



Tutorial

Joint Check

21 Jan 2020
version 5.3

- ▶ 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.

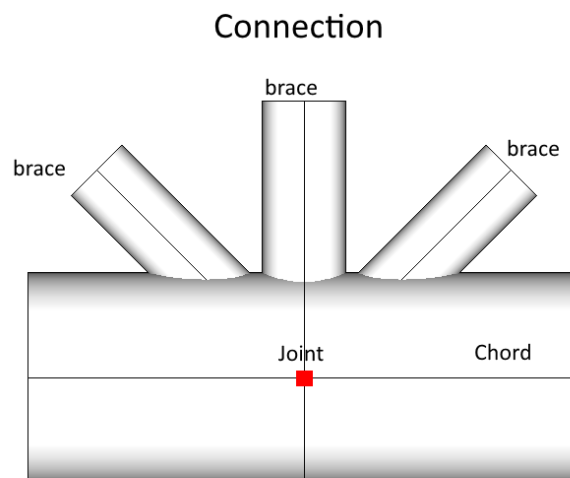
Joint Check – offshore check that verifies strength of tubular structure under tension or compression members according to the standards.

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

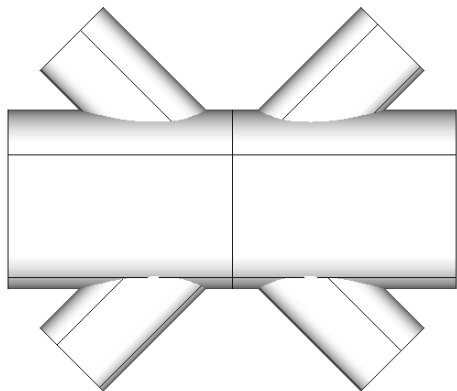
Connection is a set of elements of the same plane around a joint node.

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

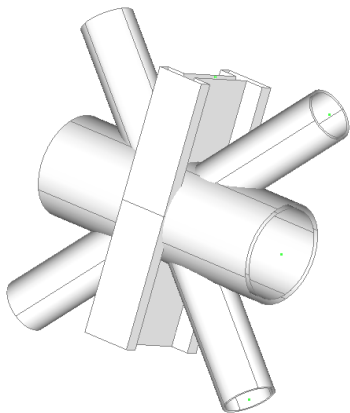
Brace is a welded to a chord element.



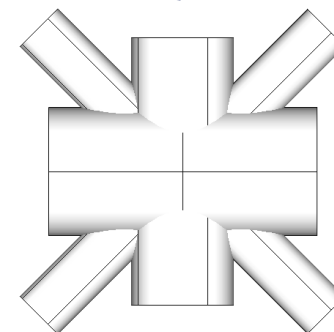
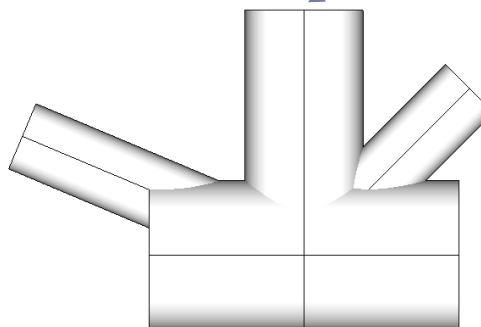
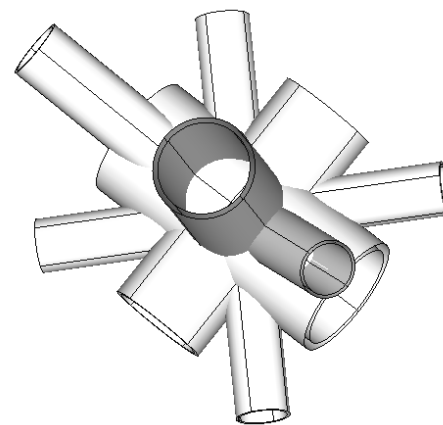
2D Connection. Set of elements of one plane



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



3D Connection. Will be split on 2D Connections



Open Project

1

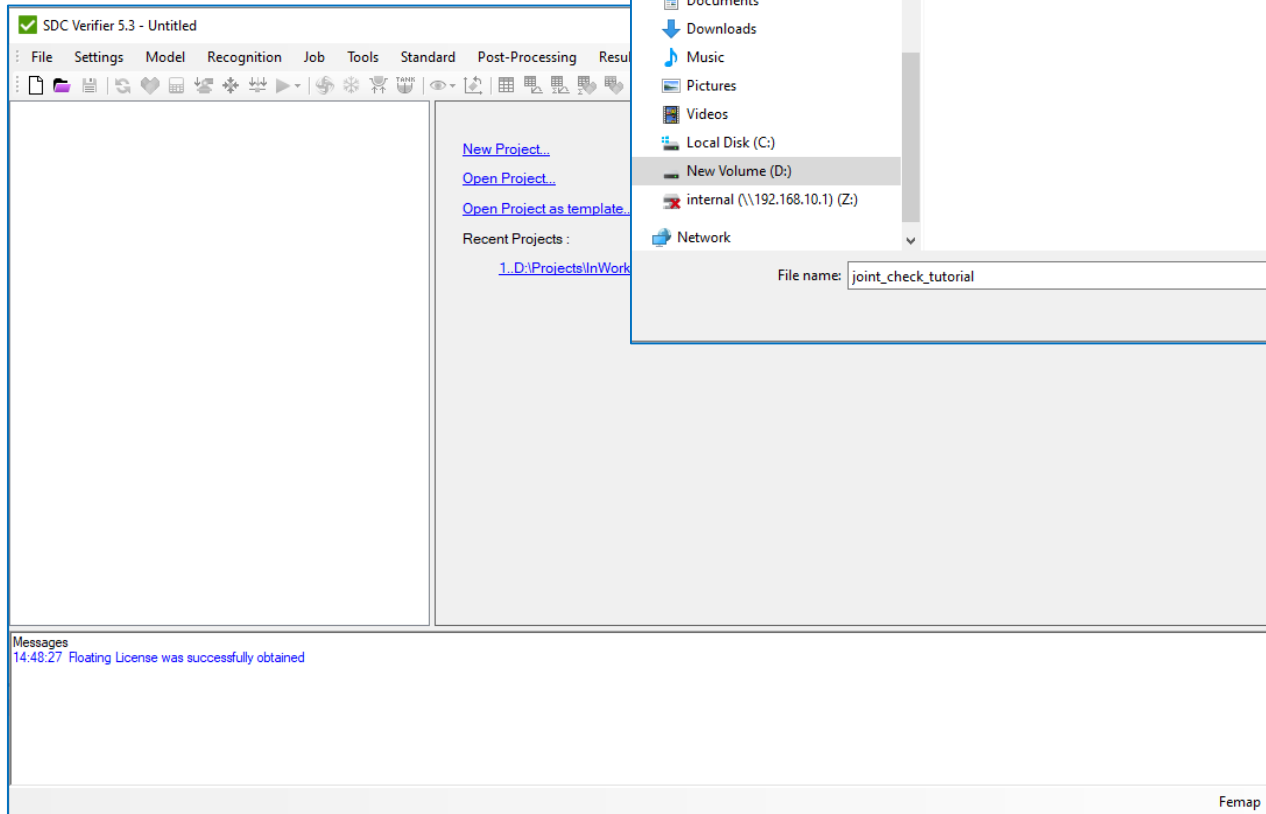
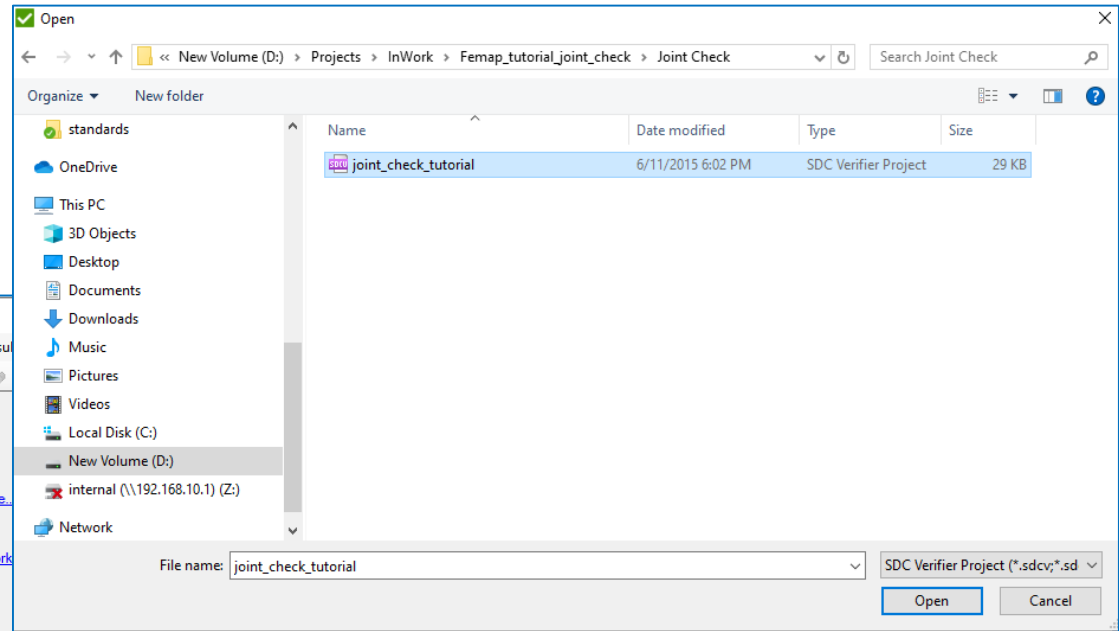
Launch **SDC Verifier** 

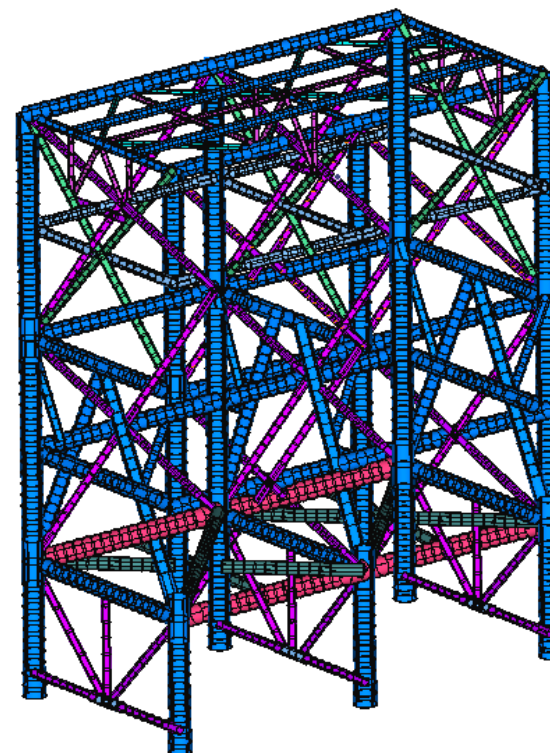
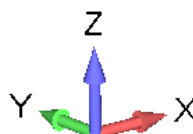
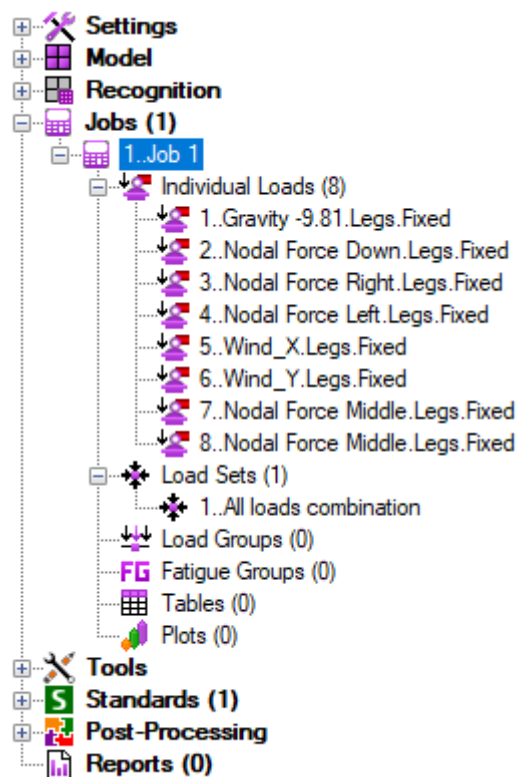
2

Execute *File - Open Project*.

3

Project: *joint_check_tutorial.sdcv*



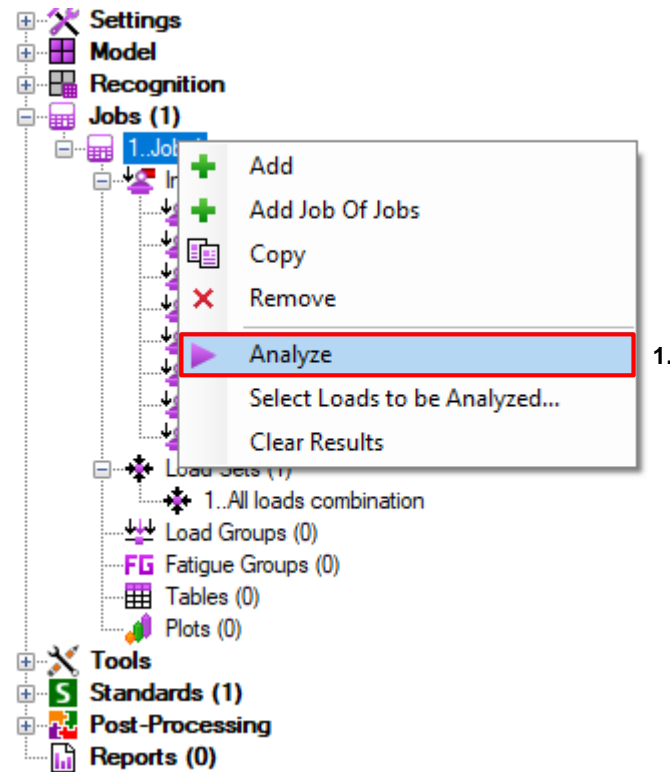


This tutorial uses project with predefined boundary conditions. The model contains only circular tube beams

Analyze Job

1

Execute  **Analyze** from *Job 1* context menu

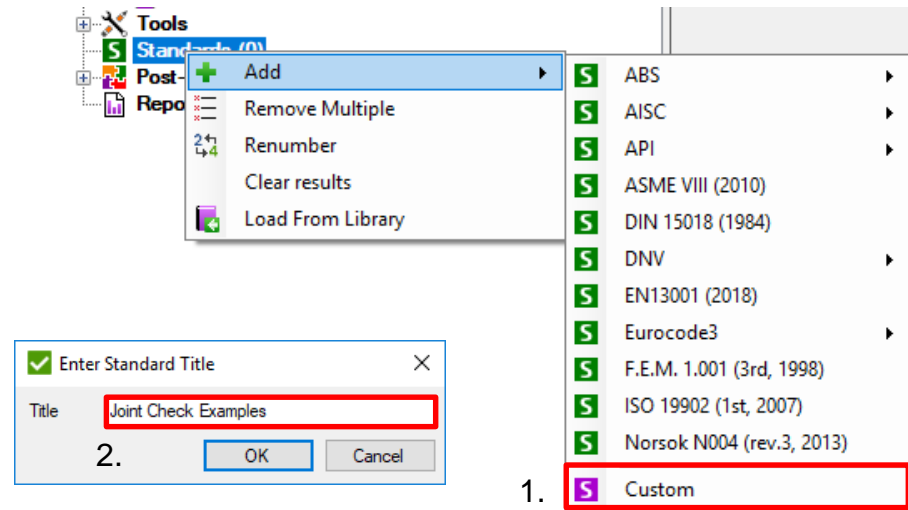


Joint Check API LRFD

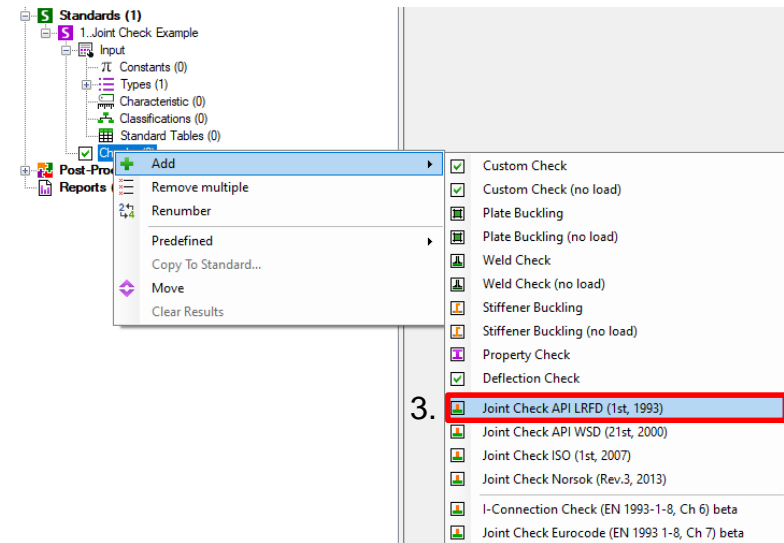
1 Execute **Standards->Add->Custom**

2 **Title:** Joint Check Examples. Press *OK*

3 Execute **Checks->Add-> Joint Check API LRFD (1st, 1993)**



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



Joint Check Settings

1

Press Find Connections to perform recognition.

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

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.

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.

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

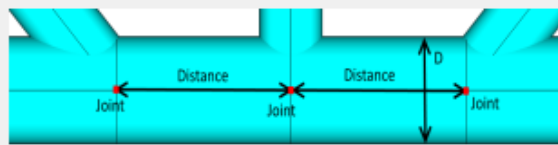
Forces tolerance. Maximum allowable difference between axial tension and compression forces that are perpendicular to the chord from the one side of the connection. If forces are balanced, all braces are considered to be K joint.

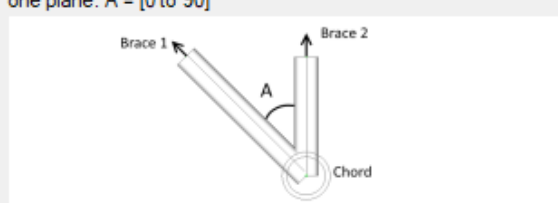
Calculate all braces as TY. Ignore all loading conditions and set all brace types to TY if turned on.

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

General
ID 1 Title Joint Check 1
Alias Check1
Description Tubular joints check according to API RP 2A

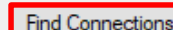
Joint nodes to be checked
Selection All Entities

Recognition settings
Maximum distance between joint nodes of one connection on the chord:
☒ Use D/4 (D - chord diameter)
☐ Custom distance 0.1


Angle between braces treated as in one plane: $A = [0 \text{ to } 90]$ 15


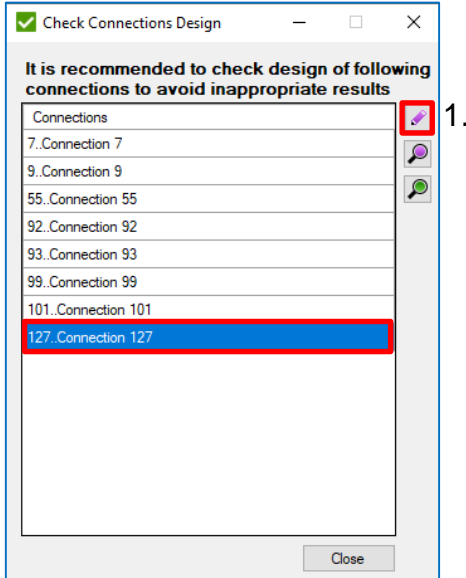
Chord maximum curvature angle [0 to 15] 3

Joint type recognition settings
Forces Tolerance, % 1
☐ Calculate all braces as TY

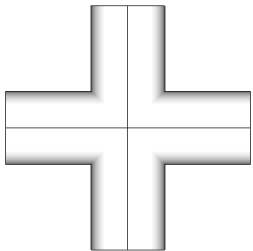


Connections design

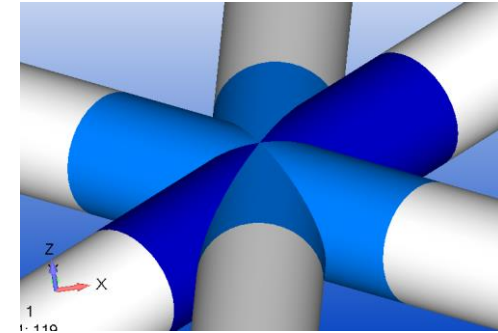
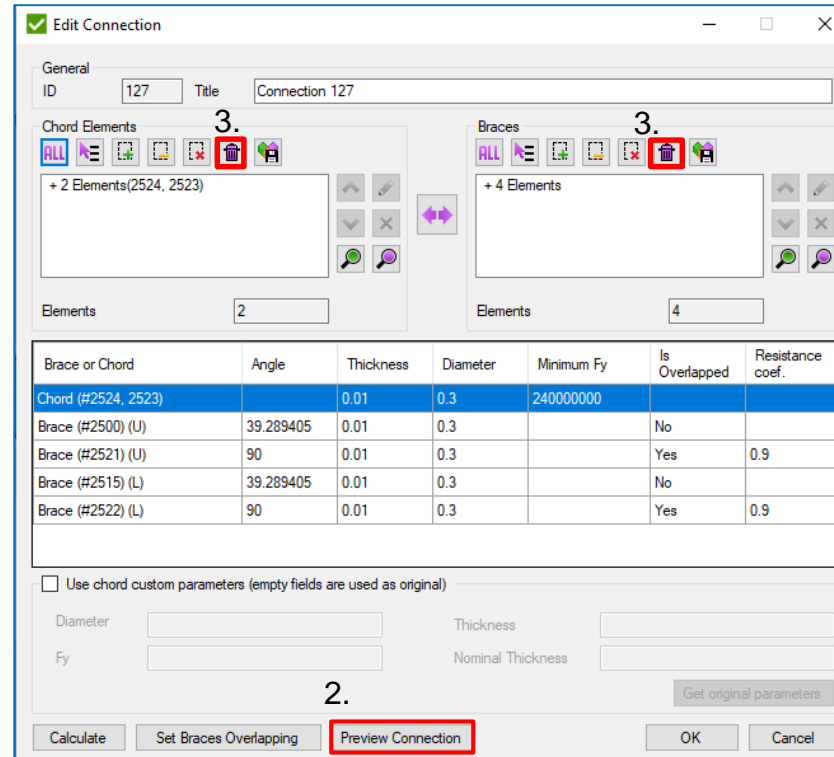
List of connections that are recommended to be checked:



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



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 127 and press *Edit* button.

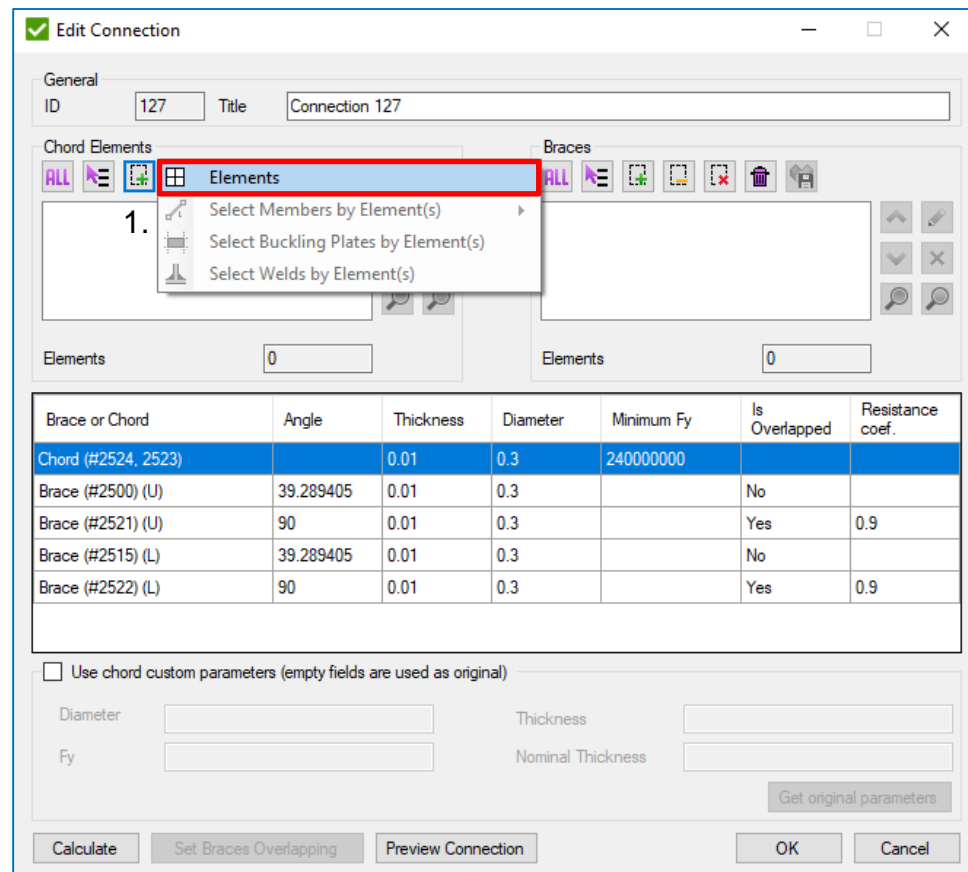
2

Press *Preview Connection*

3

Press *Remove all conditions in chord and braces selection*

- 2.



Connections design

1

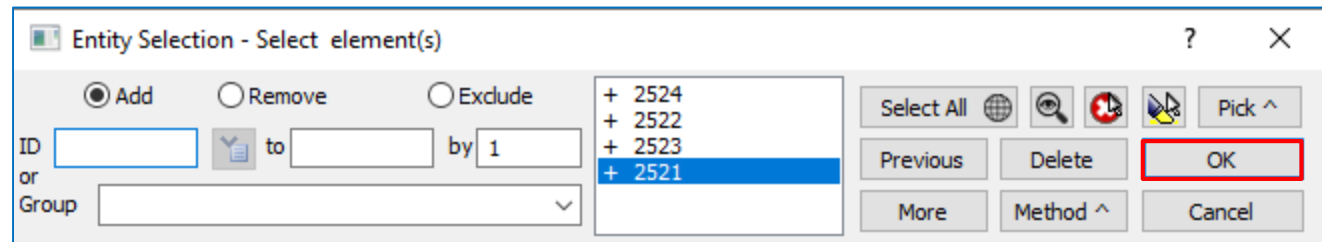
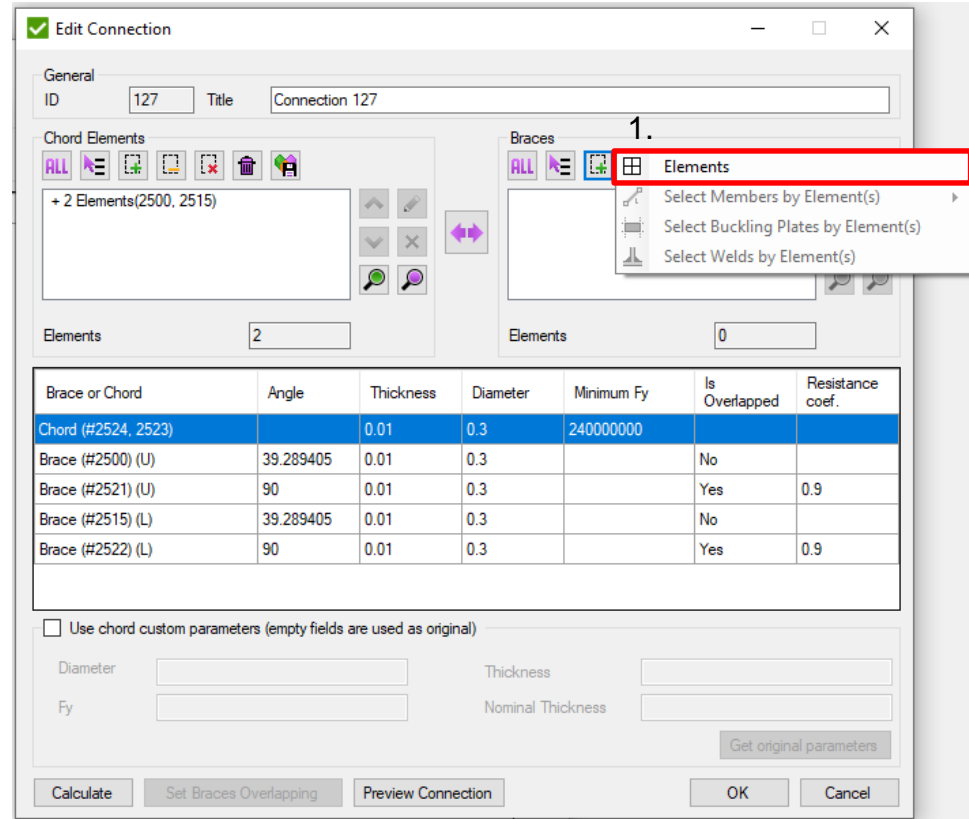
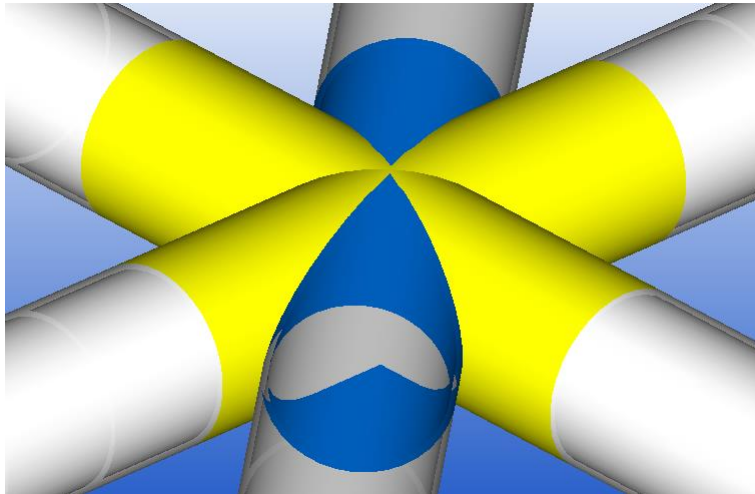
Press *Add entities using Femap* and execute *Elements*

2

Select *Element(s)* 2524, 2522, 2523, 2521.

3

Press *Ok*

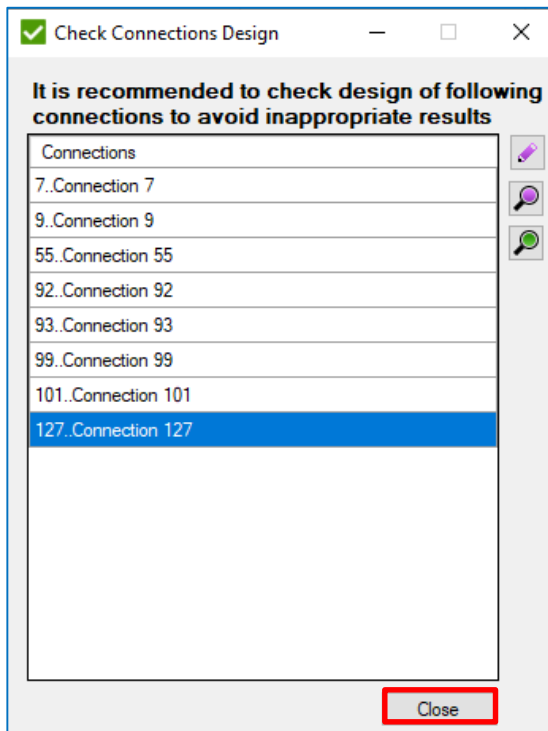


Connections design

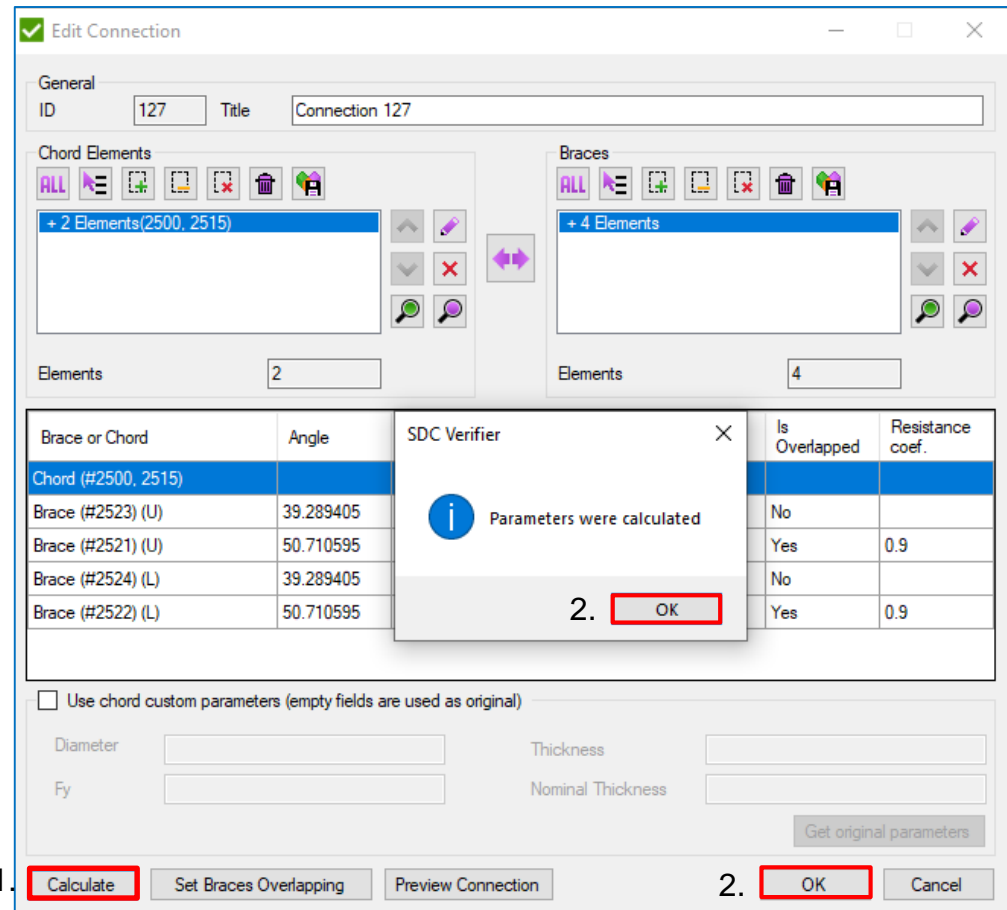
1 Press *Calculate*

2 Select *Ok* twice.

3 Press *Close*

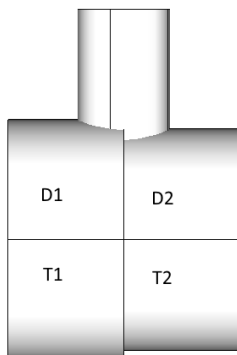


3.

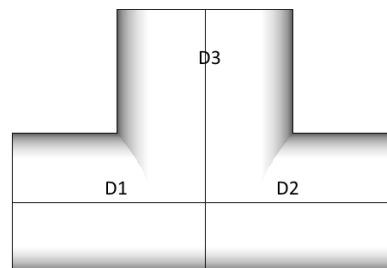


1.

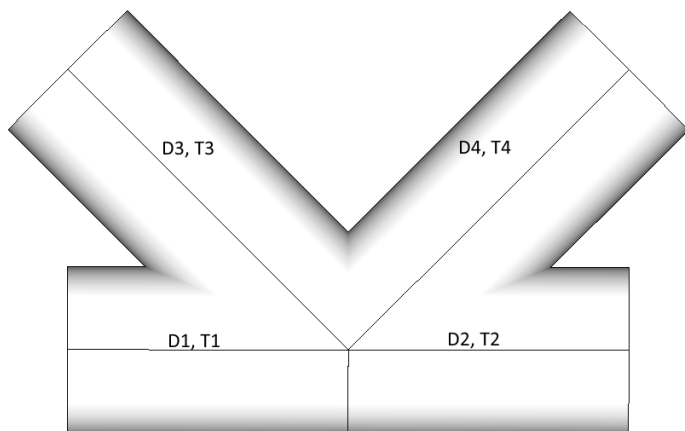
2.



When Chord is formed by elements with different properties around the joint node and $D1 \neq D2$, $D = \min(D1, D2)$; $T = \min(T1, T2)$ 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.

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.

Joint Check

General
 ID: 1 Title: Joint Check 1
 Alias: Check1
 Description: ck according to API RP 2A LRFD (1st, 1993)

Navigation
 Connection ID:

Joint nodes to be checked
 Selection: All Entities

Recognition settings
 Maximum distance between joint nodes of one connection on the chord:
☒ Use D/4 (D - chord diameter) ☐ Custom distance 0.1

Angle between braces treated as in one plane. $A = [0 \text{ to } 90]$ 15

Chord maximum curvature angle $[0 \text{ to } 15]$ 3

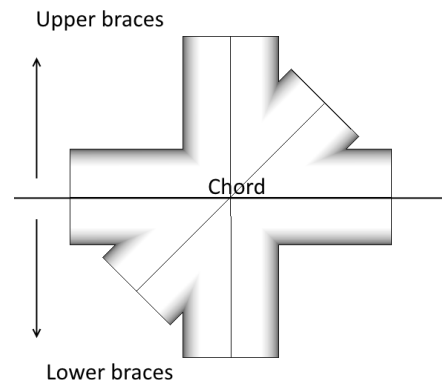
Joint type recognition settings
 Forces Tolerance, % 1

☐ Calculate all braces as TY

ID	Title	Brace or Chord	Angle	Thickness	Diameter	T > t	Is Overlapped	Resistance coef.
128	Connection 128	Chord (#1777, 1776)		0.02	0.252			
		Brace (#1772) (U)	45	0.01	0.2	Yes	No	
		Brace (#1775) (U)	45	0.01	0.2	Yes	Yes	0.9
		Brace (#1774) (L)	45	0.01	0.2	Yes	No	
129	Connection 129	Brace (#1773) (L)	45	0.01	0.2	Yes	Yes	0.9
		Chord (#1793, 1790)		0.019	0.382			
130	Connection 130	Brace (#1791) (U)	63.434954	0.012	0.342	Yes	No	
		Brace (#1792) (U)	63.434954	0.012	0.342	Yes	Yes	0.9
		Chord (#1796, 1794)		0.019	0.4			
131	Connection 131	Brace (#1798) (U)	63.434954	0.012	0.342	Yes	No	
		Brace (#1800) (U)	63.434954	0.011	0.228	Yes	Yes	0.9
		Brace (#1799) (L)	63.434954	0.012	0.342	Yes	No	
		Chord (#1797, 1795)		0.019	0.4			
132	Connection 132	Brace (#1801) (U)	63.434954	0.012	0.342	Yes	No	
		Brace (#1803) (L)	63.434954	0.011	0.228	Yes	Yes	0.9
		Brace (#1802) (L)	63.434954	0.012	0.342	Yes	No	
		Chord (#1805, 1804)		0.02	0.38			
133	Connection 133	Brace (#1806) (U)	45	0.007	0.13	Yes	No	
		Brace (#1808) (U)	90	0.008	0.15	Yes	No	
		Brace (#1807) (U)	45	0.007	0.13	Yes	No	
		Chord (#1810, 1809)		0.02	0.38			

Find Connections Clear Results Set Resistance Coefficients Overall table Set brace load transfer OK Cancel



Selection and recognition settings

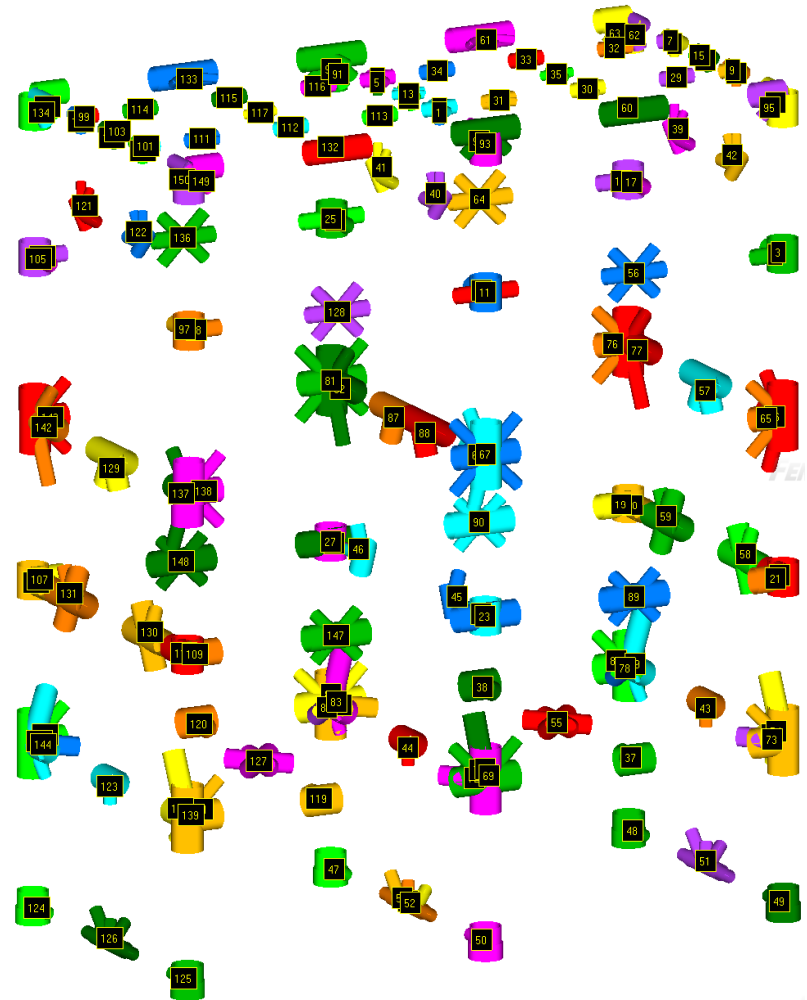


#1777,1776 – IDs of related elements in the model.
 (U) – Upper (0°-180°) braces
 (L) – Lower (180°-360°) braces

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

139	Connection 139								
140	Connection 140								
141	Connection 141								
142	Connection 142								
143	Connection 143								
144	Connection 144								
145	Connection 145								
146	Connection 146								
147	Connection 147								
148	Connection 148								
149	Connection 149								
150	Connection 150								

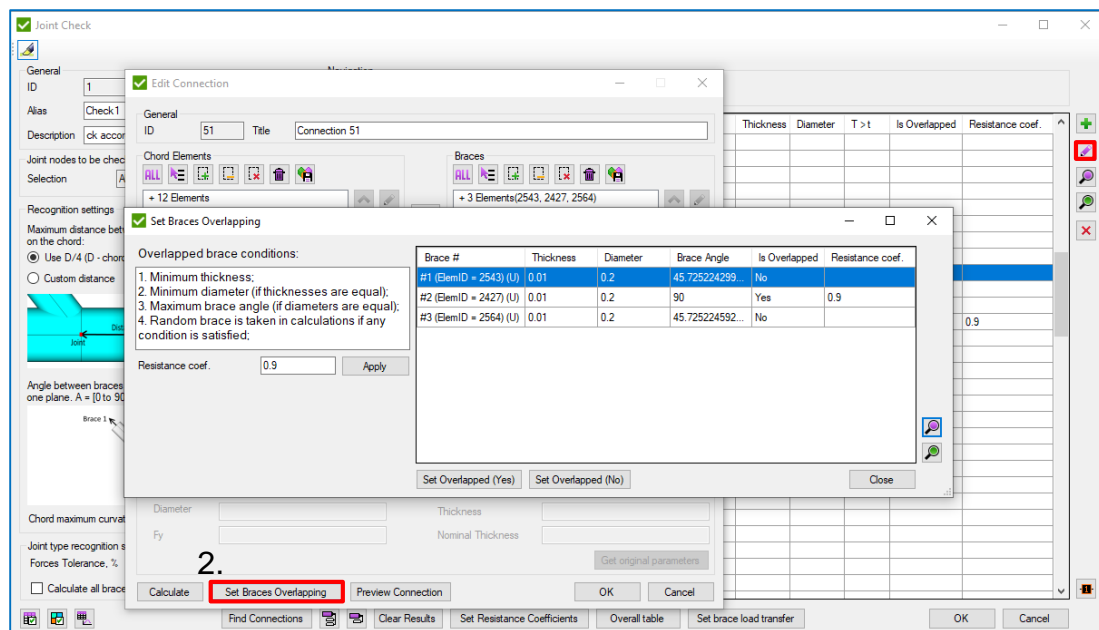


Joint Check API LRFD

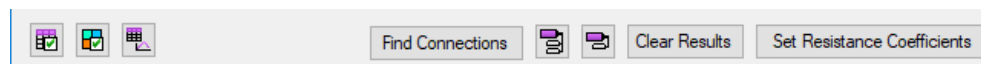
Resistance coefficient depends on the strength of welding and is used in calculations of overlapping (Section E.3.2 API 2A RP LRFD). **Table J 2.5** is taken from **Load and resistance factor design specification for structural steel buildings December, 27 1999 (AISC)**. Default value is 0.9. It can 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]. Filler metal with a strength level equal to or less than matching filler metal is permitted to be used.
Compression normal to effective area	Base	0.90	F_y	
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	$\left\{ \begin{array}{l} f \\ 0.75 \end{array} \right.$	$\left\{ \begin{array}{l} f \\ 0.60F_{EXX} \end{array} \right.$	
Tension normal to effective area	Base Weld	0.90 0.80	F_y $0.60F_{EXX}$	
Fillet Welds				
Shear on effective area	Base Weld	$\left\{ \begin{array}{l} f \\ 0.75 \end{array} \right.$	$\left\{ \begin{array}{l} f \\ 0.60F_{EXX} [g] \end{array} \right.$	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	$\left\{ \begin{array}{l} f \\ 0.75 \end{array} \right.$	$\left\{ \begin{array}{l} f \\ 0.60F_{EXX} \end{array} \right.$	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:



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

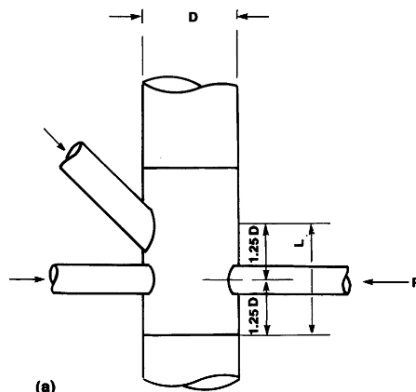
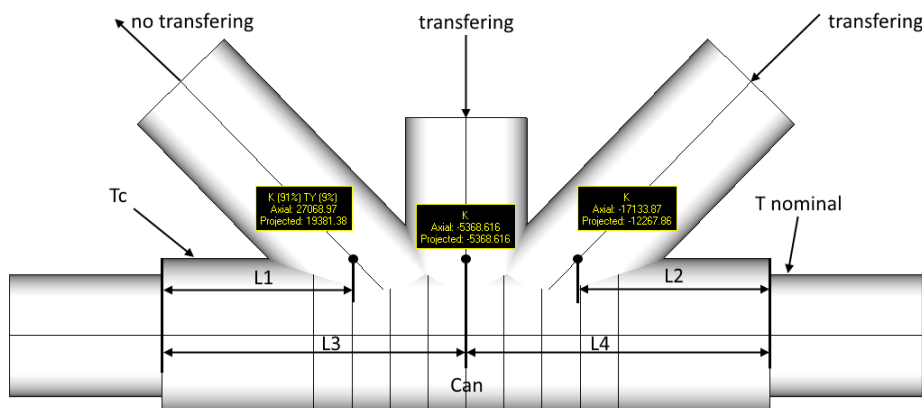


FIG. E.3-6
DEFINITION OF EFFECTIVE CORD LENGTH



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. $L1, L2 \leq 1.25D$. If $L1$ and $L2$ exceed $1.25D$ distance, can will not be recognized.

$T_c \geq T$ 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; $T_c = 0.02$;

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

Set Resistance Coefficients

Overall table

Set brace load transfer

Set braces load transfer

Connection ID	Brace #	Is Load Transfer	Effective Length
51	#01(Elem ID = 2543)	Yes	0.6293
	#11(Elem ID = 2427)	Yes	1
	#21(Elem ID = 2564)	Yes	0.6293
52	#01(Elem ID = 2442)	Yes	0.2732
53	#01(Elem ID = 2422)	Yes	0.2732
54	#01(Elem ID = 2426)	Yes	1
126	#01(Elem ID = 2554)	Yes	0.6293
	#11(Elem ID = 2425)	Yes	1
	#21(Elem ID = 2541)	Yes	0.6293

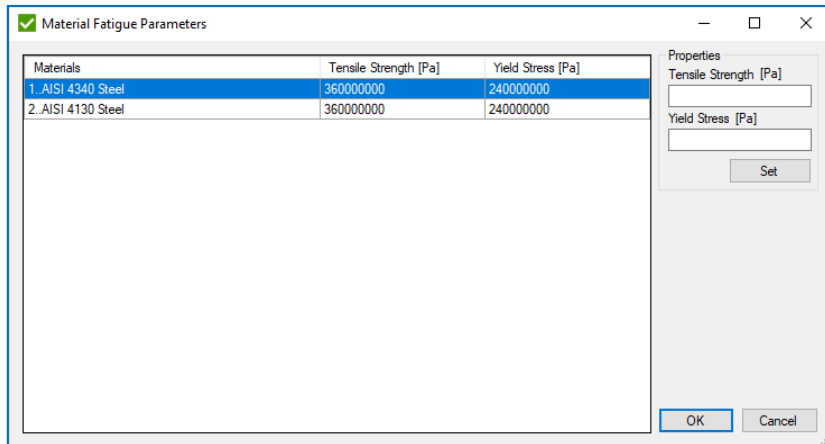
Is Load Transfer Yes

Effective Length

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:



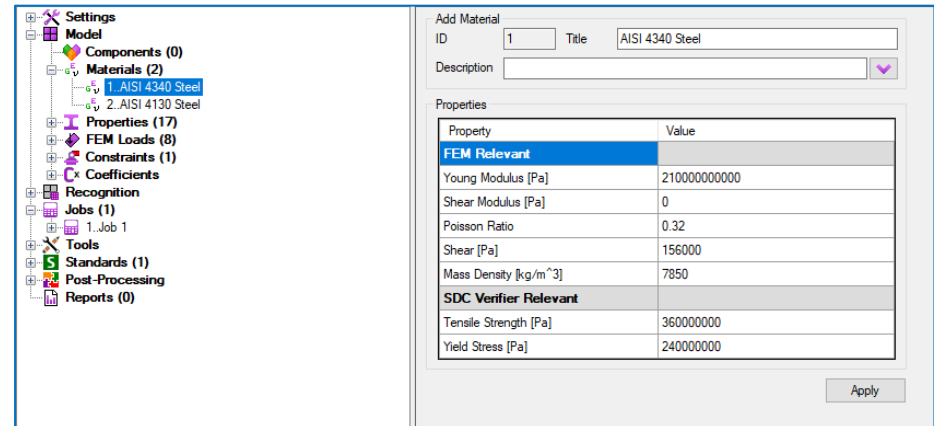
The dialog box titled "Material Fatigue Parameters" contains a table with two columns: "Materials" and "Properties". The "Materials" column lists "1. AISI 4340 Steel" and "2. AISI 4130 Steel". The "Properties" column has two sub-columns: "Tensile Strength [Pa]" and "Yield Stress [Pa]". The values for both materials are "360000000" for Tensile Strength and "240000000" for Yield Stress. There are "OK" and "Cancel" buttons at the bottom right.

Materials	Tensile Strength [Pa]	Yield Stress [Pa]
1. AISI 4340 Steel	360000000	240000000
2. AISI 4130 Steel	360000000	240000000

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.




The Main Window shows a tree view on the left with "Materials (2)" selected. The right panel has an "Add Material" section with "ID" 1 and "Title" "AISI 4340 Steel". Below is a "Properties" table with two sections: "FEM Relevant" and "SDC Verifier Relevant". The "FEM Relevant" section includes Young Modulus [Pa] (210000000000), Shear Modulus [Pa] (0), Poisson Ratio (0.32), and Shear [Pa] (156000). The "SDC Verifier Relevant" section includes Mass Density [kg/m^3] (7850), Tensile Strength [Pa] (360000000), and Yield Stress [Pa] (240000000). An "Apply" button is at the bottom right.

Property	Value
FEM Relevant	
Young Modulus [Pa]	210000000000
Shear Modulus [Pa]	0
Poisson Ratio	0.32
Shear [Pa]	156000
Mass Density [kg/m^3]	7850
SDC Verifier Relevant	
Tensile Strength [Pa]	360000000
Yield Stress [Pa]	240000000

Joint Check Expand Table

1

Press  to Add Expand table. Detailed table of results for each brace

2

Load Set: **1..All loads combination**

3

Filter by parameter : **Overall Utilization Factor**
Sort by parameter : **Overall Utilization Factor**

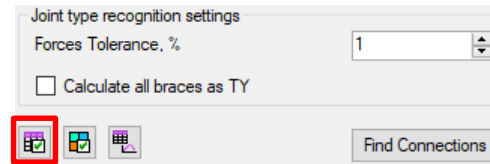
4

Press **Fill Table**

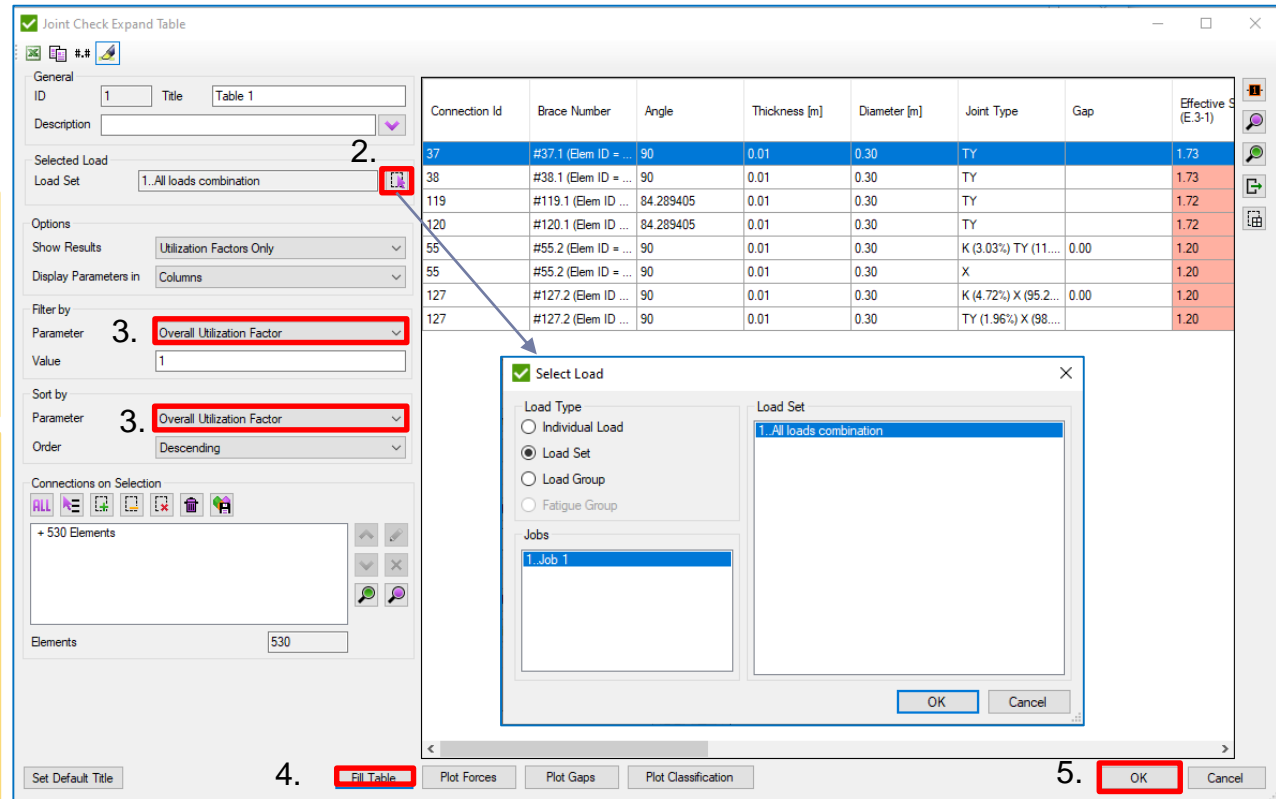
5

Press **OK**

1.



2.



4.

5.

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.

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.

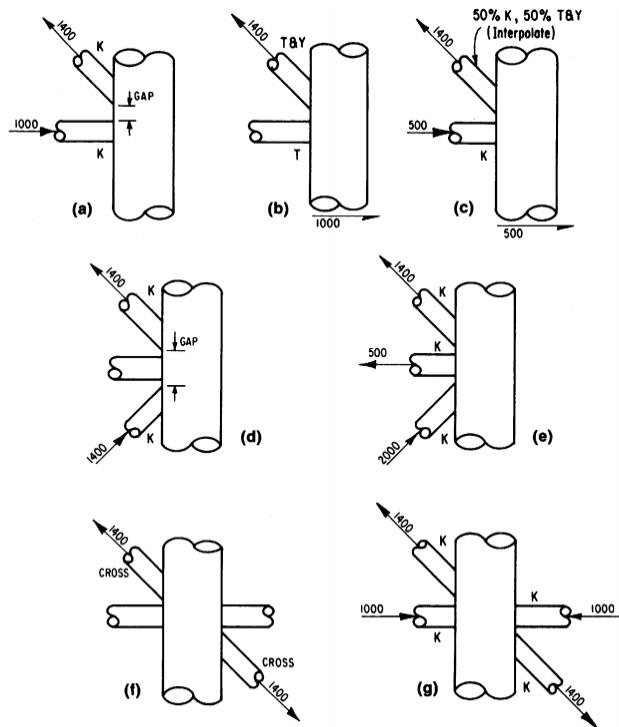
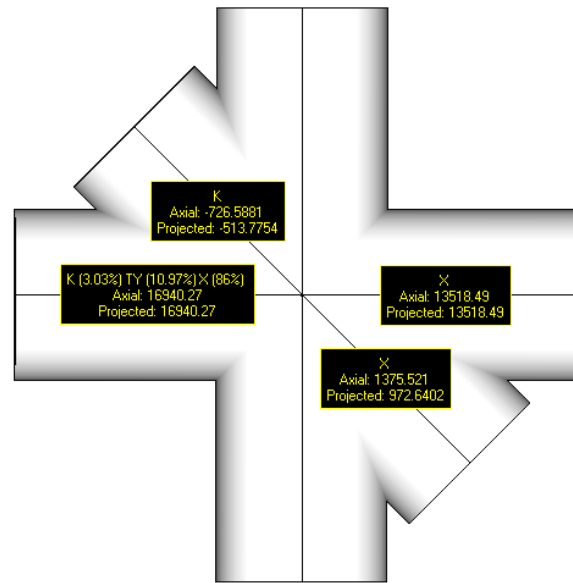


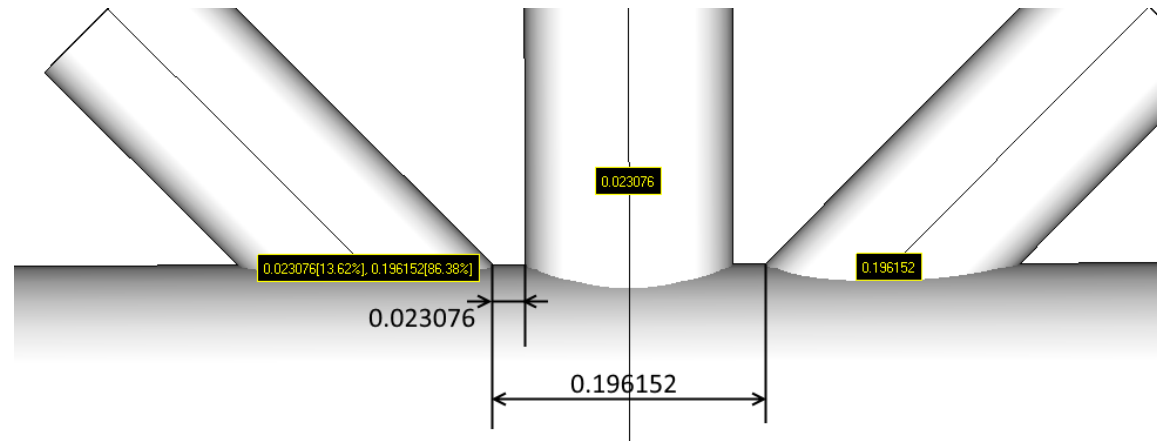
FIG. E.3-2
EXAMPLES OF JOINT CLASSIFICATION



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.



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 consider. Each gap percentage depends on the percentage of taken load:


$$percentage = \begin{cases} \frac{projected}{F_{Compression}}, & projected < 0 \\ \frac{projected}{F_{Tension}}, & projected \geq 0 \end{cases}$$

Projected – axial force of the brace, perpendicular to the chord;

F_{Tension} – sum of all positive projected axial forces;

F_{Compression} – sum of all negative projected forces;

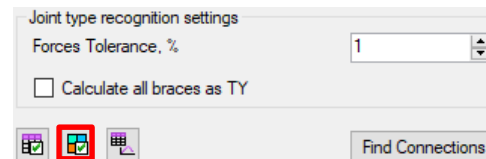
Joint Check Criteria Plot

1 Press  to Add Criteria plot

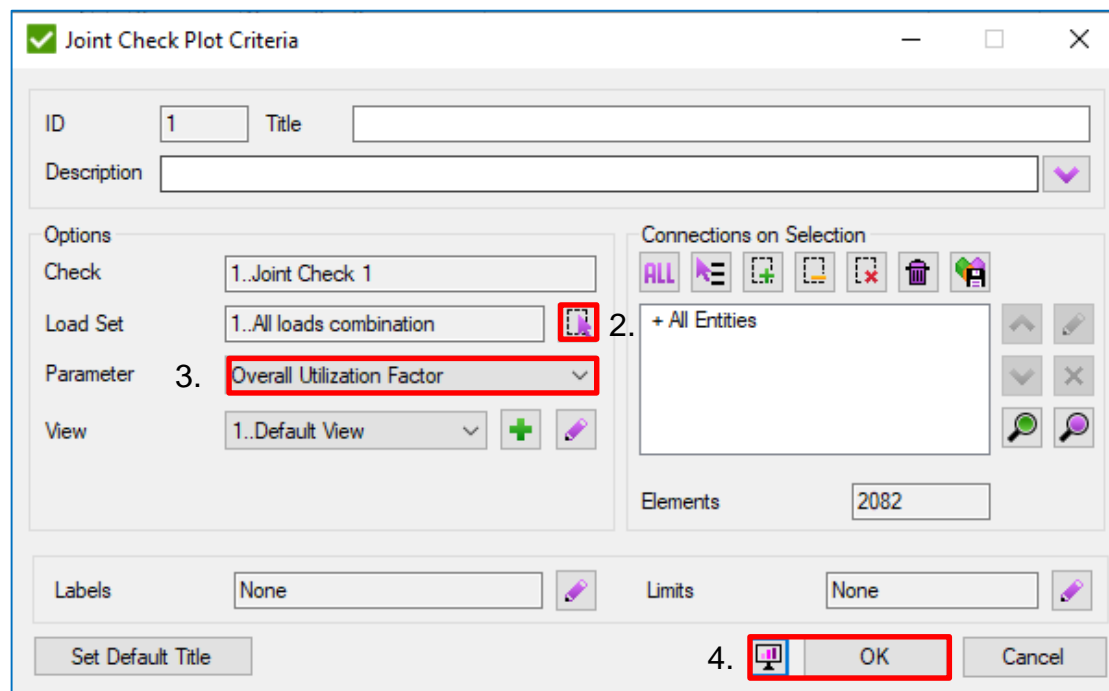
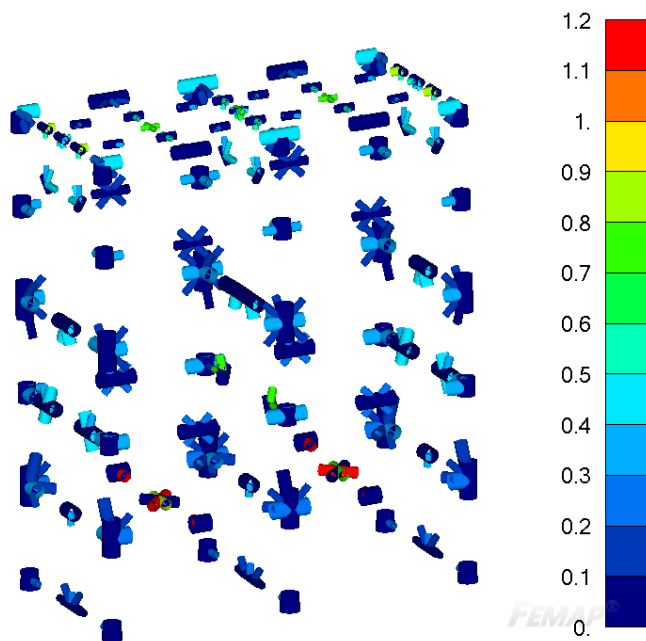
2 Load Set: **1..All loads combination**

3 Parameter : **Overall Utilization Factor**

4 Press  Preview. Press OK



1.



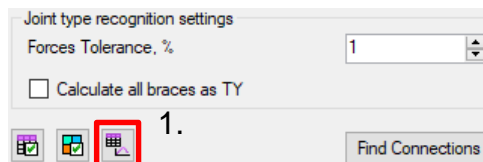
Joint Check Expand Flow Table

1 Press  to Add Expand Flow Table

2 Select all Load Sets

3 Press *Fill Table*

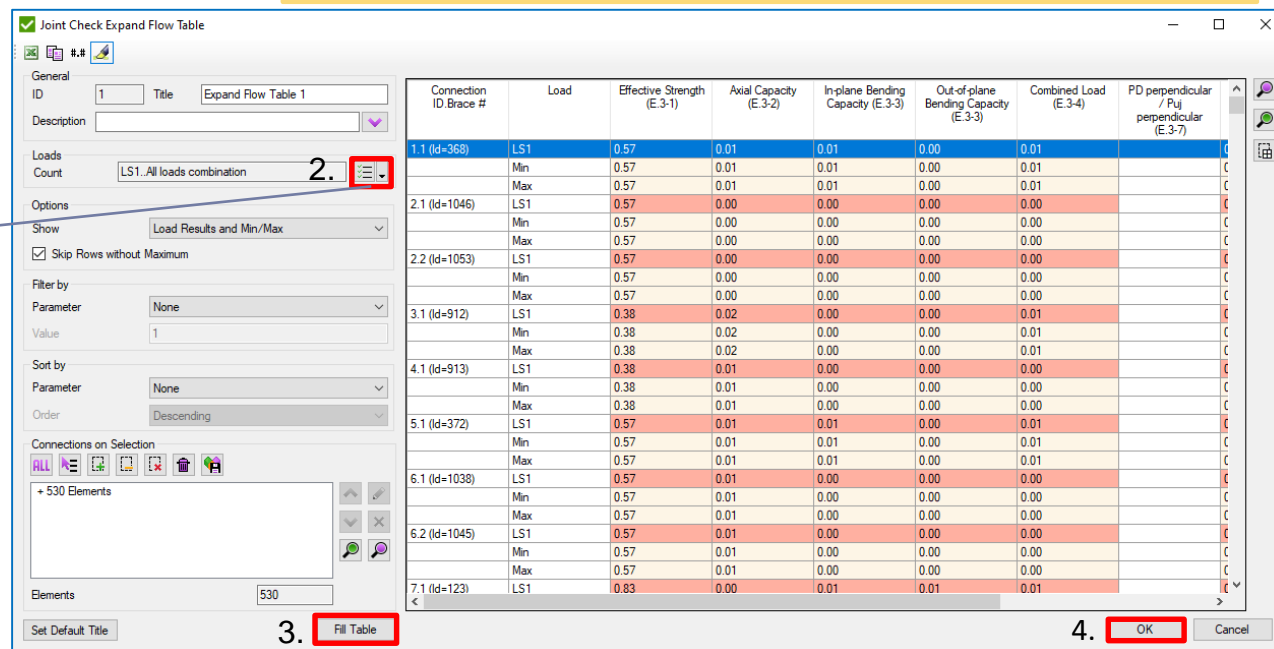
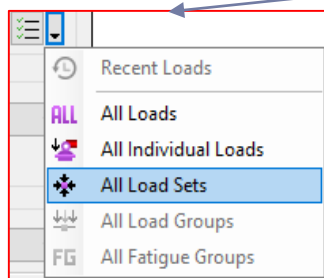
4 Press *OK*



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




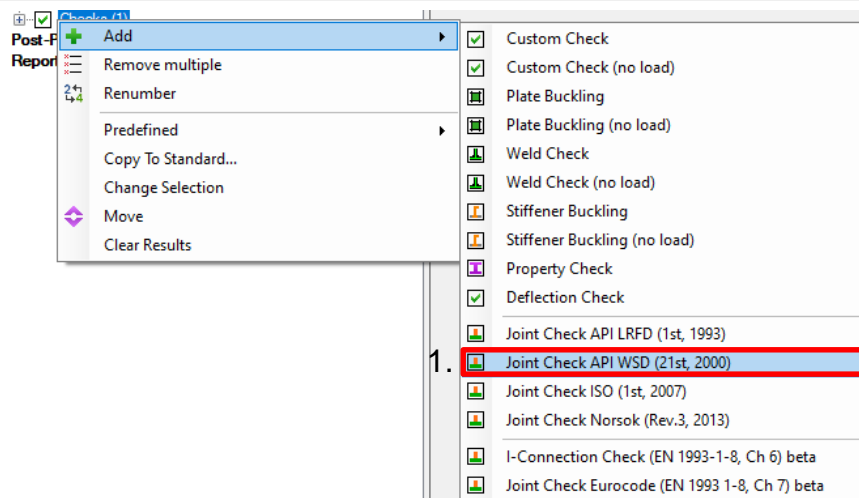
Joint Check API WSD

Joint Check API WSD interface is similar to Joint Check API LRFD.

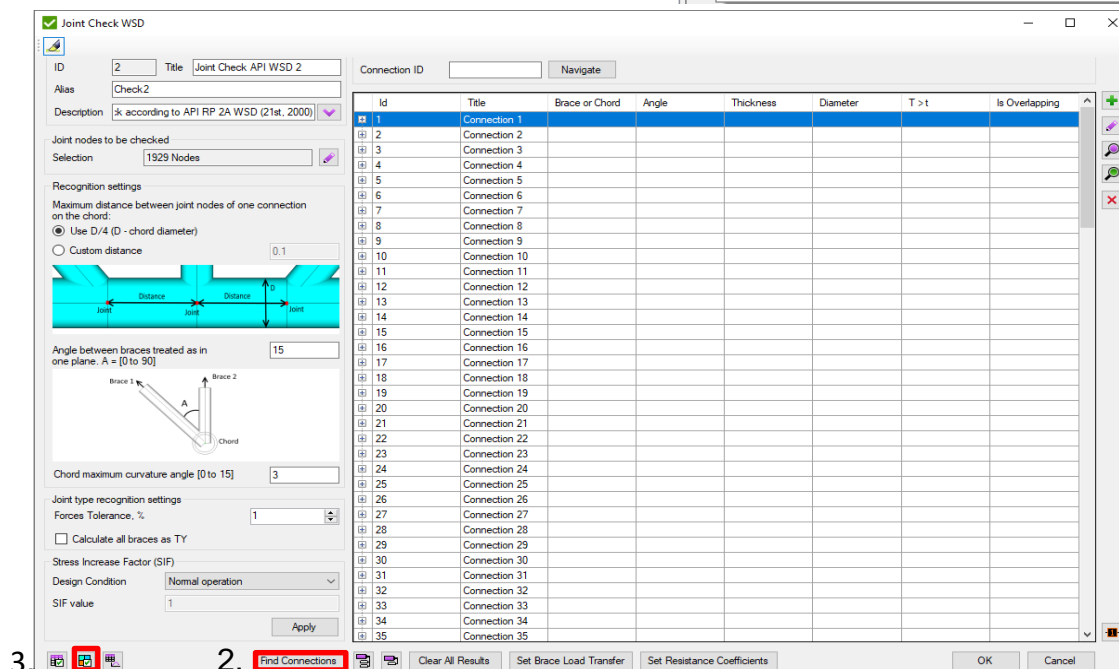
1. Execute **Checks->Add->Joint Check API WSD**

2. Press *Find Connections*

3. Press  to Add Criteria plot



Joint Check API WSD is a part of the standard **API RP 2A WSD (21st, published 2000)**

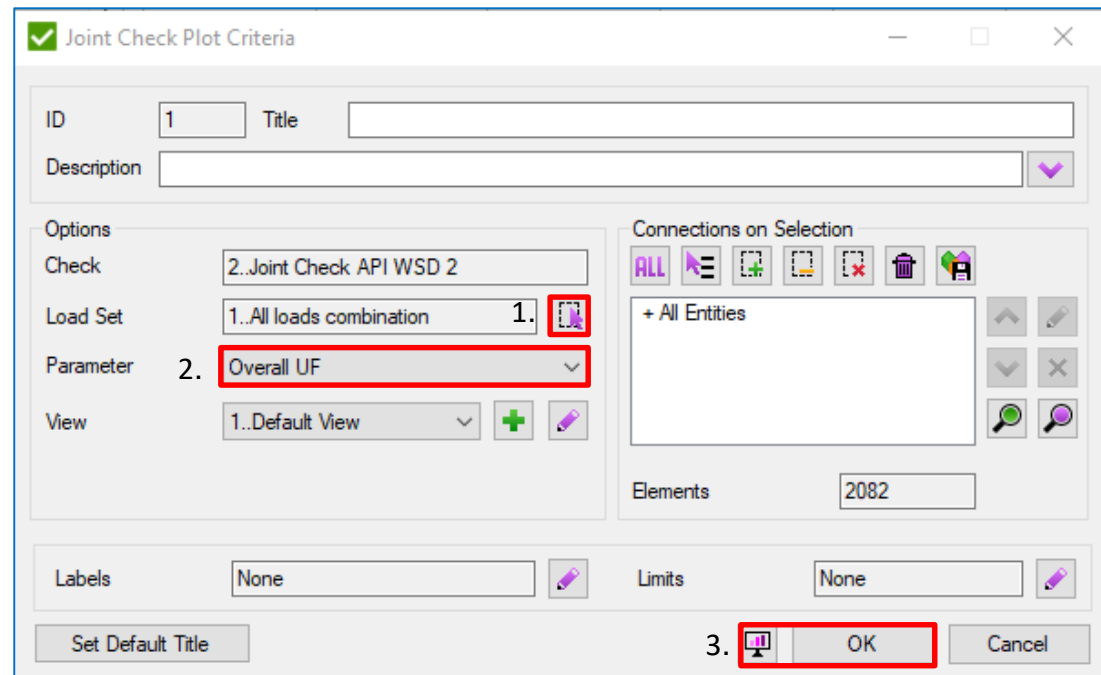
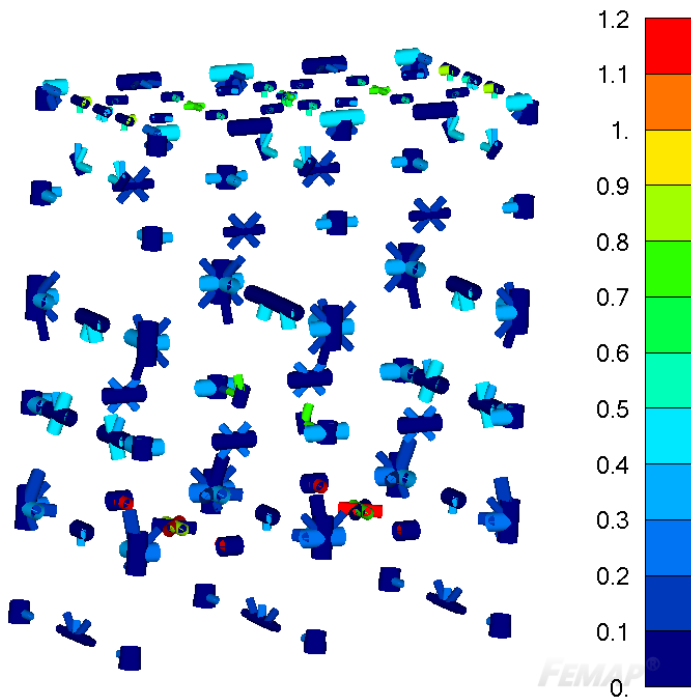


Joint Check API WSD

1 Load Set: **1..All loads combination**

2 Parameter : **Overall UF**

3 Press  *Preview*. Press *OK*




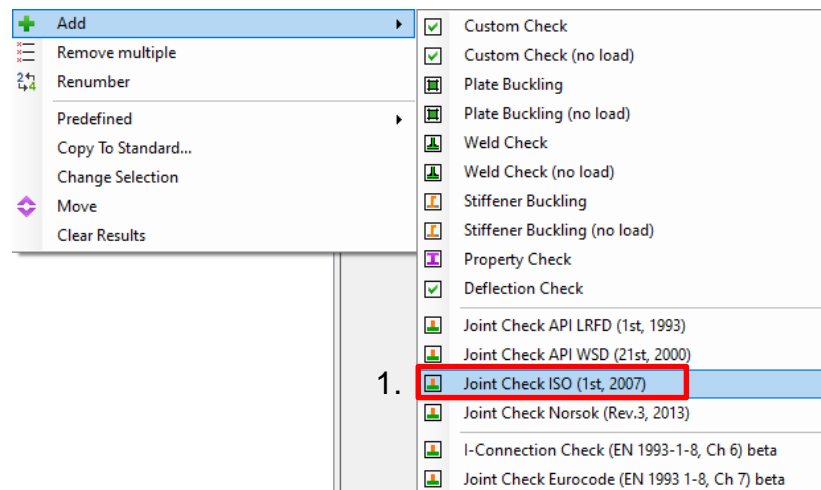
Joint Check ISO

Joint Check ISO interface is similar to Joint Check API.

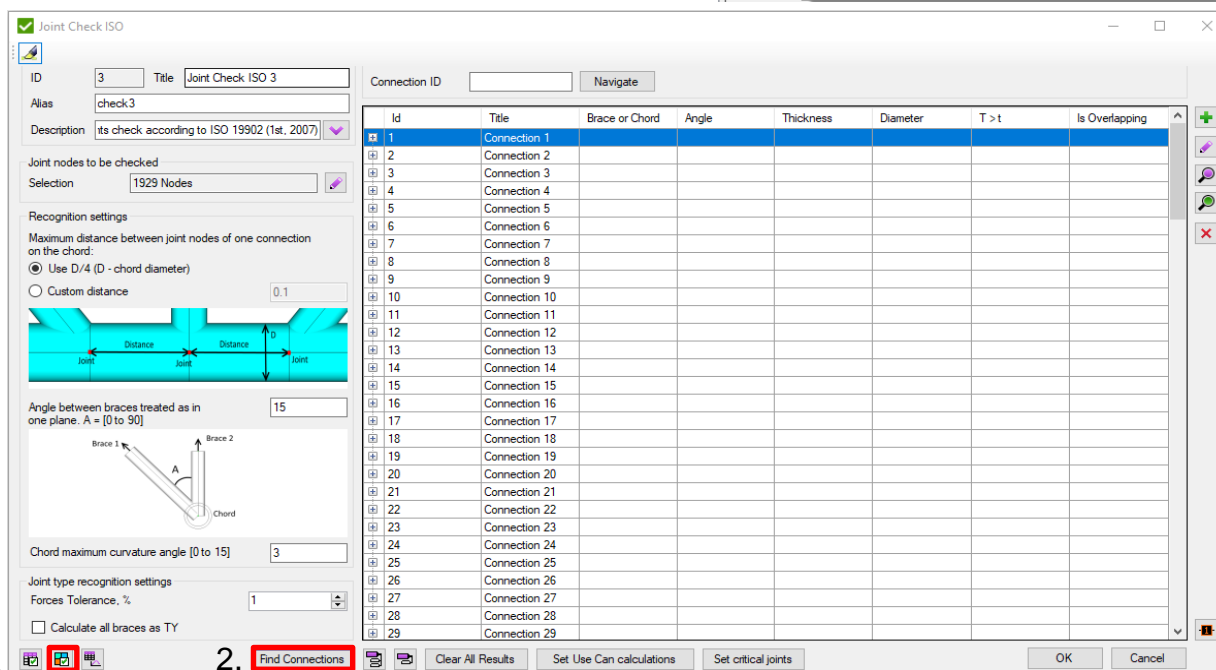
1. Execute **Checks->Add->Joint Check ISO**

2. Press *Find Connections*

3. Press  to Add Criteria plot



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

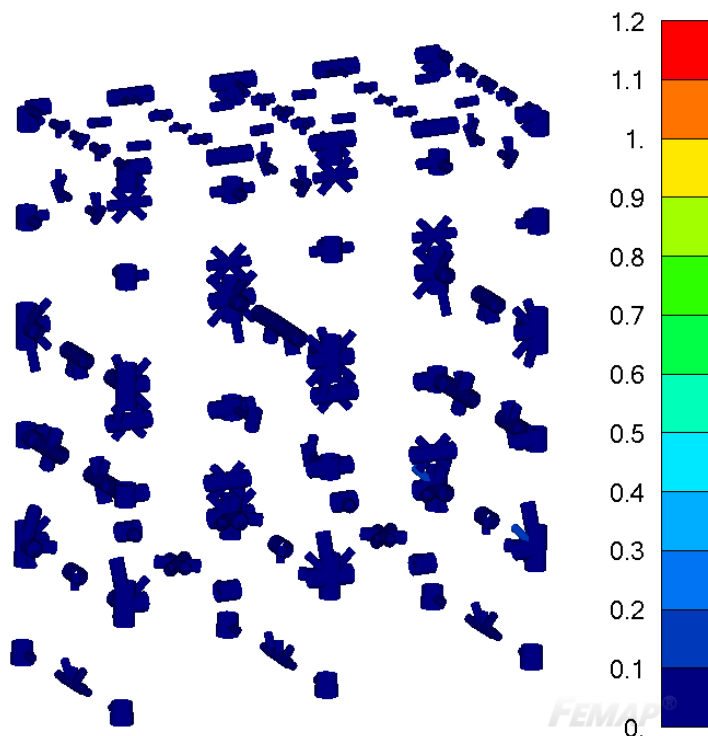


Joint Check ISO

1 Load Set: **1..All loads combination**

2 Parameter : **Overall Utilization Factor**

3 Press  Preview. Press OK




Joint Check Plot Criteria

ID: 1 Title:

Description:

Options

Check: 3..Joint Check ISO 3

Load Set: 1..All loads combination 1. 

Parameter: 2. Overall Utilization Factor

View: 1..Default View + -

Connections on Selection


+ All Entities

Elements: 2082

Labels: None

Limits: None

Set Default Title


3.  OK Cancel

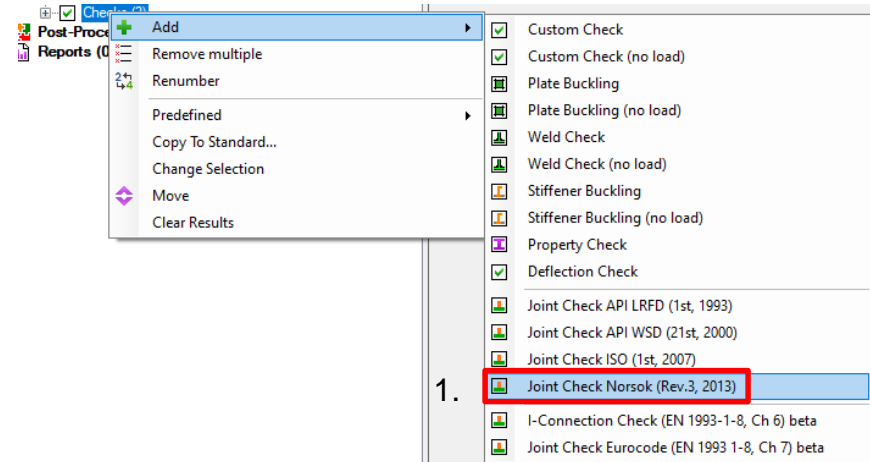
Joint Check Norsok

Joint Check Norsok interface is similar to Joint Check API

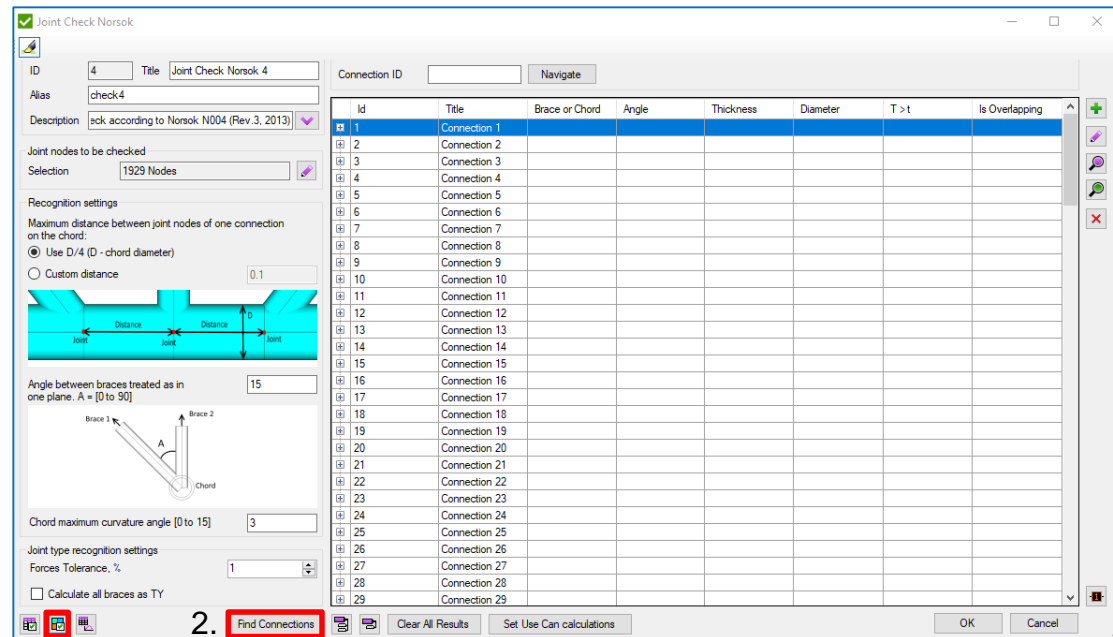
1. Execute **Checks->Add->Joint Check Norsok**

2. Press *Find Connections*

3. Press  to Add Criteria plot



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



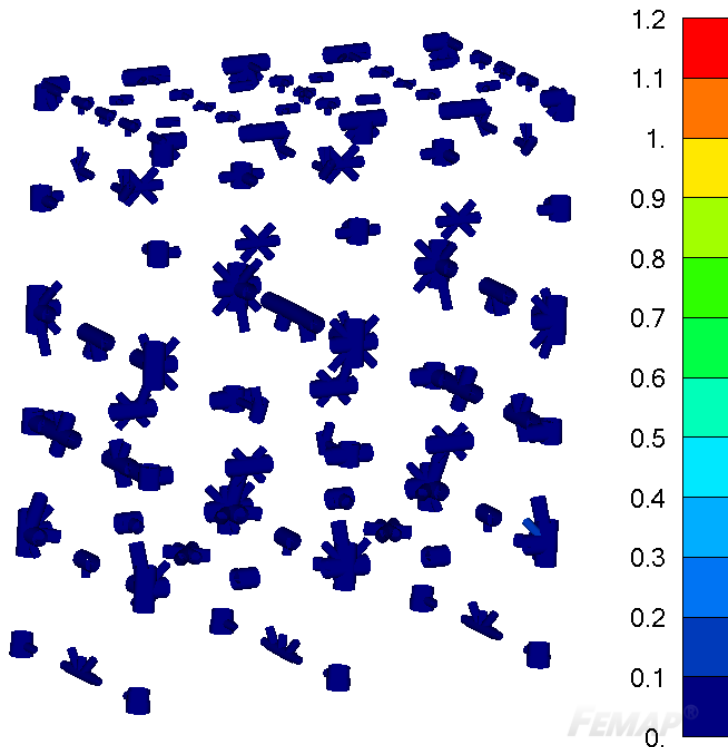
3.

Joint Check Norsok

1 Load Set: **1..All loads combination**

2 Parameter : **Overall Utilization Factor**

3 Press  Preview. Press OK




Joint Check Plot Criteria



ID: 1 Title: Description:

Options

Check: 4..Joint Check Norsok 4

Load Set: 1..All loads combination 1. 



Parameter: 2. Overall Utilization Factor

View: 1..Default View  


Connections on Selection

+ All Entities

Elements: 2082

Labels: None  Limits: None 

Set Default Title

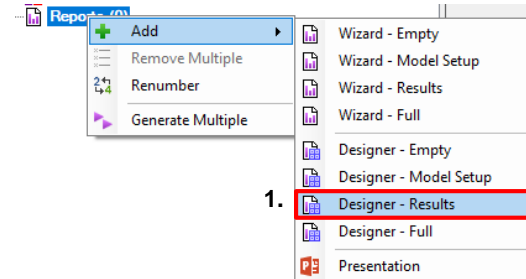
3.  OK Cancel

1

Execute *Add* => *Designer - Results* from *Report* context menu.

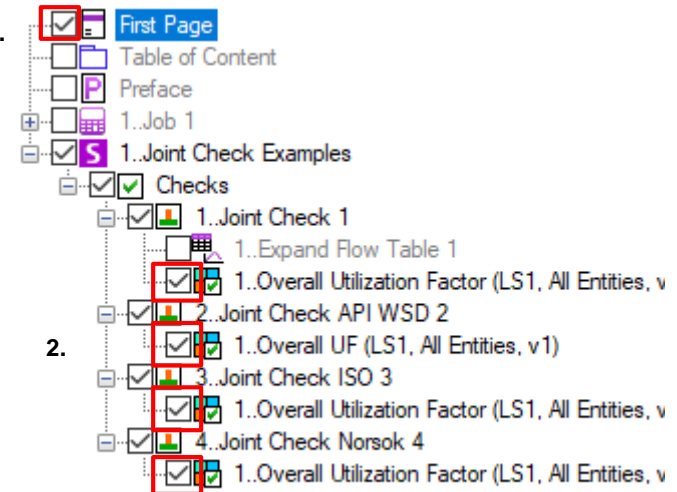
2

Include only First Page and Criteria Plots in the all Joint Checks



1.

2.



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;

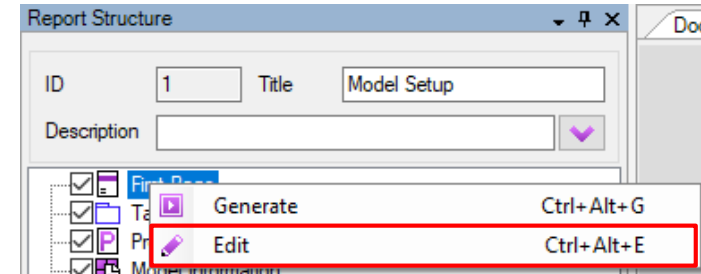
Results – for each load extreme displacement tables, stress and displacement plots are included. Predefined tables: sum of reaction forces, stresses/displacements summary tables. In addition all standards are included with a set of tables/plots created in the project;

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

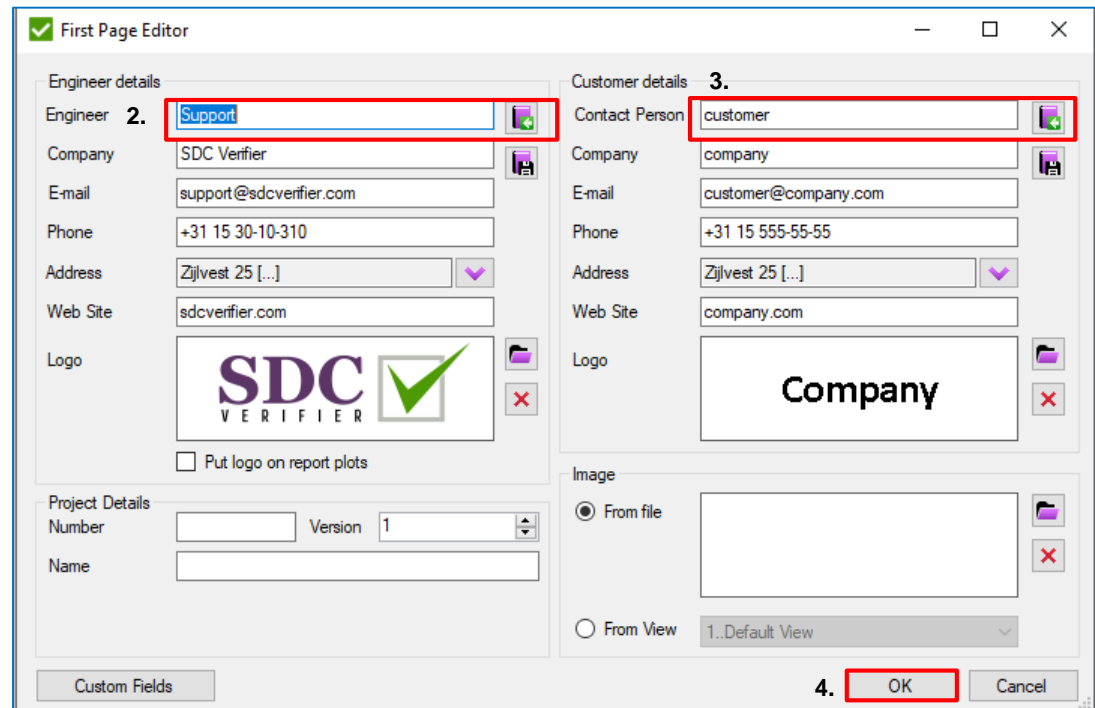
Report. First Page

- 1 Execute *Edit* from First Page context menu
- 2 Press  and select Support Engineer from the library
- 3 Press  and select Customer from the library
- 4 Press *OK*.

For an engineer and customer the default data from the library is used. It is possible to fill in your data and store it to the library  and reuse it in future projects.





1.



First Page Editor


Engineer details

Engineer 2. Support 



Company SDC Verifier 

E-mail support@sdcverifier.com

Phone +31 15 30-10-310

Address Zijlvest 25 [...] 

Web Site sdcverifier.com

Logo  


☐ Put logo on report plots


Project Details

Number Version 1

Name


Customer details 3.

Contact Person customer 



Company company 

E-mail customer@company.com


Phone +31 15 555-55-55


Address Zijlvest 25 [...] 

Web Site company.com

Logo  


Image


☒ From file 

☐ From View 1..Default View 

4. **OK** Cancel

Report exported to Microsoft Word

Press  to generate complete report.

Press  to export to Word.



Report

Prepared by:
SDC Verifier
+31 15 30-10-310
sdoverifier.com
Zijlvest 25
2011 VB Haarlem
The Netherlands

Prepared for:
company
+31 15 555-55-55
company.com
Zijlvest 25
2011 VB Haarlem
The Netherlands

Engineer:
Customer:
Project Number:
Version:
Date:

Support
customer
1
18/01/2020

First page

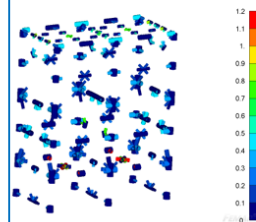
2...Joint Check API WSD 2

Page 3 of 6

Checks

This paragraph contains checks descriptions with their results.

1..Joint Check 1



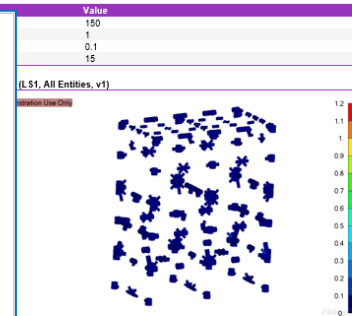
Load Set Selection
LS1..All loads combination
All Entities

Joint Check API
LRFD

SDC Verifier Prepared for company Company

3..Joint Check ISO 3

Page 4 of 6



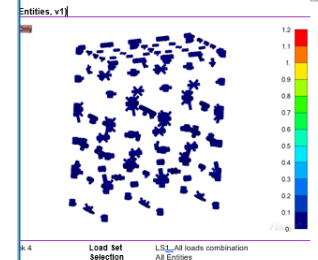
Check ISO 3
Load Set Selection
LS1..All loads combination
All Entities

Joint Check ISO

Prepared by SDC Verifier Prepared for company Company

4..Joint Check Norsok 4

Page 6 of 6



Load Set Selection
LS1..All loads combination
All Entities

Joint Check Norsok

SDC Verifier Prepared for company Company