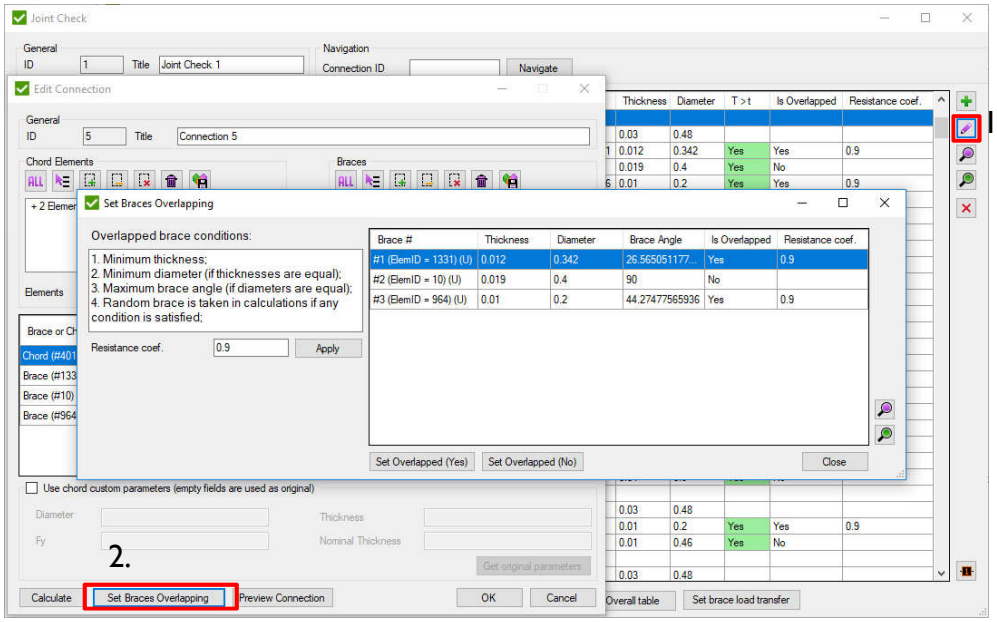


Joint Check API LRFD

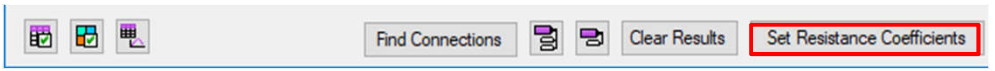
Resistance coefficient depends on the strength of welding and is used in calculations of overlapping (Section E.3.2 API 2A RP LRFD). **Table J 2.5** is taken from **Load and resistance factor design specification for structural steel buildings December, 27 1999 (AISC).** Default value is 0.9. It can be applied to overlapped braces

TABLE J2.5
Design Strength of Welds

Types of Weld and Stress [a]	Material	Resistance Factor ϕ	Nominal Strength F_{BM} or F_w	Filler Metal Requirements [b, c]
Complete-Joint-Penetration Groove Weld				
Tension normal to effective area	Base	0.90	F_y	Matching filler metal shall be used. For CVN requirements see footnote [d].
Compression normal to effective area	Base	0.90	F_y	Filler metal with a strength level equal to or less than matching filler metal is permitted to be used.
Tension or compression parallel to axis of weld				
Shear on effective area	Base Weld	0.90 0.80	$0.60F_y$ $0.60F_{EXX}$	
Partial-Joint-Penetration Groove Weld				
Compression normal to effective area	Base	0.90	F_y	Filler metal with a strength level equal to or less than matching filler metal is permitted to be used.
Tension or compression parallel to axis of weld [e]				
Shear parallel to axis of weld	Base Weld	[f] 0.75	[f] $0.60F_{EXX}$	
Tension normal to effective area	Base Weld	0.90 0.80	F_y $0.60F_{EXX}$	
Fillet Welds				
Shear on effective area	Base Weld	[f] 0.75	[f] $0.60F_{EXX}$ [g]	Filler metal with a strength level equal to or less than matching filler metal is permitted to be used.
Tension or compression parallel to axis of weld [e]	Base	0.90	F_y	
Plug or Slot Welds				
Shear parallel to faying surfaces (on effective area)	Base Weld	[f] 0.75	[f] $0.60F_{EXX}$	Filler metal with a strength level equal to or less than matching filler metal is permitted to be used.



It is possible to set overlapped braces and their resistance coef. manually in 1.*Edit Connection* -> 2.*Set Braces Overlapping*. Alternatively set coefficients to multiple connections by pressing *Set Resistance Coefficients* button:



Joint Check API LRFD

Load transfer has an influence on a chord stability. Axial branch capacity is calculated using Can and Nominal chord element parameters (**Section E.3.4 API 2A RP LRFD**)

E.3.4 Load Transfer Across Chords. Cross joints, launch leg joints, and other joints in which load is transferred across the chord should be designed to resist general collapse. However, for such joints reinforced only by a joint can having increased thickness T_c and length L (for cases where joint cans are centered on the brace of interest L is defined as shown in Figure E.3-6a) and having brace chord diameter ratio less than 0.9, the allowable axial branch load shall be taken as:

$$P = P(1) + \frac{L}{2.5D}[P(2)-P(1)] \quad \text{for } L < 2.5D \quad \text{(E.3.4-1a)}$$

$$P = P(2) \quad \text{for } L > 2.5D \quad \text{(E.3.4-1b)}$$

where:

P(1) = P_a from Equation E.3.1-4a using the nominal chord member thickness

P(2) = P_a from Equation E.3.1-4a using thickness T_c

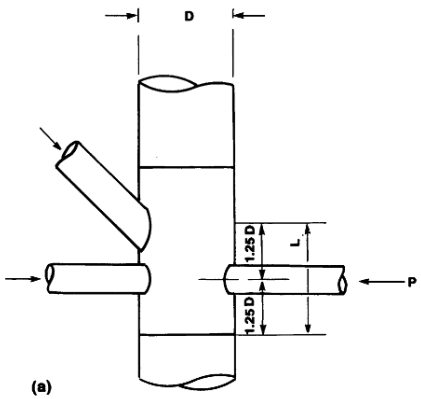
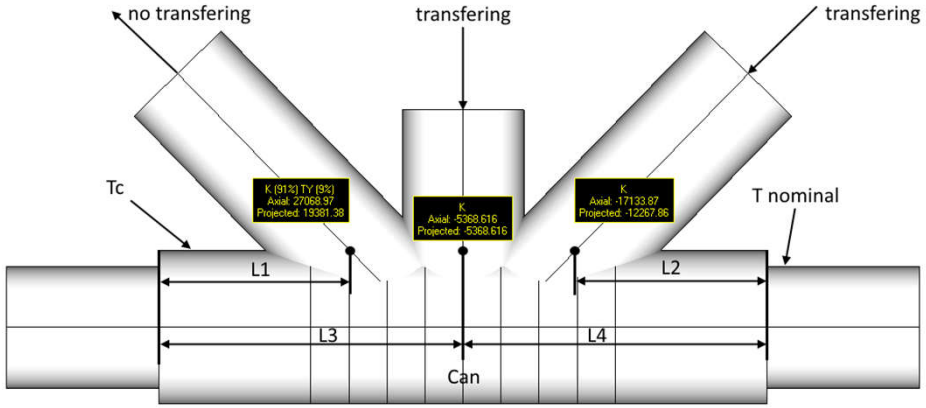
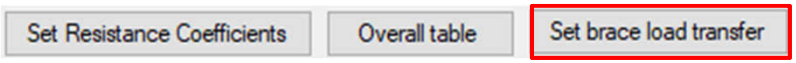


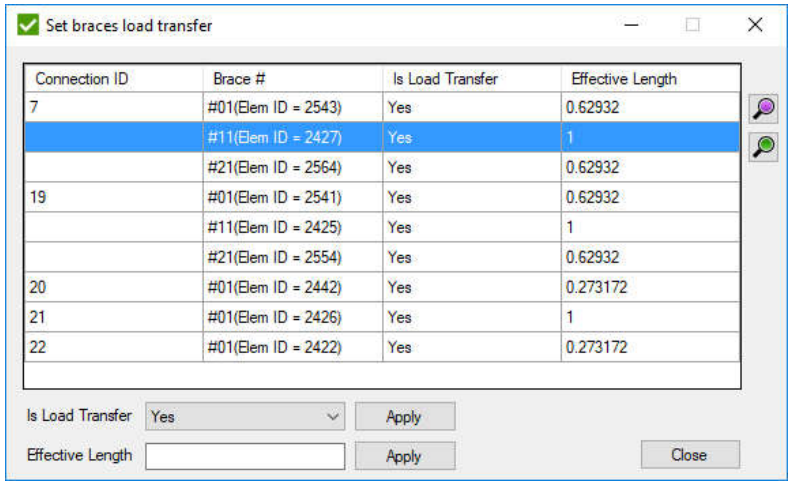
FIG. E.3-6
DEFINITION OF EFFECTIVE CORD LENGTH



Effective length is calculated for each brace separately. It is the minimum distance from the end of the can till the point of intersection of chord and brace multiplied on 2. L1, L2 <=1.25D. If L1 and L2 exceed 1.25D distance, can will not be recognized.
Tc ≥ T nominal.
L = 2 * L1 = 0.6293 – effective length for the left brace
L = 2 * L3 = 2 * L4 = 1 – effective length for the middle brace
L = 2 * L2 = 0.6293 – effective length for the right brace
T nominal = 0.01; Tc = 0.02;

It is possible to set load transfer and effective length manually by pressing *Set brace load transfer* button.

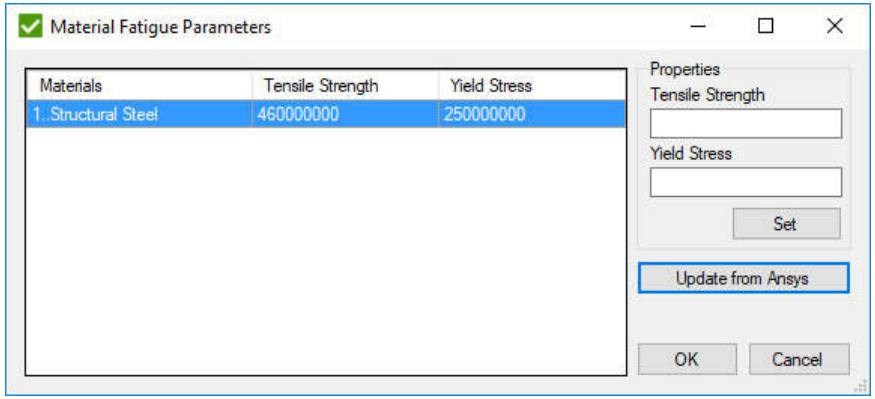




Material Properties

All results are based on material fatigue parameters Tensile Strength and Yield Stress. Parameters are used to define allowable static stress of material. **Sallowable = Min(Yield Stress, Tensile Strength * 2 / 3).** For ISO and Norsok joint checks: **Sallowable = Min(Yield Stress, Tensile Strength * 0.8).**

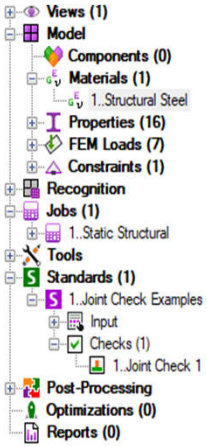
If material parameters are not set, window will be displayed before calculating results:

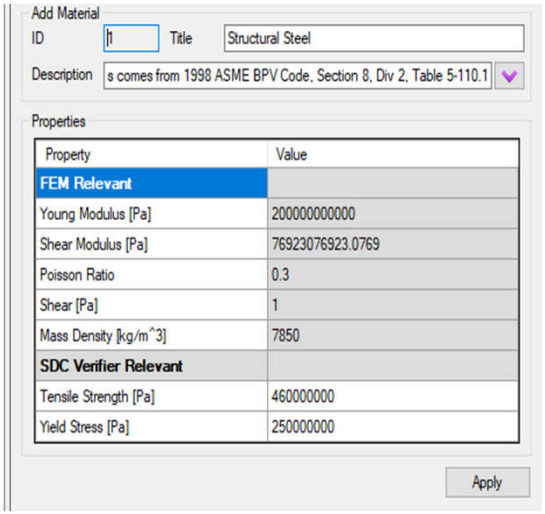


Set values for Tensile and Yield and press *Set* to selected materials.

Press OK to apply changes and continue calculations, Cancel to discard.

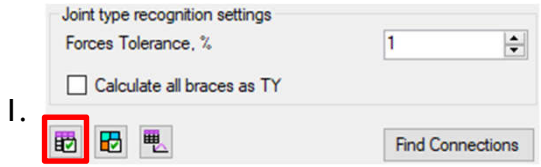
Alternatively it is possible to set values for selected materials in the Main Window. Select material, fill parameters and press Apply.





Joint Check Expand Table

1. Press *Add Expand table*. Detailed table of results for each brace
2. *Selected Load*: **Load Group'1..Load Group 1'**
3. *Show only joints that fail* : **ON**
   Sort by parameter : **Overall Utilization Factor**
4. Press *Fill Table*
5. Press *OK*



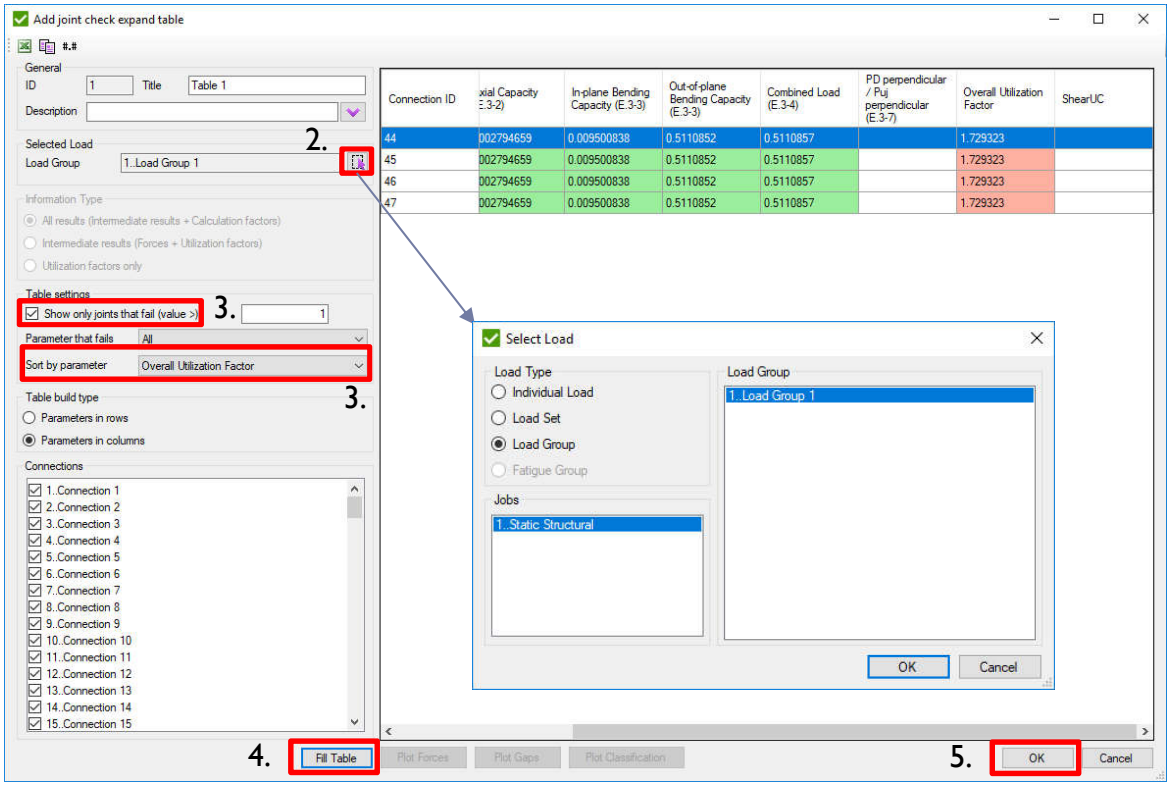


Table build type allows to fill parameters in columns and connections in rows and vice versa. *Parameters in rows* can be used for a single connection for example.

Plot Forces – plot original, transformed axial forces and brace joint types

Plot Gaps – plot gaps if there is more than one brace in connection

Plot Classification – plot brace joint types

Brace Joint Type

Joint classification as K, T & Y, or cross (X) should apply to individual braces according to their load pattern for each load case. To be considered a K-joint, the punching load in a brace should be essentially balanced by loads on other braces in the same plane on the same side of the joint. In T and Y joints the punching load is reacted as beam shear in the chord. In cross joints the punching load is carried through the chord to braces on the opposite side. For braces that carry part of their load as K-joints, and part as T & Y or cross joints interpolate based on the portion of each in total. Examples are shown in Figure E.3-2. See Commentary on Joint Classifications.

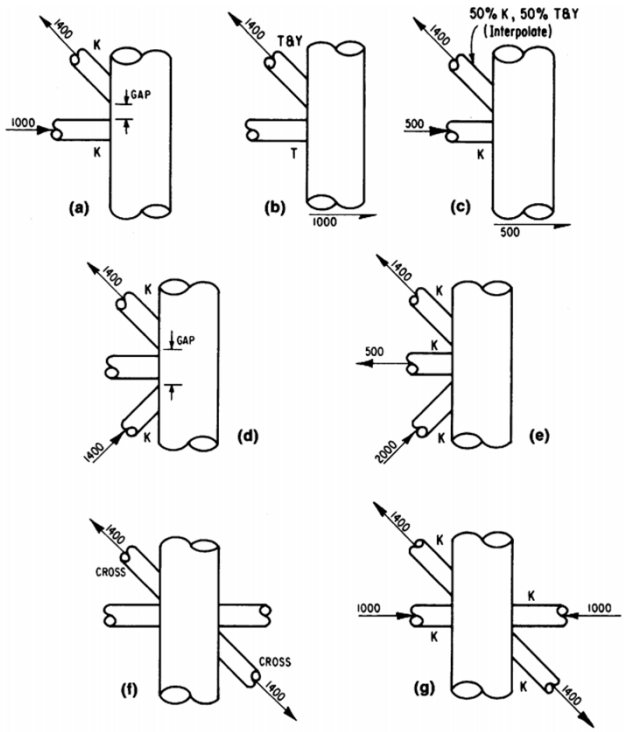


FIG. E.3-2
EXAMPLES OF JOINT CLASSIFICATION

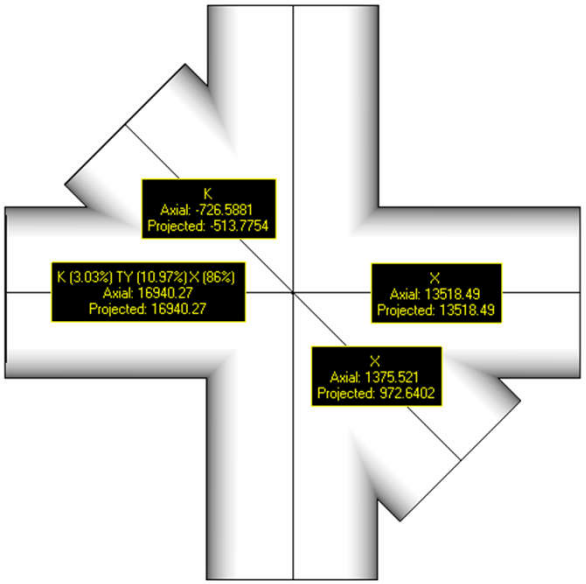
Joint type is based on type of loading. By checking if forces of connection are balanced joint types are classified on K, TY and X (Cross).

K – tension and compression loads are balanced.

TY – tension or compression load goes as shear force in a chord.

X (Cross) – Connection has to contain braces from the both sides to check on cross joint. If balanced forces of all braces of one side and balanced forces of all braces of other side are equal then all braces are classified as X (Cross).

Interpolation – the order of joint type recognition is following: K -> X (Cross) -> TY. Each brace can have all 3 types of joint type taken as percentage of axial load of brace to summation of all braces loads.

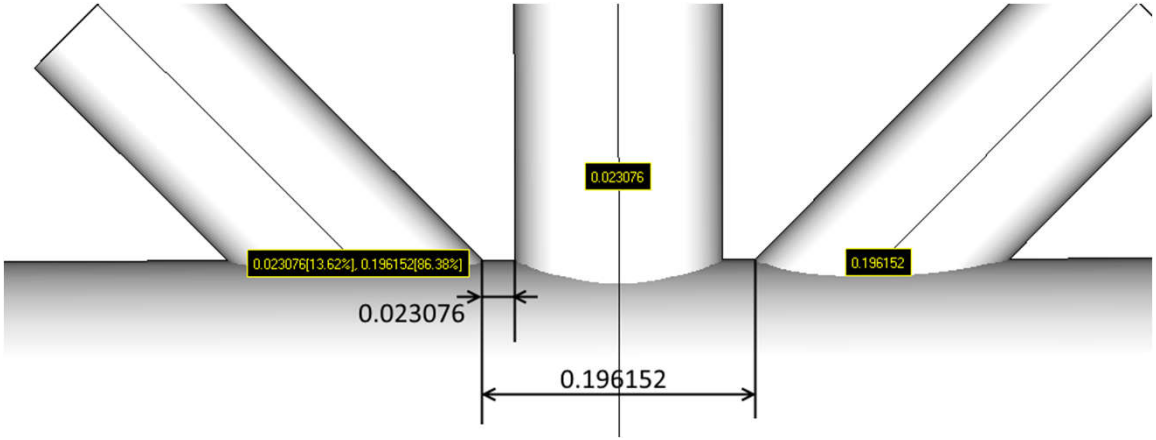


Projected – axial force that is perpendicular to the chord.

If Projected = 0 – brace type is set to TY.

If percentage is not mentioned 100% is taken for the type.

Gaps



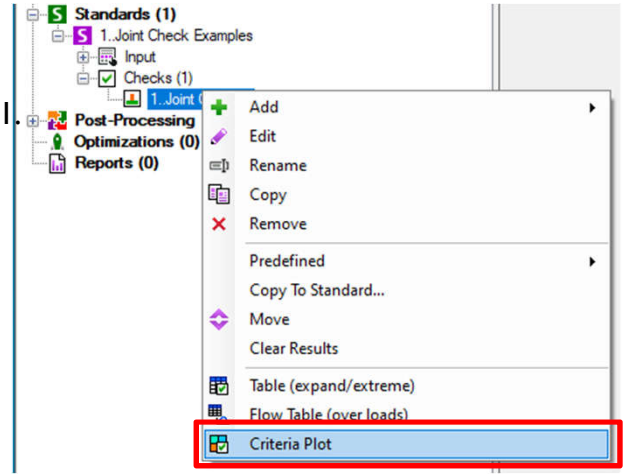
Gap is the distance between two differently loaded braces (tension and compression) on a shell of a chord.
Depending on load it is possible that brace can have two or more gaps to considerate. Each gap percentage depends on the percentage of taken load:

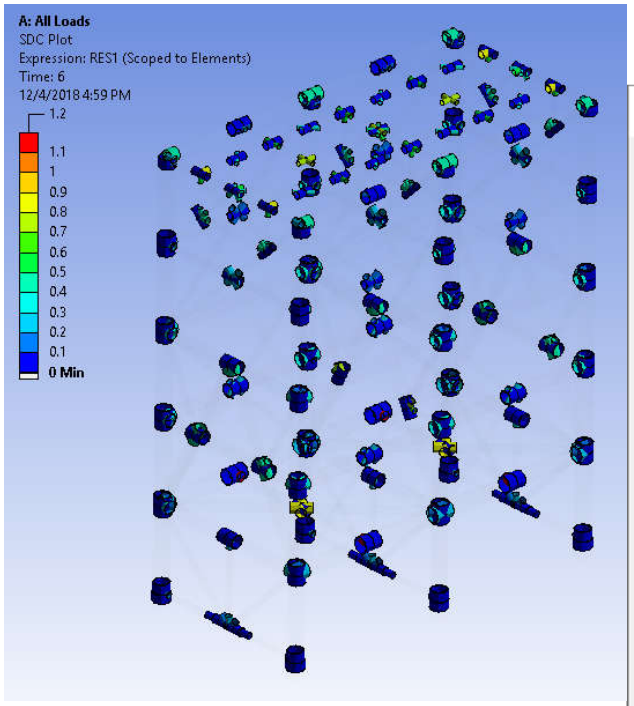
$$percentage = \begin{cases} \frac{projected}{FCompression}, & projected < 0 \\ \frac{projected}{FTension}, & projected \geq 0 \end{cases}$$

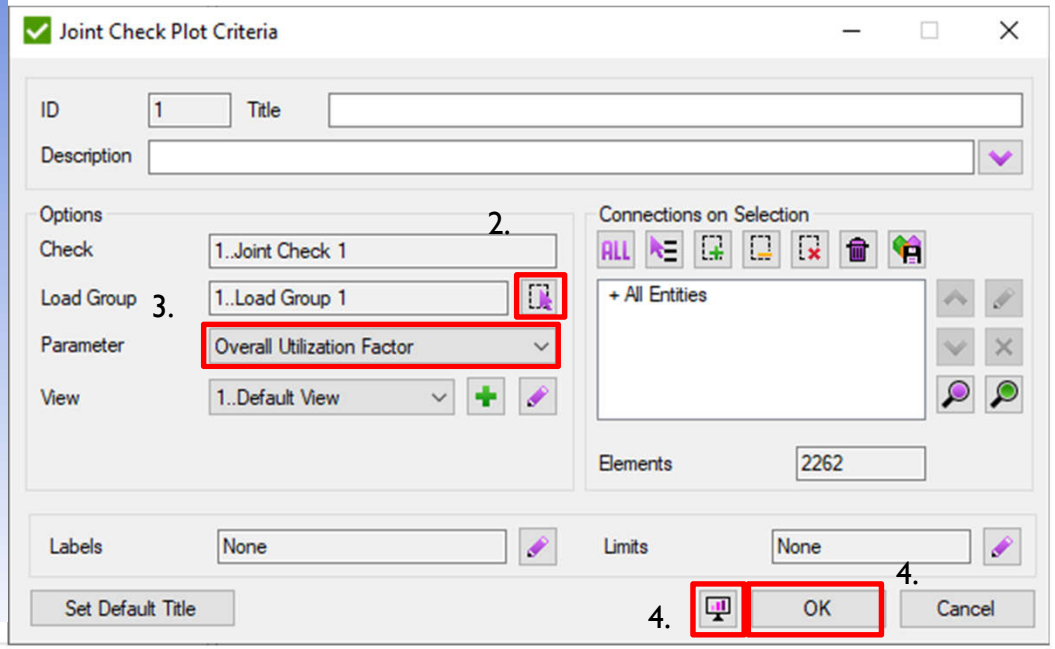
Projected – axial force of the brace, perpendicular to the chord;
FTension – sum of all positive projected axial forces;
FCompression – sum of all negative projected forces;

Joint Check Criteria Plot

1. Execute **Joint Check 1->Criteria Plot**
2. *Select Load*: **Load Group'1..Load Group 1'**
3. *Parameter* : **Overall Utilization Factor**
4. Press . Press *OK*







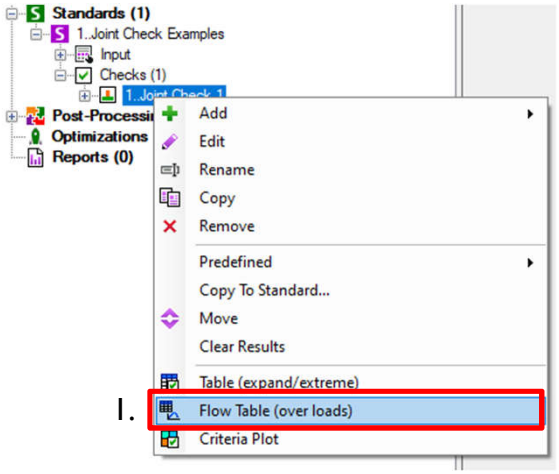
Joint Check Expand Flow Table

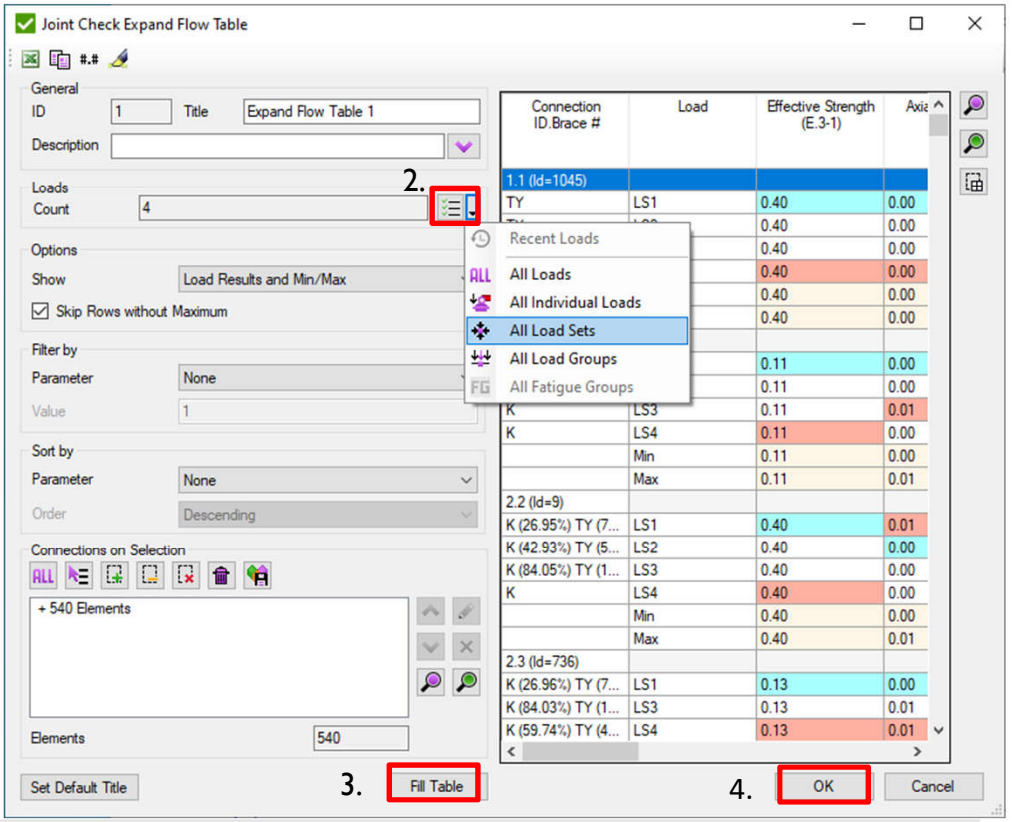
1. Press *Add Expand Flow Table*
2. Select all Load Sets
3. Press *Fill Table*
4. Press *OK*

Expand Flow table is used to display multiple load results at once for each selected connection

Skip rows without maximum – for the single connection if load does not cause extreme values on any parameter it will not be displayed.

It is possible to display only **Load Results**, only **Min/Max** results or both



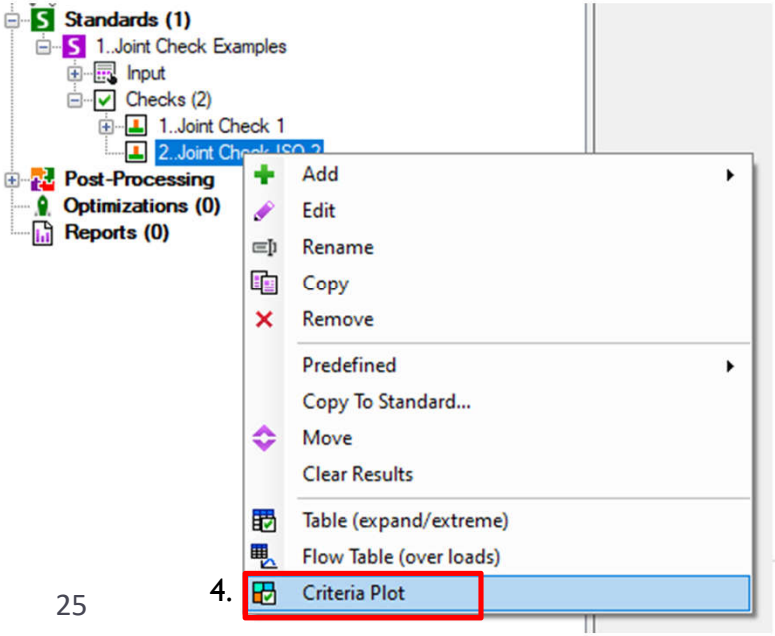


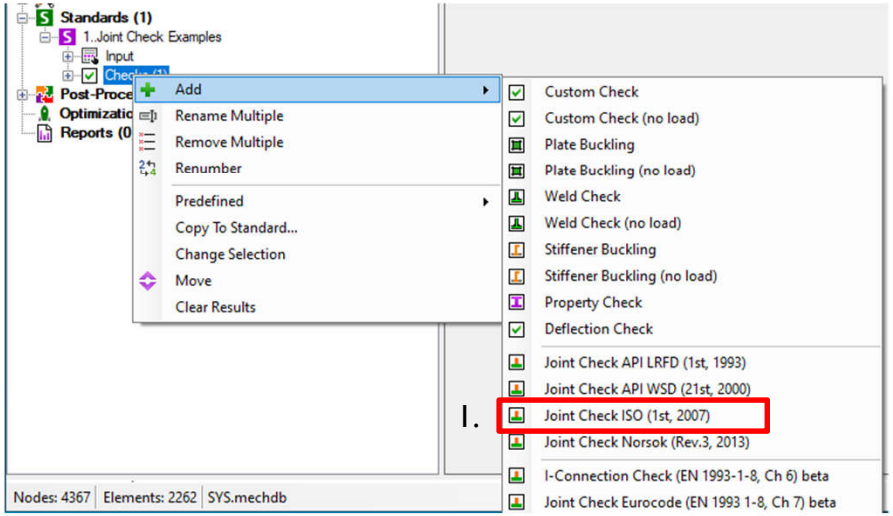
Joint Check ISO

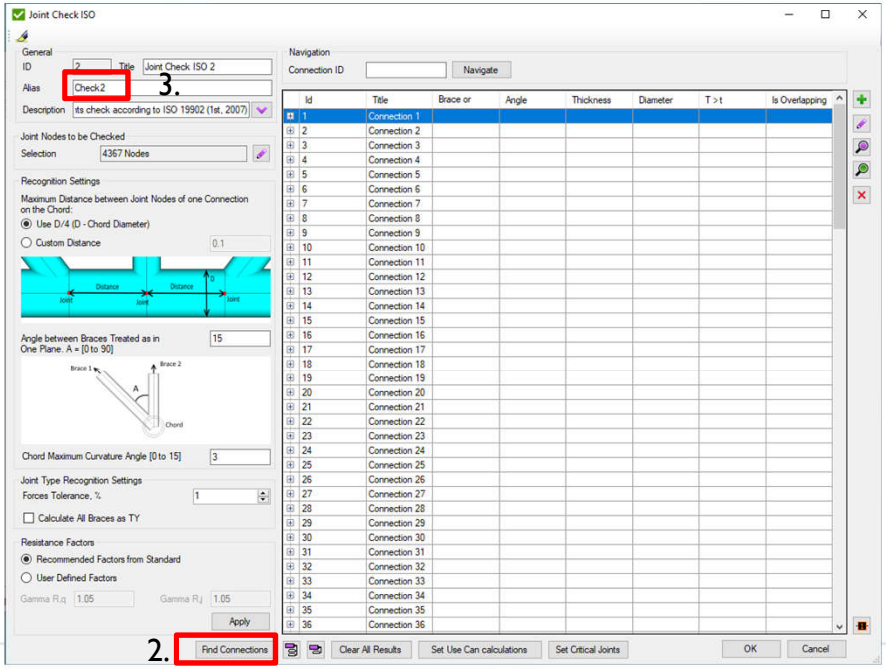
Joint Check ISO interface is similar to **Joint Check API.**

1. Execute **Checks->Add->Joint Check ISO**
2. Press *Find Connections*
3. Alias: **Check2**
4. Execute **Joint Check ISO 2->Criteria Plot**

Joint Check ISO is a part of the standard **ISO 19902 (first edition, published 12 DEC 2007)**

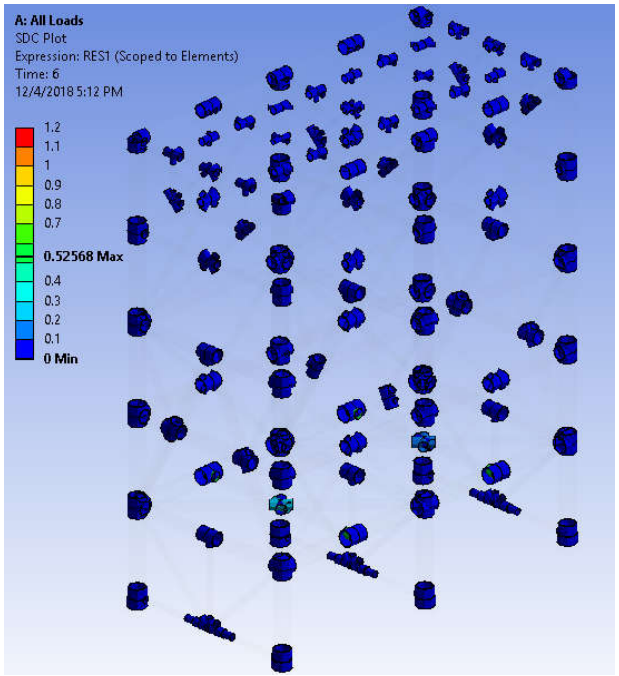


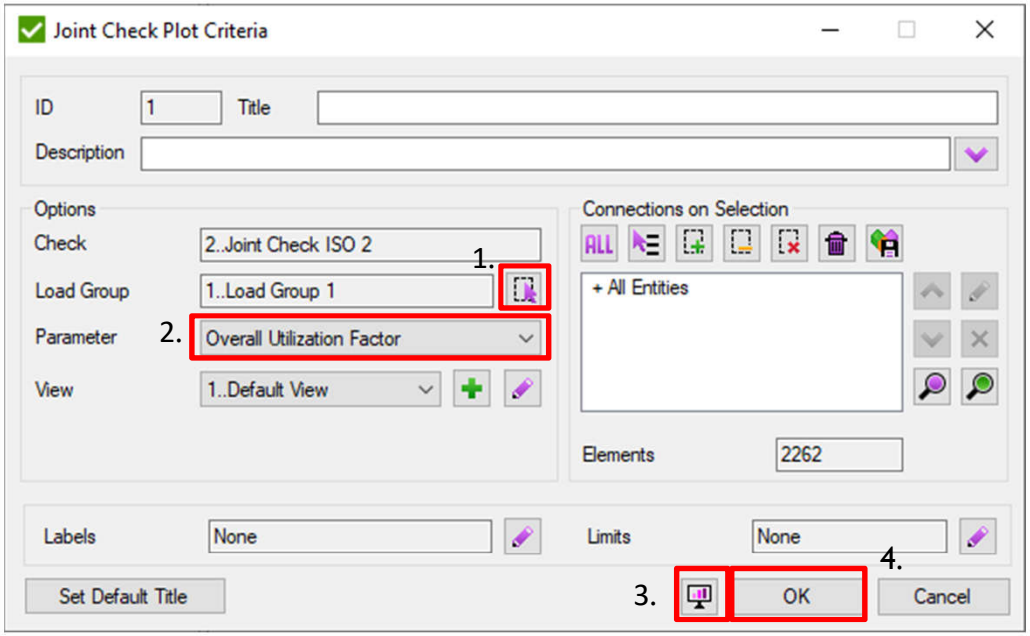




Joint Check ISO

1. *Select Load*: **Load Group '1..Load Group 1'**
2. *Parameter* : **Overall Utilization Factor**
3. Press . Press *OK*

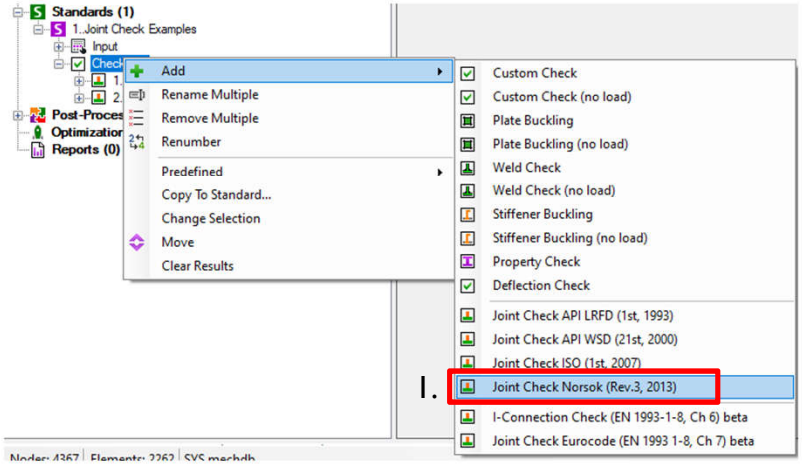




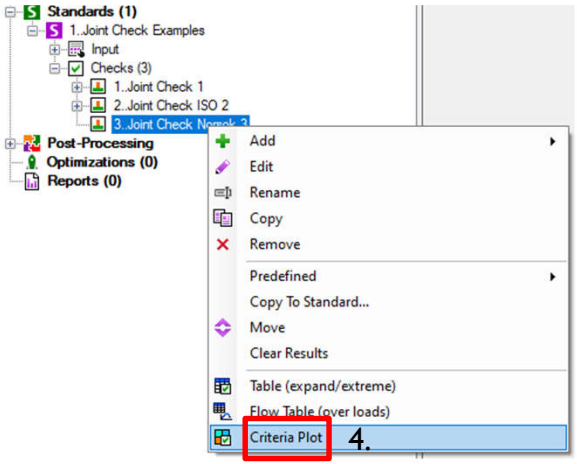
Joint Check Norsok

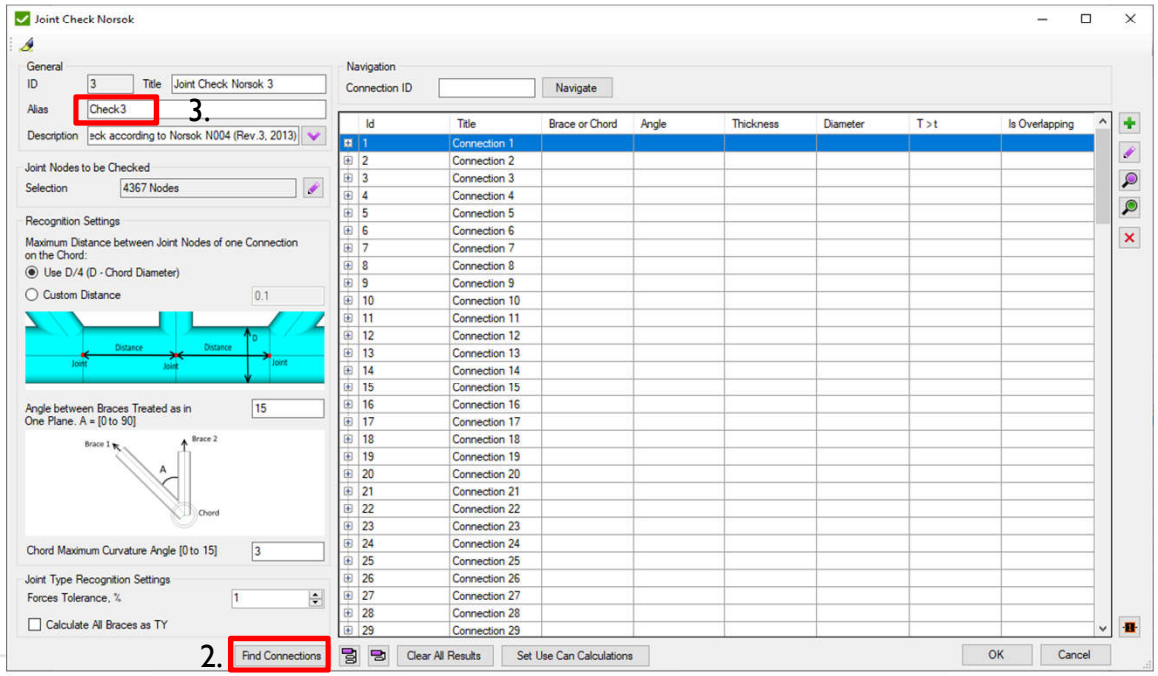
Joint Check Norsok interface is similar to **Joint Check API**

1. Execute **Checks->Add->Joint Check Norsok**
2. Press *Find Connections*
3. Alias: **Check3**
4. Execute **Joint Check Norsok 2->Criteria Plot**



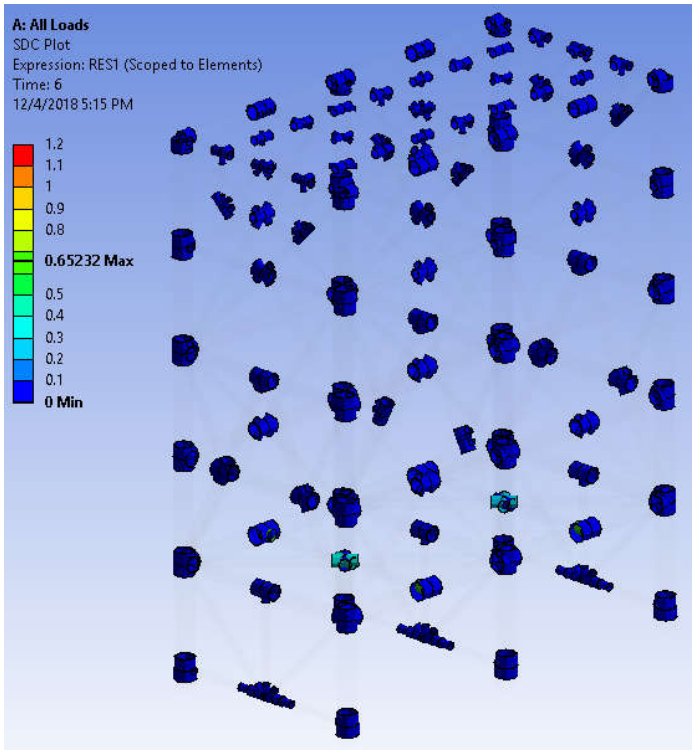
Joint Check Norsok is a part of the standard **Norsok N004 (Rev. 3, February 2013)**

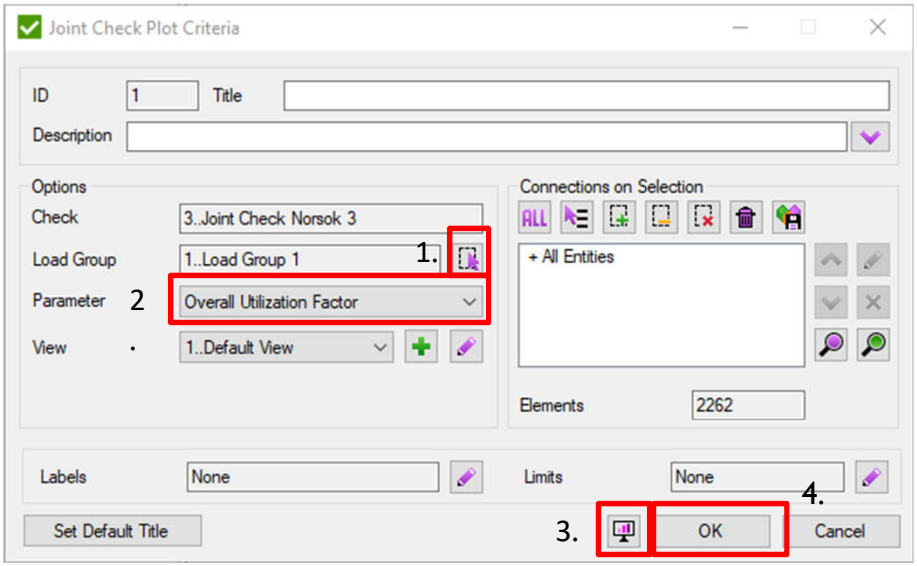




Joint Check Norsok

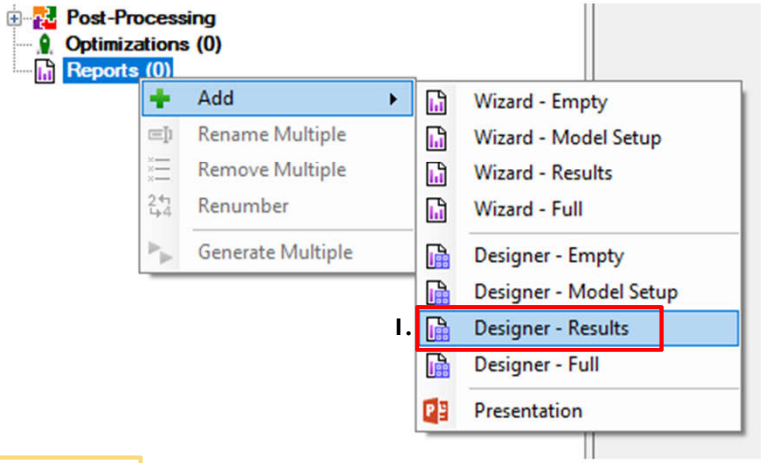
1. *Select Load*: **Load Group '1..Load Group 1'**
2. *Parameter* : **Overall Utilization Factor**
3. Press *Preview plot.* Press *OK*





Report

1. Execute *Reports* => *Add* => Designer – Results.
2. Exclude Tables in the Joint Check API



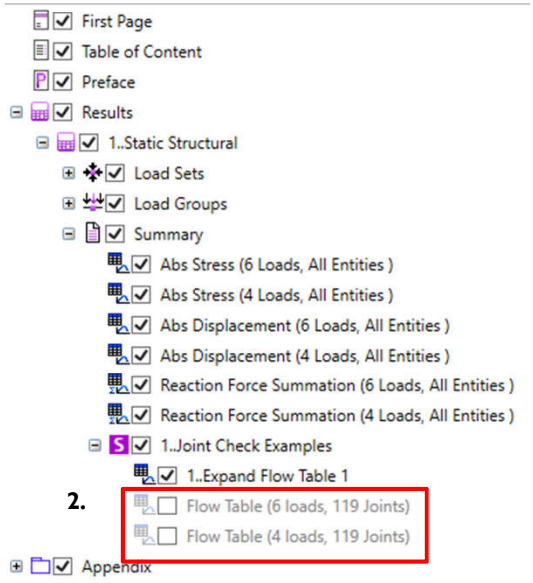
There are 4 templates of the reports:

Empty – only first page and preface items are included;

Model Setup – description of the model data (materials, properties, components, boundary conditions) is included;

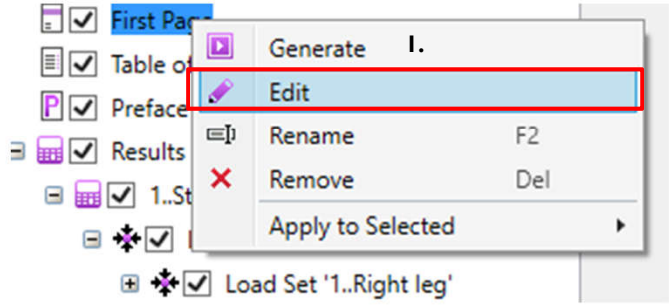
Results – for each load extreme displacement tables, stress and displacement plots are included. Predefined tables: sum of reaction forces, stresses/displacements summary tables. In addition all standards are included with a set of tables/plots created in the project;

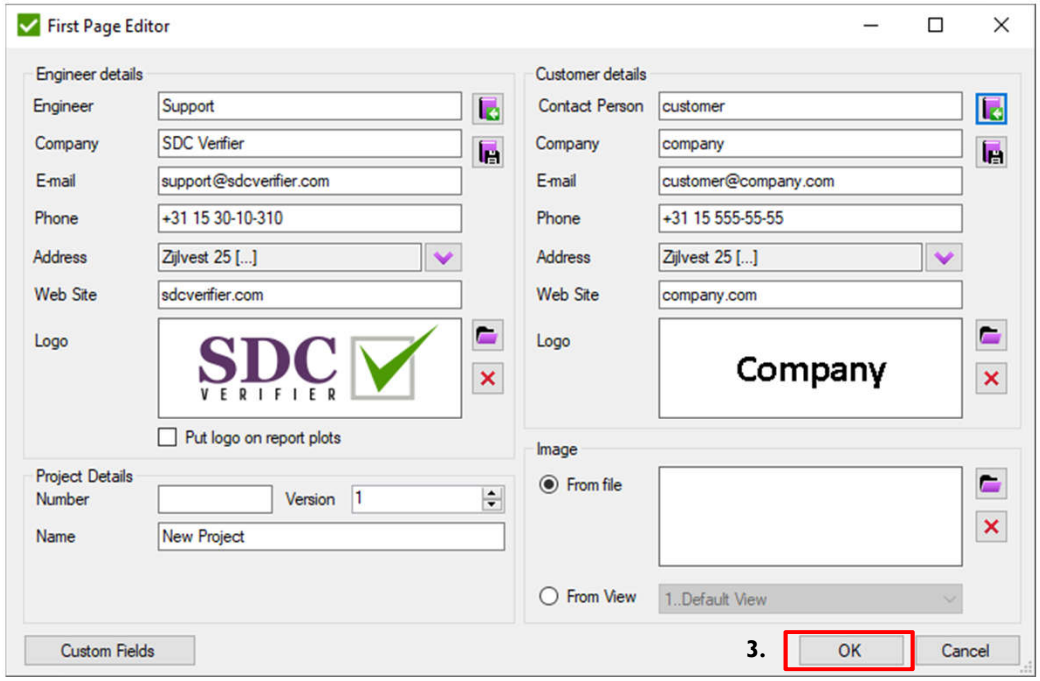
Full – Model Setup + Results + all tables/plots created in jobs.



Report. First Page

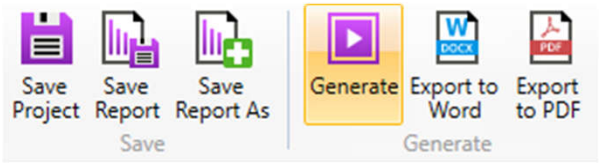
1. Right click on *First Page => Edit.*
2. Fill in information about project.
3. Press *OK*.



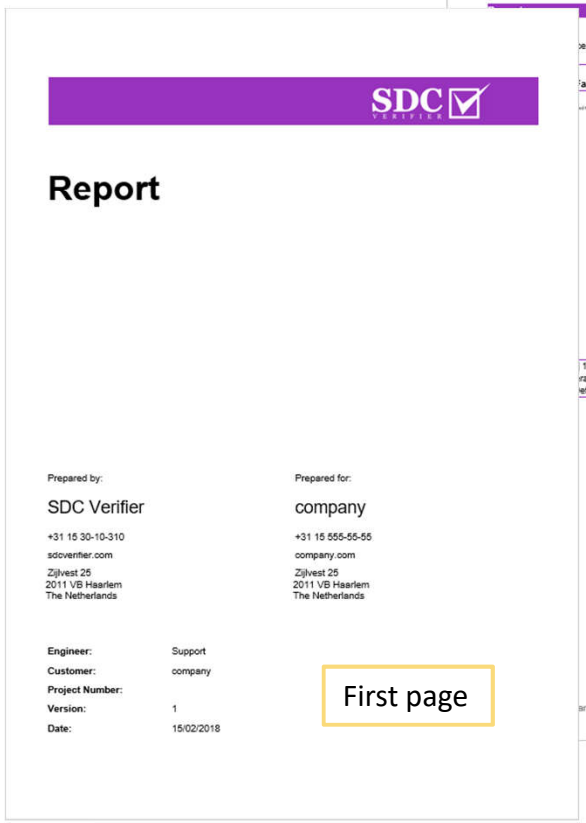


Report exported to Microsoft Word

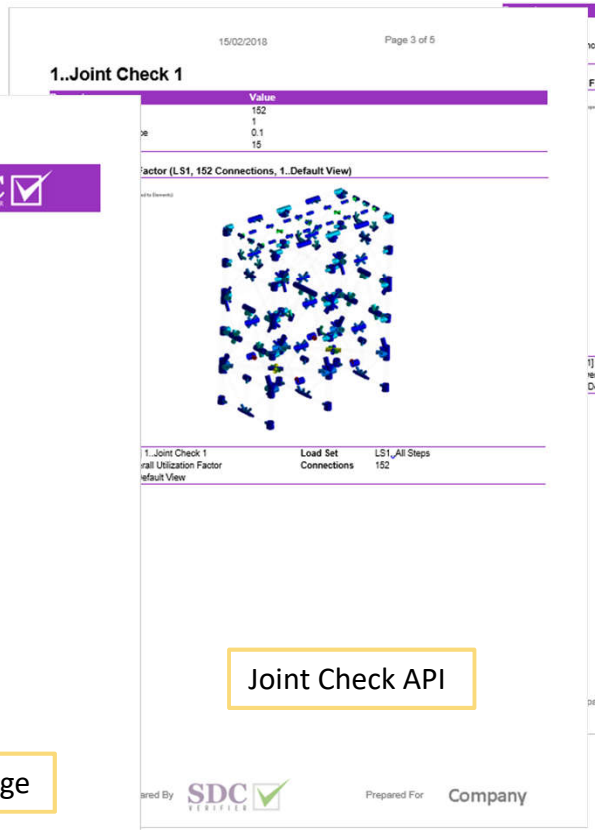
Press to generate complete report.



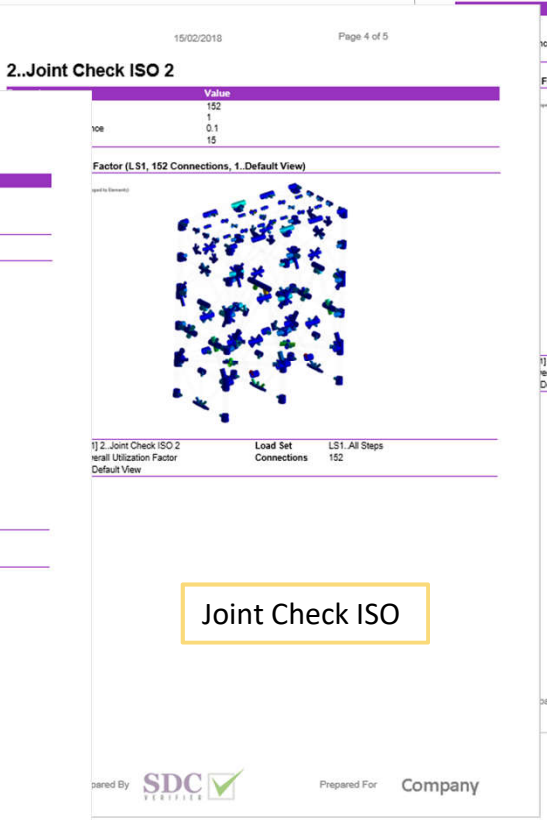
Press to export to Word.



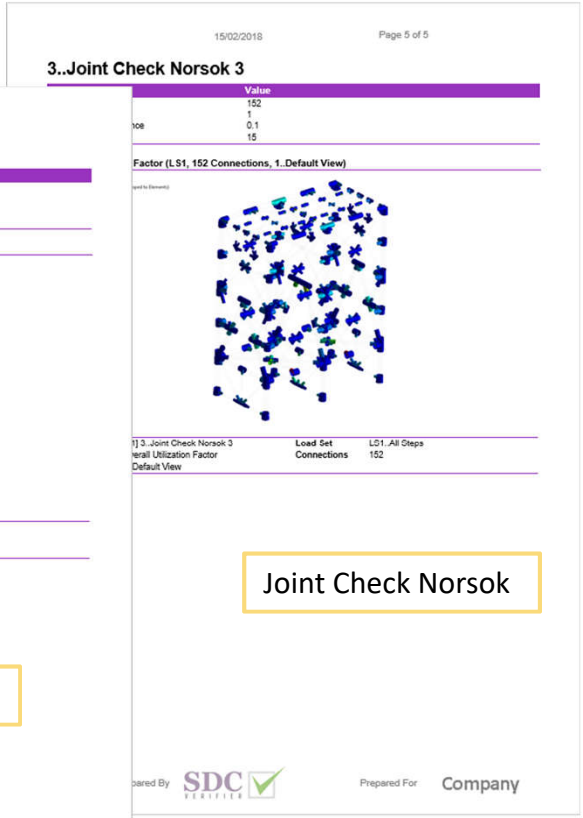
First page



Joint Check API



Joint Check ISO



Joint Check Norsok