TUTORIAL
SCAFFOLDING COUPLERS

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Introduction

SCIA Engineer enables you to design and check scaffold structures. The software provides are library with couplers according to the scaffold code and couplers of manufacturers. In that way you can quickly select the desired coupler type and use them into your projects. In case you need to work with couplers which are not present in the SCIA library, you can quickly create them by yourself, store them in a user library and add them to your projects.

After calculating the project you can perform checks on the couplers and have a look at brief or detailed output.

This tutorial will explain:
- Couplers – general principle;
- Couplers of manufacturers in SCIA Engineer;
- Add couplers to the library;
- Coupler checks.

Couplers in SCIA Engineer

SCIA Engineer contains couplers with rigidities and maximal forces from the code and manufacturer couplers with rigidities and maximal forces based on validation documents (e.g. Zulassung). You can quickly select and use the desired coupler type with automatically the correct maximal forces and nonlinear functions attached to it.

This chapter also illustrates the background of the maximal forces and the nonlinear functions.

When you need a coupler type which is not present in the SCIA library, you can quickly create it by yourself and add it to the library.

Couplers – general principle

Various couplers types are available in SCIA Engineer. For the different couplers, go to **Menu bar > Libraries** > **Structure and analysis** > **Hinge type**.
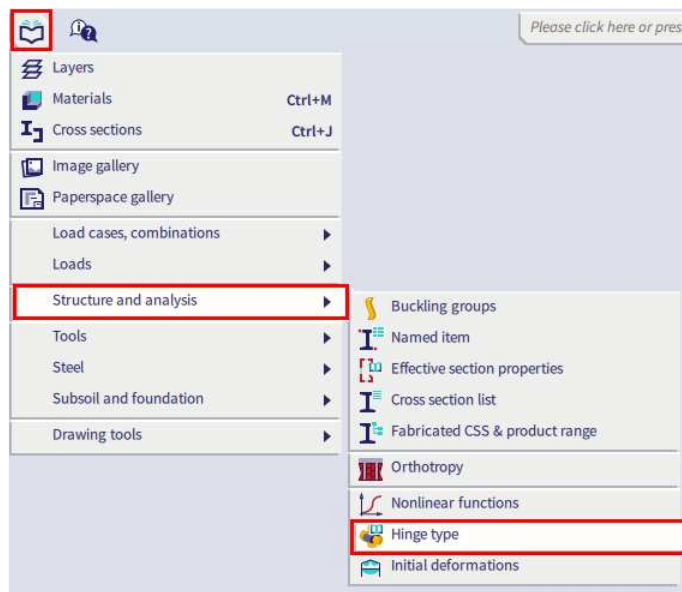
In this '**Hinge type**' library you can choose following non-manufacturer types (from EN 12811) for the parameter '**Hinge type**':

Right angle	Friction sleeve	Swivel	Base jack	Parallel	General
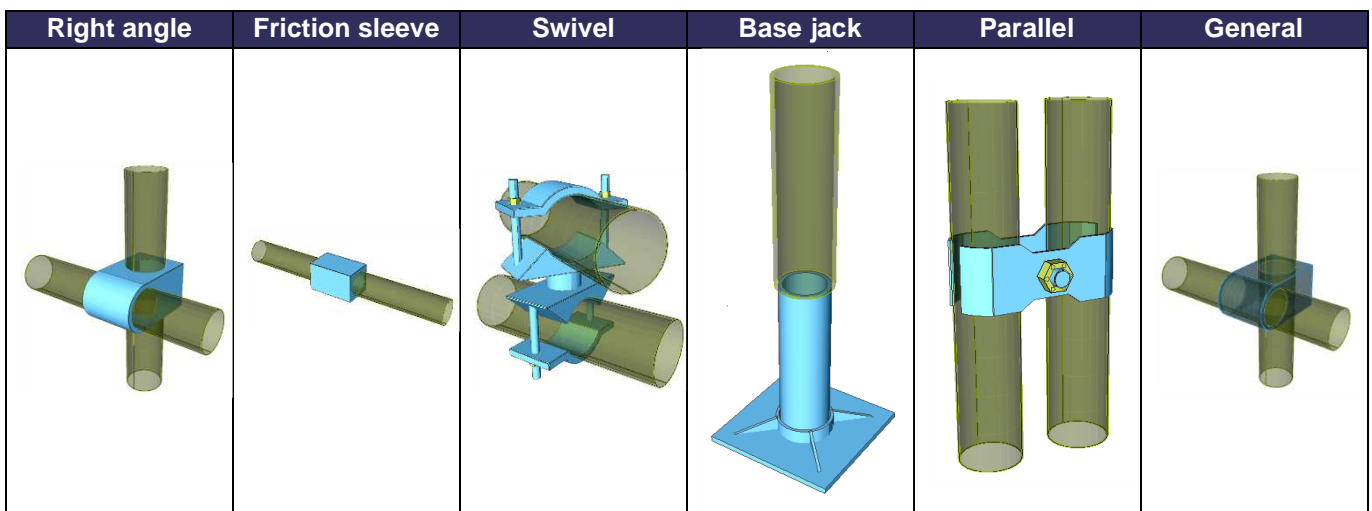
Note: if the functionality 'Scaffolding' is not ticked on in Project settings > tab Functionality you will not be able to see the hinge type library.

For these couplers, not only the rigidities are entered in a flexible or nonlinear way, but also the maximal allowable forces are defined, as displayed below for the '**Right angle**' coupler:
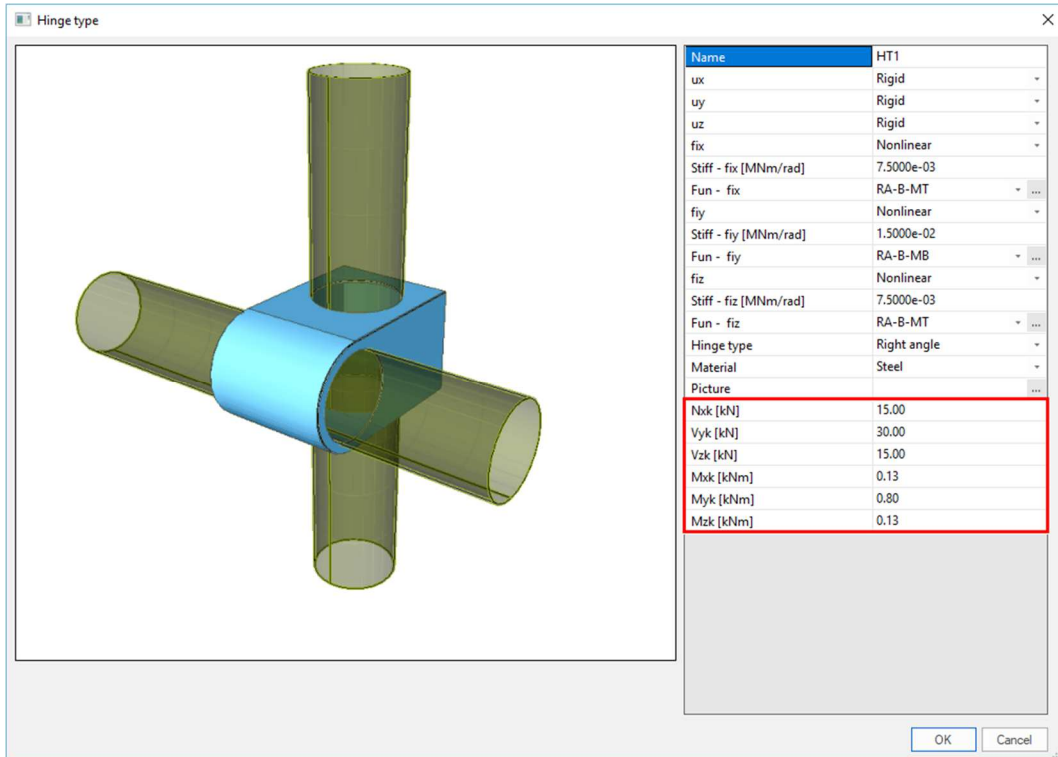
The rigidities and maximal forces are taken from the code EN 12811-1 Annex C Characteristic values of the resistances for couplers.

Coupler type	Resistance	Characteristic value				
		class A	class B		class AA	class BB
Right-angle coupler (RA)	Slipping force $F_{s,k}$ in kN	10,0	15,0		15,0	25,0
	Cruciform bending moment $M_{B,k}$ in kNm	---	0,8		---	---
	Pull-apart force $F_{p,k}$ in kN	20,0	30,0		---	---
	Rotational moment $M_{T,k}$ in kNm	---	0,13		---	---
Friction type sleeve coupler (SF)	Slipping force $F_{s,k}$ in kN	6,0	9,0		---	---
	Bending moment $M_{B,k}$ in kNm	---	2,4		---	---
Swivel coupler (SW)	Slipping force $F_{s,k}$ in kN	10,0	15,0		---	---
Parallel coupler (PA)	Slipping force $F_{s,k}$ in kN	10,0	15,0		---	---
For symbols see Figures C.3 and C.4						

Table C.1 — Characteristic values of resistances for couplers

Key

M_B is the cruciform bending moment (kNm/rad);
φ is the angle of rotation (rad);
$c_{\varphi 1}, c_{\varphi 2}$ are the cruciform stiffnesses ;

Figure C.1 — M_B-φ relationship for class B right angle couplers

Key

M_T is the rotational moment (kNm)
ϑ is the angle of rotation (rad)
c_ϑ is the rotational rigidity

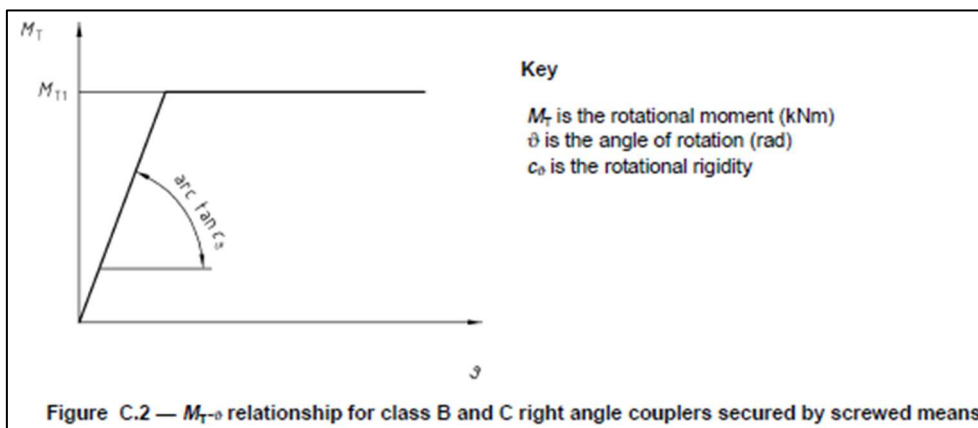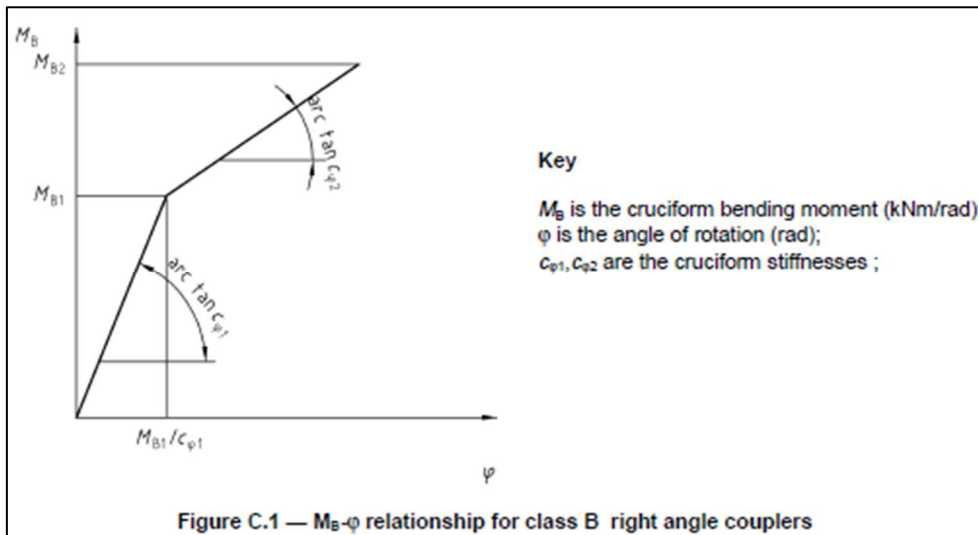**Figure C.2 — M_T-ϑ relationship for class B and C right angle couplers secured by screwed means**

Table C.2 — Design values $c\varphi_1$ and $c\varphi_2$ of cruciform stiffnesses for class B right angle couplers attached to steel- and aluminium tubes

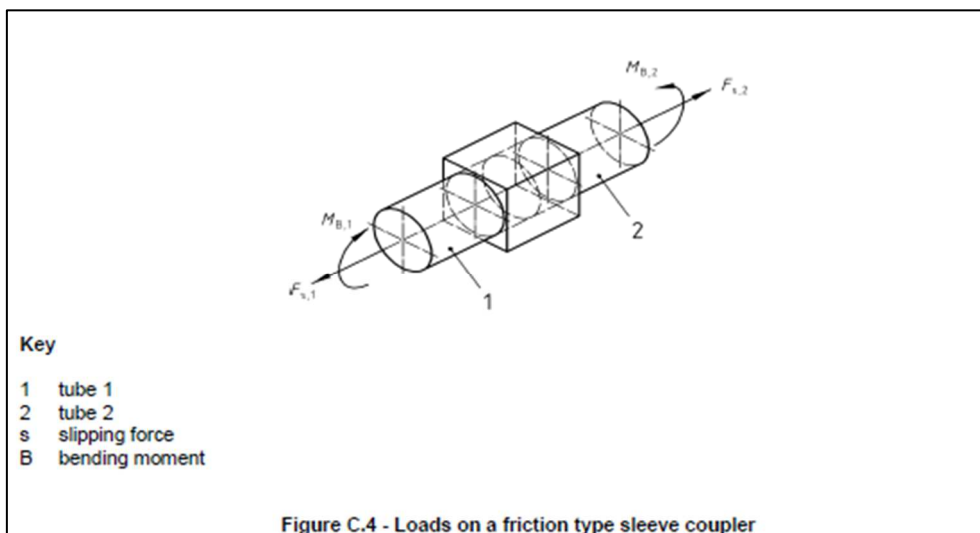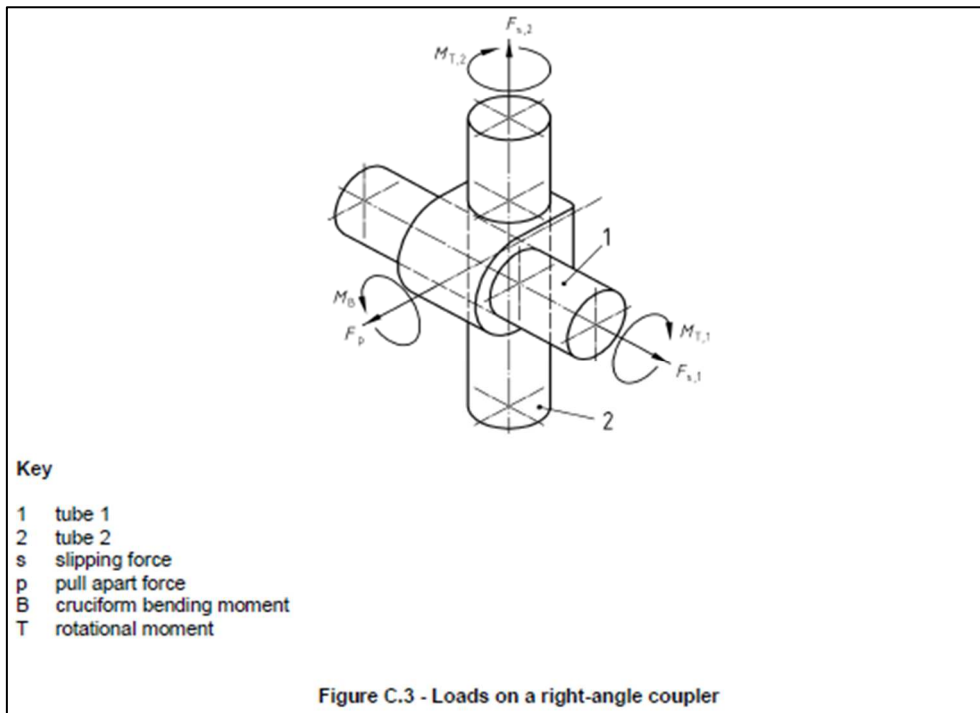|	Steel Tube				Aluminium tube			
	$c_{\varphi 1}$ [kNm/rad]	M_{B1} [kNm]	$C_{\varphi 2}$ [kNm/rad]	M_{B2} [kNm]	$c_{\varphi 1}$ [kNm/rad]	M_{B1} [kNm]	$c_{\varphi 2}$ [kNm/rad]	M_{B2} [kNm]
	15,0	0,48	6,0	0,8	13,0	0,48	5,0	0,8
For symbols see Figure C.1								

Table C.3 — Design values c_ϑ of rotational stiffness for class B right angle couplers
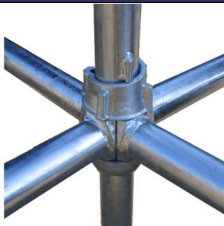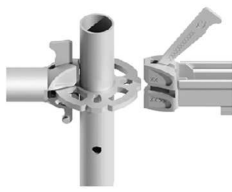
	c_ϑ [kNm/rad]	M_{T1} [kNm]
	7,5	0.13
For symbols see Figure C.2		

Key

1   tube 1
2   tube 2
s   slipping force
p   pull apart force
B   cruciform bending moment
T   rotational moment

Figure C.3 - Loads on a right-angle coupler

Key

1   tube 1
2   tube 2
s   slipping force
B   bending moment

Figure C.4 - Loads on a friction type sleeve coupler

Couplers of manufacturers in SCIA Engineer

Not only the types that are mentioned in the code are available in SCIA Engineer. You can also find couplers from manufacturers in the library: Cuplock, Layher and Catari (the Catari coupler is available since SCIA Engineer 20):

Cuplok	Catari US

Cuplok

Name	Cuplok
ux	Nonlinear
Stiff - ux [MN/m]	4.3640e+01
Fun - ux	Cuplok-N1
uy	Rigid
uz	Rigid
fix	Nonlinear
Stiff - fix [MNm/rad]	1.8270e-02
Fun - fix	Cuplok-Mx1
fiy	Nonlinear
Stiff - fiy [MNm/rad]	6.5000e-02
Fun - fiy	Cuplok-My1
fiz	Flexible
Stiff - fiz [MNm/rad]	2.5000e-03
Hinge type	Cuplok
Material	Steel
Picture	
Nxk [kN]	54.12
Vyk [kN]	0.00
Vzk up [kN]	18.15
Vzk down [kN]	21.78
Mxk [kNm]	1.04
Myk [kNm]	2.29
Mzk [kNm]	0.00

Catari US

Name	Catari (Universal System US)
ux	Rigid
uy	Rigid
uz	Rigid
fix	Free
fiy	Nonlinear
Stiff - fiy [MNm/rad]	3.8950e-02
Fun - fiy	Catari US – My
fiz	Free
Hinge type	Catari US
Material	Steel
Picture	
Nxk+ [kN]	47.20
Vyk [kN]	9.10
Vzk [kN]	19.90
Mxk [kNm]	0.00
Myk+ [kNm]	1.39
Myk- [kNm]	1.30
Mzk [kNm]	0.00

Layher Variante K2000+	Layher Variante II	Layher Variante LW

Layher Variante K2000+

Name	Layher (Variante K2000+)
ux	Rigid
uy	Flexible
Stiff - uy [MN/m]	4.8500e+00
uz	Rigid
fix	Nonlinear
Stiff - fix [MNm/rad]	1.3876e-03
Fun - fix	Layher K2000+ -Mx2
fiy	Nonlinear
Stiff - fiy [MNm/rad]	7.6680e-02
Fun - fiy	Layher K2000+ - My2
fiz	Flexible
Stiff - fiz [MNm/rad]	5.1000e-03
Hinge type	Layher (Variante K2000+)
Material	Steel
Picture	
Nxk [kN]	34.10
Vyk [kN]	11.00
Vzk [kN]	29.04
Mxk [kNm]	0.58
Myk [kNm]	1.11
Mzk [kNm]	0.41

Layher Variante II

Name	Layher (Variante II)
ux	Rigid
uy	Flexible
Stiff - uy [MN/m]	4.8500e+00
uz	Rigid
fix	Free
fiy	Nonlinear
Stiff - fiy [MNm/rad]	6.5820e-02
Fun - fiy	Layher II - My1
fiz	Flexible
Stiff - fiz [MNm/rad]	5.1000e-03
Hinge type	Layher (Variante II)
Material	Steel
Picture	
Nxk [kN]	24.97
Vyk [kN]	7.37
Vzk [kN]	19.14
Mxk [kNm]	0.00
Myk [kNm]	0.75
Mzk [kNm]	0.41

Layher Variante LW

Name	Layher (Variante LW)
ux	Rigid
uy	Nonlinear
Stiff - uy [MN/m]	8.3330e-01
Fun - uy	Layher Variante LW – Vy
uz	Rigid
fix	Nonlinear
Stiff - fix [MNm/rad]	2.4620e-03
Fun - fix	Layher Variante LW – Mx
fiy	Nonlinear
Stiff - fiy [MNm/rad]	1.1560e-01
Fun - fiy	Layher Variante LW – My
fiz	Nonlinear
Stiff - fiz [MNm/rad]	1.0000e-02
Fun - fiz	Layher Variante LW – Mz
Hinge type	Layher (Variante LW)
Material	Steel
Picture	
Nxk [kN]	38.61
Vyk [kN]	18.26
Vzk [kN]	34.87
Mxk [kNm]	0.58
Myk [kNm]	1.32
Mzk [kNm]	0.44

<u>Note</u>: 'Layher Variante LW' was called 'Layher Variante HS' before SCIA Engineer 20.

As you can see each of these couplers has its **specific nonlinear functions and maximal forces**, which are stored in the SCIA database and which are **automatically assigned** when you choose the desired coupler type.

You have to select the appropriate material (steel or aluminium), because this will have an influence on the safety factor of the coupler: when choosing for the material steel, the safety factor will be taken out of the National Annex of EN 1993-1-1, while for aluminium the National Annex of EN 1999-1-1 is used.

As example we can have a look at a certain coupler, for example the type **Variante K2000+** of **Layher**. The values for N_{xk}, V_{yk}, V_{zk}, M_{xk}, M_{yk} and M_{zk} are automatically filled in (taken from Zulassung Z-8.22-64). The equation for the rotation is given by φ_d [rad] = M/(9140 – 73.6M) and is presented by following curve:
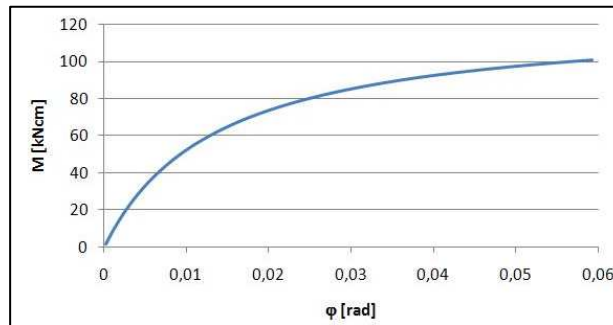
According to this curve, a nonlinear function My is linked automatically to the coupler:
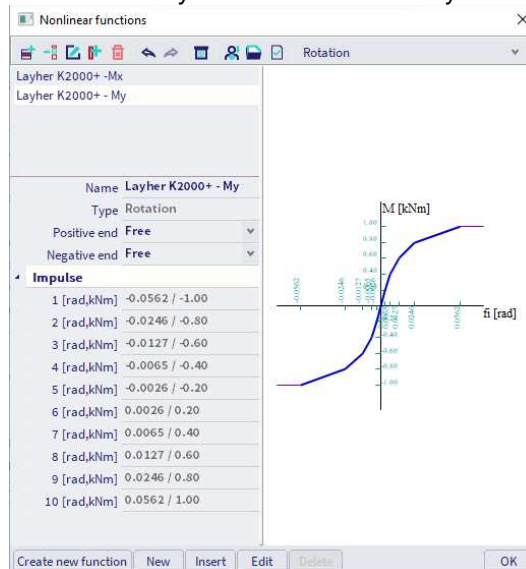
You can find a similar function for Mx:
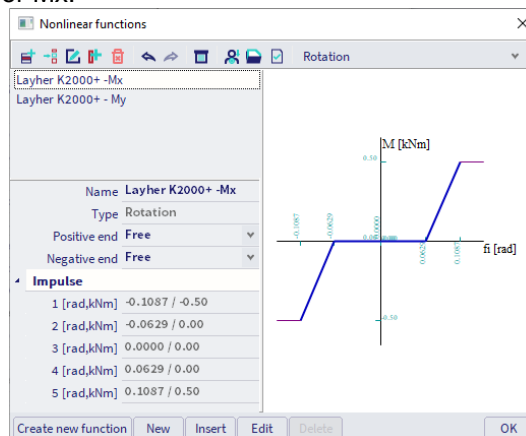
These nonlinear functions can be found under Menu bar > Libraries > Structure and analysis > Nonlinear functions.

Add couplers to SCIA Engineer

If you want to add other types of (manufacturer) couplers to the library, you can create the nonlinear functions by yourself.

In order to do this easily, you can use the Excel file 'gvSEN NonLinear Function Input - rev01' from the SCIA garage (https://resources.scia.net/en/garage/sciagarage.htm).

With the Excel sheet you can easily create the nonlinear function, export it to a XML file and import this XML file into SCIA Engineer.

You also must fill in the maximal allowable forces in the hinge type window.

Let us demonstrate this by adding the Layher Variante K2000+ type manually to the software.

First, we open the Excel file and add the values for the nonlinear functions on the 'Input' tab. Information about the parameters and units is found on the 'Instructions' tab. We can immediately create the function for Mx and the function for My:

Then we create the XML file by clicking on the button 'Export Non-Linear Functions'. Make sure to enable the macros (click on the button 'Enable Content' if this bar would pop up). Choose a name for the XML file and save it on a certain location (e.g. on your desktop). Now a .xml and a .xml.def file are created.

In SCIA Engineer you can import the functions via Menu bar > File > Update from > XML file.

The functions are now imported and visible in under Menu bar > Libraries > Structure and analysis > Nonlinear functions.

Finally, the hinge type can be created via Menu bar > Libraries > Structure and analysis > Hinge type (do not forget to activate the functionality 'Scaffolding' in Menu bar > Project settings > tab Functionalities).

Click on 'New', choose the settings for ux, uy, uz, fix, fiy and fiz, choose the nonlinear functions in case you choose for Nonlinear and fill in the values for Nxk, Vyk, Vzk, Mxk, Myk and Mzk:
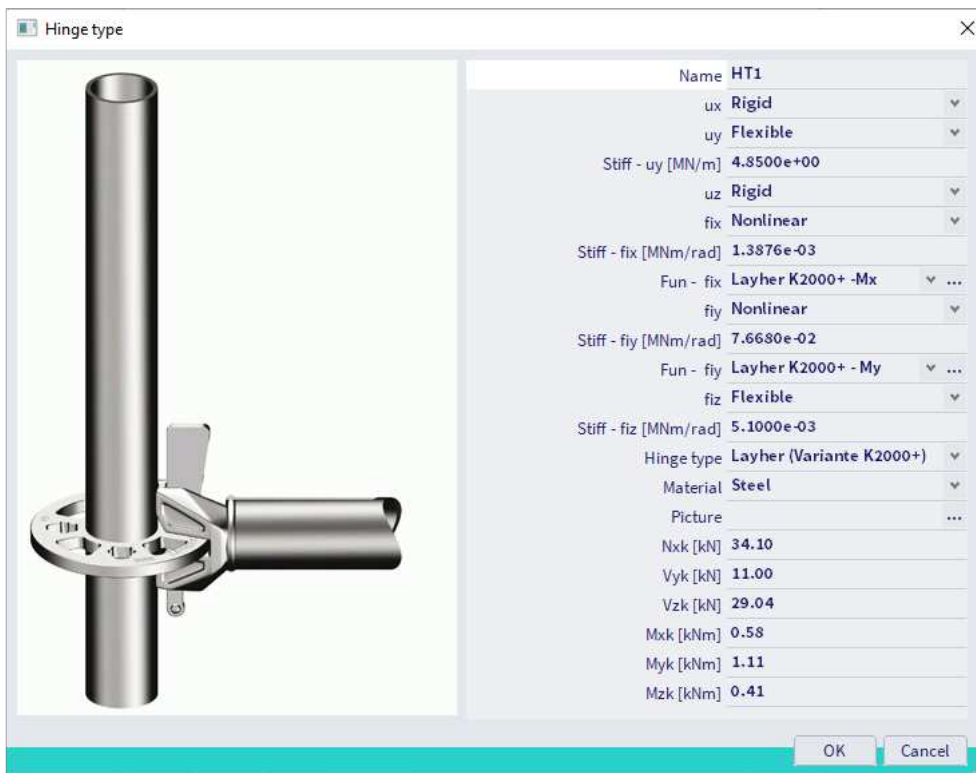
As 'Hinge type' you should choose a type that corresponds the most with the coupler that you want to create. To decide this type, you can use information about the checks in the overview tables of the chapter 'Couplers checks'. If you choose for example the type 'General', no interaction check will be executed.

After creating the hinge type you could use the disk icon in the 'Hinge type library' window to save the hinge type into a database file. Afterwards you could load this database file into other projects, so you have to create the hinge type only once.
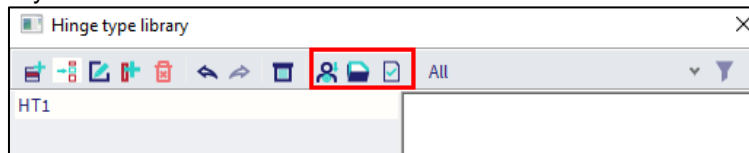
You add the hinges to the desired beams via Input panel > workstation Structure > category Boundary conditions > **Hinge on 1D** and as 'Hinge type' you select 'Library' so you can select the desired hinge type from the hinge type library.
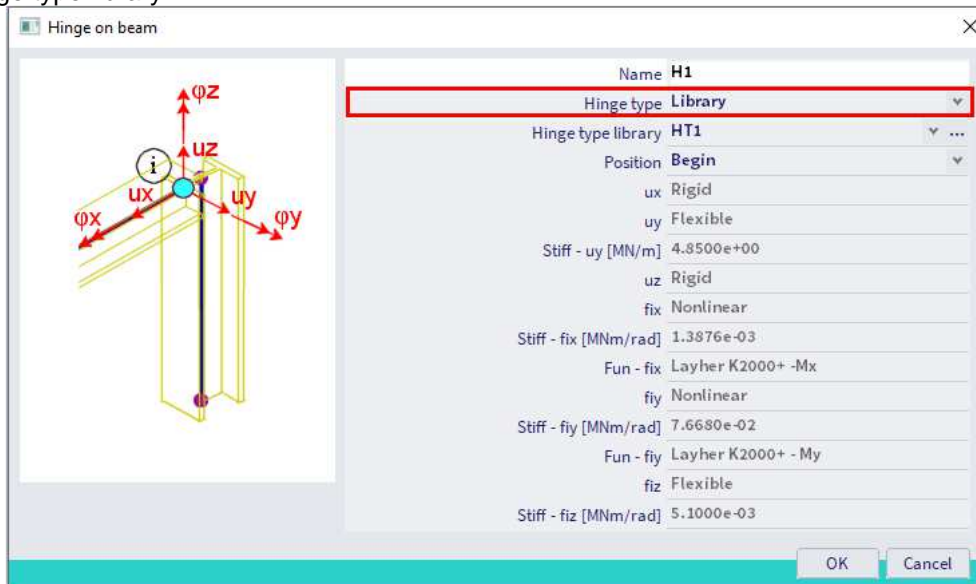
Couplers checks

The coupler check can be performed by SCIA Engineer with the command **Menu bar > Design > Steel members** > **Scaffolding coupler check** (or **Menu bar > Design > Aluminium** > **Scaffolding coupler check** for aluminium couplers) or via the same command in the Proces toolbar.

This check performs a unity check for the couplers for which a maximal allowable force is given in the coupler library:

General couplers

Following table provides an overview of the performed component checks for each type:

	F_x	F_y	F_z	M_x	M_y	M_z	Interaction
Right angle	✓	✓	✓	✓	✓	✓	✓
Friction sleeve	✓	-	-	-	✓	-	✓
Swivel	✓	-	-	-	-	-	-
Base jack	-	-	-	-	✓	✓	-
Parallel	-	-	✓	-	-	-	-
General	✓	✓	✓	✓	✓	✓	-

For a right angle coupler the interaction formula is:

$$\frac{N+V_z}{2\cdot\frac{F_{s,k}}{\gamma_M}} + \frac{V_y}{\frac{F_{p,k}}{\gamma_M}} + \frac{M_y}{2.4\cdot\left(\frac{M_{B,k}}{\gamma_M}\right)} = \frac{|N_{Ed}|+|V_{z,Ed}|}{\frac{N_{x,k}+V_{z,k}}{\gamma_M}} + \frac{|V_{y,Ed}|}{\frac{V_{y,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{2.4\cdot\left(\frac{M_{y,k}}{\gamma_M}\right)} \leq 1$$

For a friction sleeve coupler the formula is:

$$\frac{N}{2\cdot\frac{F_{s,k}}{\gamma_M}} + \frac{M_y}{\frac{M_{B,k}}{\gamma_M}} = \frac{|N_{Ed}|}{2\cdot\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} \leq 1$$

With:

- $F_{s,k}$: characteristic slipping force, taken as $N_{x,k}$ and $V_{z,k}$ of the coupler properties: $2F_{s,k}=N_{x,k}+V_{z,k}$
- $F_{p,k}$: characteristic pull-apart force, taken as $V_{y,k}$ of the coupler properties
- M_B: characteristic bending moment, taken as $M_{y,k}$ of the coupler properties
- N normal force
- V_y: shear force in y direction
- V_z: shear force in z direction
- M_y: bending moment about the y axis
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers
- $N_{x,k}$, $V_{y,k}$, $V_{z,k}$, $M_{y,k}$: coupler resistances given by EN 12811-1 Table C1

Loads on a coupler are defined by following figures (left below is a right angle coupler and right below is a friction type sleeve coupler), see also chapter 'Couplers - general principle':
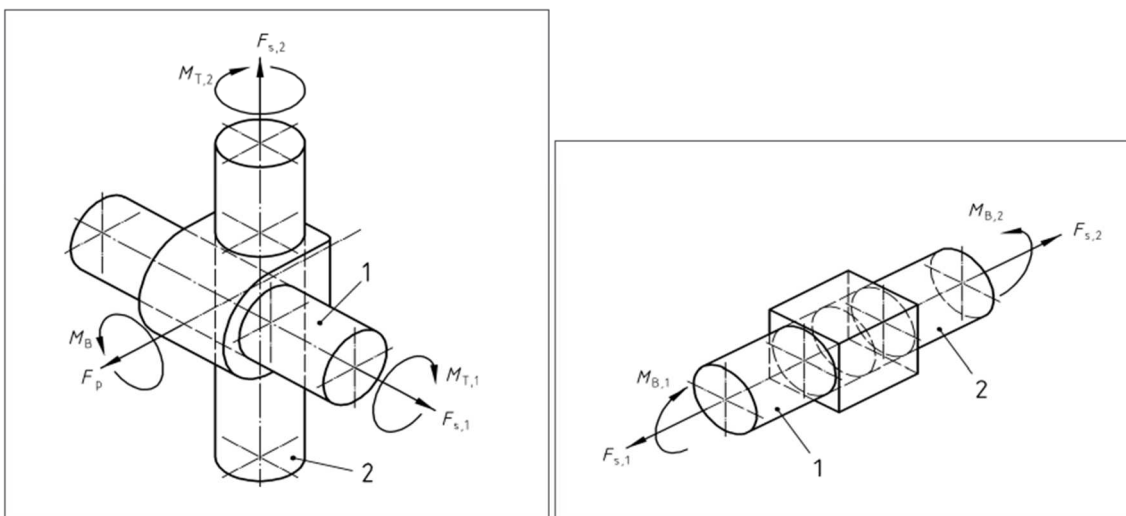
Manufacturer couplers

In addition to the list of general couplers, following table provides an overview of the performed component checks for each type of manufacturer coupler:

	F_x	F_y	F_z	M_x	M_y	M_z	Interaction 1	Interaction 2	Interaction 3
Cuplok	✓	-	✓	✓	✓	-	✓	✓	✓
Layher K2000+	✓	✓	✓	✓	✓	✓	✓	✓	✓
Layher Variante II	✓	✓	✓	-	✓	✓	✓	✓	✓
Layher LW	✓	✓	✓	✓	✓	✓	✓	✓	✓
Catari US	✓	✓	✓	-	✓	-	-	-	-

Note: The Catari US coupler type and the interaction 3 check are available since SCIA 20.

Cuplock

The Cuplock coupler which connects a ledger and a standard is described in Zulassung Nr. Z-8.22-208:2017. The interaction equations are:

Interaction 1:

$$\frac{N}{\frac{N_{x,k}}{\gamma_M}} + \frac{M_y}{\frac{M_{y,k}}{\gamma_M}} + \frac{M_x}{\frac{M_{x,k}}{\gamma_M}} = \frac{|N_{Ed}|}{\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} + \frac{|M_{x,Ed}|}{\frac{M_{x,k}}{\gamma_M}} \leq 1$$

With:

- N: slipping force, taken as normal force in the ledger
- M_y: bending moment about the y axis
- M_x: torsional moment around the x axis
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers
- $N_{x,k}$, $M_{y,k}$, $M_{x,k}$: coupler resistances given by Z-8.22-208:2017 Table 4

Interaction 2:

$$\frac{M_y}{\frac{M_{y,k}}{\gamma_M}} + \frac{(N + N_v \cdot \sin(\alpha))}{\frac{N_{x,k}}{\gamma_M}} + \frac{M_x}{\frac{M_{x,k}}{\gamma_M}} = \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} + \frac{\left|N_{Ed} + \Sigma\left(N_{v,Ed} \cdot \sin(\alpha)\right)\right|}{\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{x,Ed}|}{\frac{M_{x,k}}{\gamma_M}} \leq 1$$

With:

- N: slipping force, taken as normal force in the ledger
- M_y: bending moment about the y axis
- M_x: torsional moment around the x axis
- N_v: normal force in a connecting vertical diagonal
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers
- α: angle between connecting vertical diagonal and standard
- $N_{x,k}$, $M_{y,k}$, $M_{x,k}$: coupler resistances given by Z-8.22-208:2017 Table 4

Interaction 3:

$$I_S + 0.7 \cdot I_A = \frac{a}{b} + 0.7 \cdot I_A = \frac{\sqrt{m_{act}^2 + n_{act}^2}}{\sqrt{m^2 + n^2}} + 0.7 \cdot I_A \leq 1$$

With:

- I_A: M_y utilization of connected coupler
- I_S: in-plane utilization of column (the definition of lengths a and b are given by article 3.3.2.2 build 1)
- a: initial length
- b: projected length
- m_{act}: actual utilization of in-plane bending moment in column section $= \frac{|M_{st,Ed}|}{M_{st,Rd}}$
- $M_{st,Ed}$: design bending moment in column section adjacent to the coupler
- $M_{st,Rd}$: bending moment resistance of the column cross-section $= \frac{\alpha_{pl} \cdot w_{el} \cdot f_{yk}}{\gamma_M}$ and $\alpha_{pl} = \frac{w_{pl}}{w_{el}} \leq 1.25$
- n_{act}: actual utilization of normal force in column section $= \frac{|N_{st,Ed}|}{N_{st,Rd}}$
- $N_{st,Ed}$: design normal force in column section adjacent to the coupler
- $N_{st,Rd}$: normal force resistance of column cross-section $= \frac{A_{st} \cdot f_{yk}}{\gamma_M}$
- m: value of bending moment utilization when combined UC is equal to 1 (the smallest positive root of the cubic function)
- n: corresponding value of normal force utilization calculated from current curve function
  $= \left(\frac{n_{act}}{m_{act}} \right) \cdot m$
- A_{st}: cross-section area of column cross-section
- $w_{el/pl}$: elastic / plastic section modulus of column cross-section
- v_{act}: actual utilization of vertical in-plane shear in column section $= \frac{|V_{st,Ed}|}{V_{st,Rd}}$
- $V_{st,Ed}$: design shear force in column section adjacent to the coupler
- $V_{st,Rd}$: shear force resistance of column cross-section $= \frac{A_{v,st} \cdot f_{yk}}{\sqrt{3} \cdot \gamma_M}$
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers

Column internal forces are selected considering the possible rotation of the column. If the angle between the connected beam LCS and column LCS is smaller than 45 deg, then:
- $M_{st,Ed} = M_{y,st,Ed}$, else $M_{z,st,Ed}$
- $V_{st,Ed} = V_{y,st,Ed}$, else $V_{z,st,Ed}$

Also, in certain geometries there can be two sections to choose from. In this case the selection is based on Von Mises stress calculation. The section which will result in larger stress will be used for the further calculation of I_S. The stress will be calculated as indicated below:

$$\sigma = \sqrt{\sigma_{tot,Ed}^2 + 3 \cdot \tau_{Ed}^2} = \sqrt{(\sigma_N + \sigma_M)^2 + 3 \cdot \tau_{Ed}^2} = \sqrt{\left(\frac{|N_{st,Ed}|}{A_{st}} + \frac{|M_{st,Ed}|}{W_{el,st}} \right)^2 + 3 \cdot \left(\frac{|V_{st,Ed}|}{A_{v,st}} \right)^2}$$

The bending moment utilization of column m, may be calculated by solving a derived cubic function, using coefficients C_1 and C_2 depending on the shear force utilization of column section v_{act}:

$$C_2 \cdot m^3 + 4 \cdot C_1 \cdot C_2 \cdot m^2 + 4 \cdot m - 4 \cdot C_1 = 0$$

With:

- C_1: for $v_{act} \leq \frac{1}{3}$: $C_1 = 1$

  for $\frac{1}{3} \leq v_{act} \leq 0.9$: $C_1 = \sqrt{1 - v_{act}^2}$

- C_2: for $v_{act} \leq \frac{1}{3}$: $C_2 = \frac{n_{act}}{m_{act}}$

  for $\frac{1}{3} \leq v_{act} \leq 0.9$: $C_2 = \frac{n_{act}}{m_{act}} \cdot \sqrt{1 - v_{act}^2}$

Special cases are:
- $m_{act} \leq 0.0001 \rightarrow l_S = n_{act}$
- $n_{act} = 0 \rightarrow l_S = m_{act}$
- $m_{act} \leq 0.0001$ and if $n_{act} = 0 \rightarrow l_S = 0$

For the case when $0.9 < v_{act}$ an error will be displayed and UC_Interaction 3 will be set to 999.

To recognize a member as a column, the type of the member has to be either '**column**', '**gable column**' or '**secondary column**' and the cross-section has to be Formcode 3 (CHS). In case two columns are found, both need to be within one buckling system. If the above is not fulfilled or if there are more column members found, the column geometry is not recognized and the unity check is set to 999.

Layher

The Layher coupler which connects a ledger and a standard is described in Zulassung Nr. Z-8.22-64:2018 for Variante II and Variante K2000+ and in Zulassung Nr. Z-8.22-939:2019 for Variante LW.

Interaction 1, Variante II:

$$\frac{N^{(+)}}{N_{Rd}} + \frac{M_y}{M_{y,R,d}} + \frac{\max(V_z - 1.4 \; ; \; 0)}{M_y} + \frac{V_y}{25.0} = \frac{N_{Ed}^+}{\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} + \frac{\max(|V_{z,Ed}| - V_{z,Ed,min} \; ; \; 0)}{\frac{V_{z,k}}{\gamma_M}} + \frac{|M_{z,Ed}|}{\frac{M_{z,k}}{\gamma_M}} + \frac{|V_{y,Ed}|}{V_{y,Rd}} \leq 1$$

Interaction 1, Variante K2000+:

$$\frac{N^{(+)}}{N_{Rd}} + \frac{M_y}{M_{y,R,d}} + \frac{\max(V_z - 2.1 \; ; \; 0)}{M_y} + \frac{V_y}{27.1} + \frac{M_T}{M_{T,R,d}} \leq 1$$

$$\frac{N_{Ed}^+}{\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} + \frac{\max(|V_{z,Ed}| - V_{z,Ed,min} \; ; \; 0)}{\frac{V_{z,k}}{\gamma_M}} + \frac{|M_{z,Ed}|}{\frac{M_{z,k}}{\gamma_M}} + \frac{|V_{y,Ed}|}{V_{y,Rd}} + \frac{|M_{x,Ed}|}{\frac{M_{x,k}}{\gamma_M}} \leq 1$$

Interaction 1, Variante LW:

$$\frac{N^{(+)}}{N_{Rd}} + \frac{|M_y|}{M_{y,R,d}} + \frac{\max(|V_z| - 2.5 \; ; \; 0)}{V_{z,R,d}} + \frac{|M_z|}{|M_{z,R,d}|} + \frac{|V_y|}{|V_{y,R,d}|} + \frac{M_T}{M_{T,R,d}} \leq 1$$

$$\frac{N_{Ed}^+}{\frac{N_{x,k}}{\gamma_M}} + \frac{|M_{y,Ed}|}{\frac{M_{y,k}}{\gamma_M}} + \frac{\max(|V_{z,Ed}| - V_{z,Ed,min} \; ; \; 0)}{\frac{V_{z,k}}{\gamma_M}} + \frac{|M_{z,Ed}|}{\frac{M_{z,k}}{\gamma_M}} + \frac{|V_{y,Ed}|}{V_{y,Rd}} + \frac{|M_{x,Ed}|}{\frac{M_{x,k}}{\gamma_M}} \leq 1$$

Note: an additional check for welds is not supported.

With:
- N: slipping force, taken as normal force in the ledger
- (+): this index indicates a tensile force (≥0)
- V_y: shear force in y direction
- V_z: shear force in z direction
- M_y: bending moment about the y axis
- M_x: torsional moment around the x axis
- M_z: torsional moment around the z axis
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers
- α: angle between connecting vertical diagonal and standard
- $N_{x,k}, M_{y,k}, M_{z,k}, M_{x,k}, V_{y,k}, V_{z,k}$: coupler resistances given by Z-8.22-64:2018 Table 5 for Variante II and Variante K2000+ en Z-8.22-939:2019 Table 5 for Variante LW
- $V_{z,Ed,min}$: 1.4 kN for Variante II, 2.1 kN for Variante K2000+ and 2.5 kN for Variante LW

Interaction 2:

$$(n^A + n^B)^2 + (v^A + v^B)^2 \leq 1$$

	Ledger A / Vertical diagonal B
n^A	$\dfrac{N^{A(+)} + \lvert M_y^A \rvert / e}{\xi\, N_{R,d}}$
n^B	$\dfrac{0,707 \sin \alpha\, N_V^{(+)} + \left(\dfrac{e_D}{e}\right) \cdot \cos \alpha\, \lvert N_V \rvert}{\xi\, N_{R,d}}$
v^A	$\dfrac{V_z^A}{V_{z,R,d}}$
v^B	$\dfrac{\cos \alpha\, N_V}{V_{z,R,d}}$

Ledger:

$$nA = \frac{N_{Ed}^+ + \dfrac{\lvert M_{y,Ed} \rvert}{e}}{\xi \cdot \dfrac{N_{x,k}}{\gamma_M}}$$

$$nB = \frac{0.707 \cdot \sum\left(\sin(\alpha) \cdot N_{v,Ed}^+\right) + \dfrac{e_D}{e} \cdot \sum\left(\cos(\alpha) \cdot \lvert N_{v,Ed} \rvert\right)}{\xi \cdot \dfrac{N_{x,k}}{\gamma_M}}$$

Vertical diagonal:

$$vA = \frac{V_{z,Ed}}{\dfrac{V_{z,k}}{\gamma_M}}$$

$$vB = \frac{\sum\left(\cos(\alpha) \cdot N_{v,Ed}\right)}{\dfrac{V_{z,k}}{\gamma_M}}$$

With:
- N: slipping force, taken as normal force in the ledger
- (+): this index indicates a tensile force (≥0)
- N_v: normal force in a connecting vertical diagonal
- M_y: bending moment about the y axis
- V_z: shear force in z direction
- γ_M: safety factor, taken as γ_{M0} of EN 1993-1-1 for steel couplers or γ_{M1} of EN 1999-1-1 for aluminium couplers
- α: angle between connecting vertical diagonal and standard
- $N_{x,k}$, $V_{z,k}$: coupler resistances given by Z-8.22-64:2018 Table 5 for Variante II and Variante K2000+ en Z-8.22-939:2019 Table 5 for Variante LW
- e: 2.75 cm for Variante II, 3.30 cm for Variante K2000+ and 3.30 kN for Variante LW
- e_D: 5.7 cm
- ξ: 1.26 cm for Variante II, 1.85 cm for Variante K2000+ and 1.85 kN for Variante LW

Interaction 3, Variante II:

$$I_S + 0.148 \cdot I_A = \frac{\sigma_N}{f_{yd}} + 0.148 \cdot I_A = \frac{\frac{|N_{st,Ed}|}{A_{st}} + \frac{|M_{st,Ed}|}{W_{el,st}}}{f_{yd}} + 0.148 \cdot I_A \leq 1$$

With:
- I_A: My utilization of connected coupler
- I_S: in-plane utilization of column
- $N_{st,Ed}$: design normal force in column section adjacent to the coupler
- $M_{st,Ed}$: design bending moment in column section adjacent to the coupler
- A_{st}: cross-section area of column cross-section
- $W_{el,st}$: elastic section modulus of column cross-section

Interaction 3, Variante K2000+ (given by Z-8.22-64 Table 6):
$$I_S + 0.316 \cdot I_A \leq 1$$

The calculation routine is similar as the one described for Cuplok coupler.

Interaction 3, Variante LW (given by Z-8.22-939):
$$I_S + 0.170 \cdot I_A \leq 1$$

The calculation routine is similar as the one described for Cuplok coupler.

Catari US

The resistances and stiffness function of Catari Universal System (US) coupler are given by AENOR Product Certificate A34/000035. The reference only provides normal force resistance for tension.

Example

As example we consider a steel scaffolding, based on the Layher system:
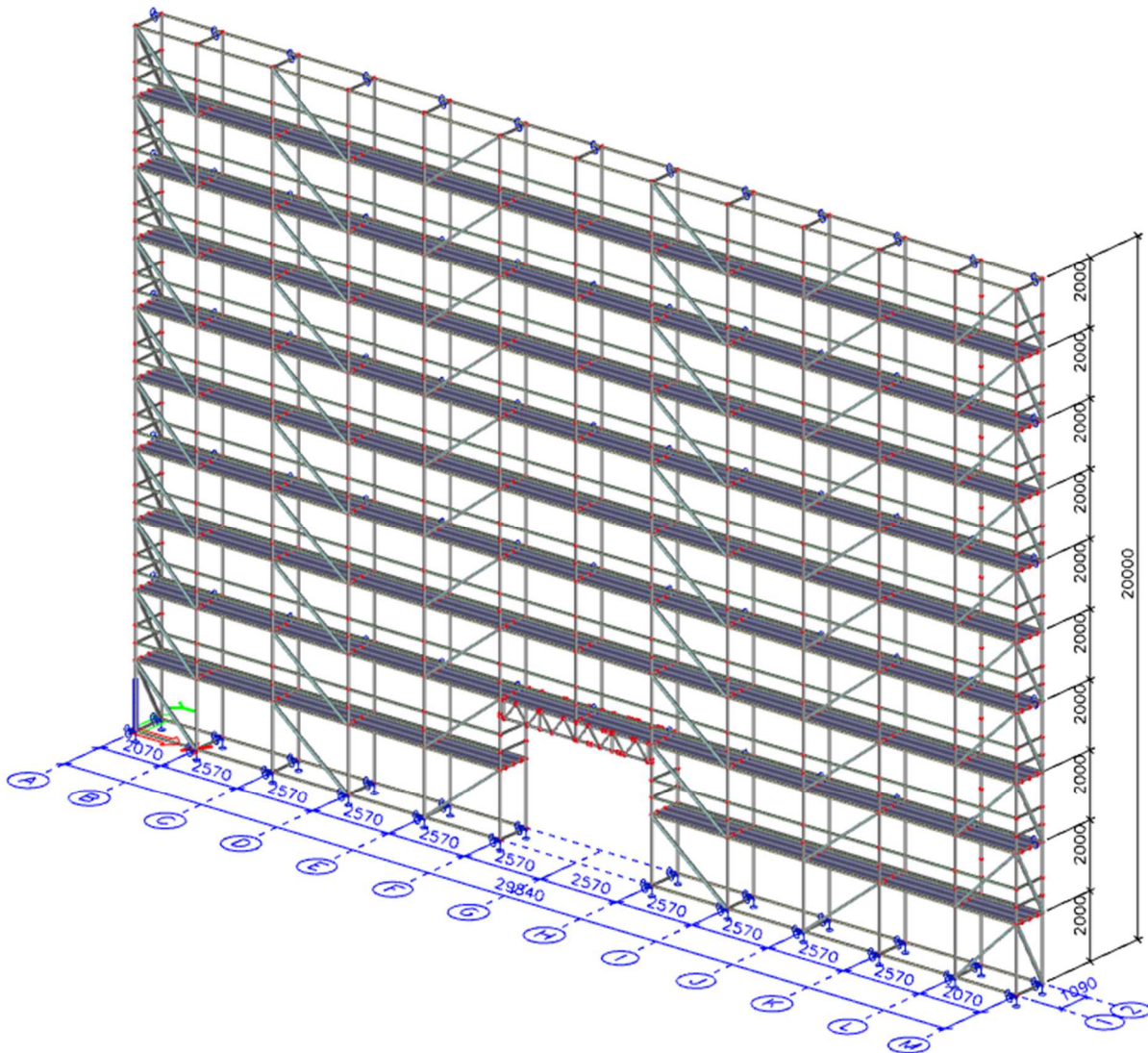

After modelling the structure (elements, couplers, supports, nonlinearities, …), adding the loads and calculating nonlinearly we can perform the checks on the beams and the checks on the couplers.

For the checks on the couplers choose for **Menu bar > Design > Steel members > Scaffolding coupler check** and ask the results for the nonlinear class or combinations:
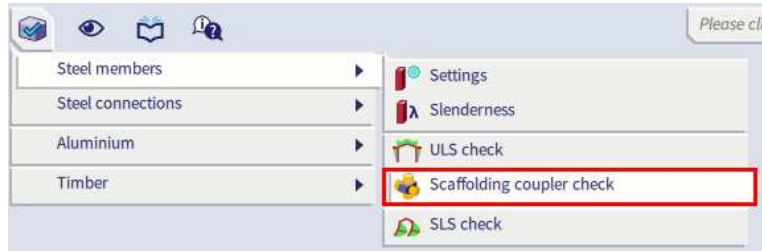
The maximum unity check of 0.60 is found in coupler H1300 (on beam S5919):
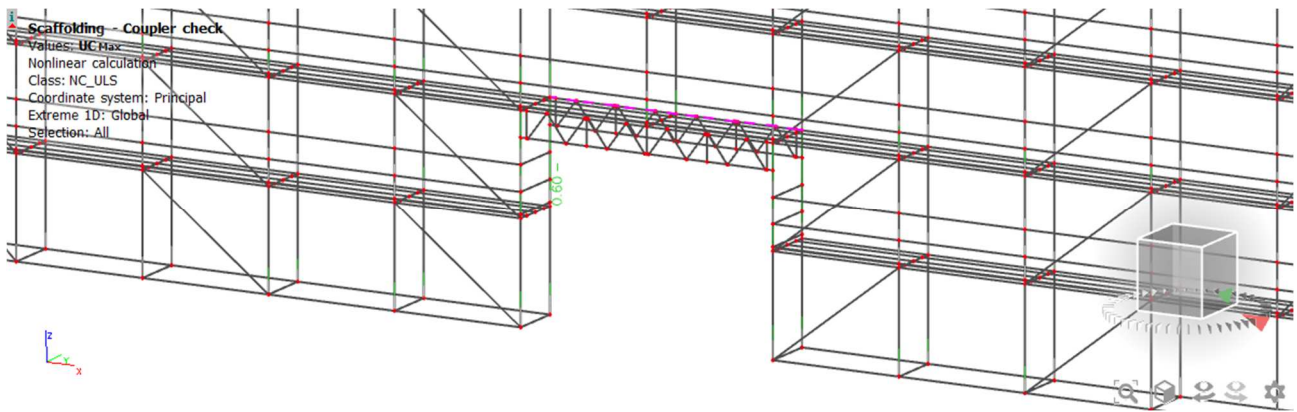
The preview window shows you the output. The figure below gives you the brief output:

Scaffolding - Coupler check

Nonlinear calculation
Class: NC_ULS
Coordinate system: Principal
Extreme 1D: Global
Selection: All
Scaffolding - Coupler Check

Name	dx [m]	Case	UC$_{Max}$ [-]	UC$_{Fx}$ [-]	UC$_{Fy}$ [-]	UC$_{Fz}$ [-]	UC$_{Mx}$ [-]	UC$_{My}$ [-]	UC$_{Mz}$ [-]	UC$_{Interaction1}$ [-]	UC$_{Interaction2}$ [-]	UC$_{Interaction3}$ [-]
S5919	5.140	NC_CO20	**0.60**	0.47	0.02	0.11	0.00	0.09	0.01	0.60	0.10	0.15

A detailed output including formulas is available since SCIA Engineer 20:

Scaffolding - Coupler check

Nonlinear calculation
Class: NC_ULS
Coordinate system: Principal
Extreme 1D: Global
Selection: All

EN 12811-1 Code Check
National annex: Belgian NBN-EN NA

Scaffolding Coupler	Member	Location / Length [m]	Material	Coupler type	Case	UC Max [-]
H1300	S5919	5.140/5.140	Steel	Layher (Variante K2000+)	NC_ULS	0.60

Partial safety factors

γ_{M0}	1.10

Design internal forces

		Member	Scaffolding Coupler	Unit
Normal force	N_{Ed}	14.43	14.43	kN
Shear force	$V_{y,Ed}$	0.20	0.20	kN
Shear force	$V_{z,Ed}$	2.95	2.95	kN
Torsion moment	$M_{x,Ed}$	0.00	0.00	kNm
Bending moment	$M_{y,Ed}$	0.09	0.09	kNm
Torsion moment	$M_{z,Ed}$	0.00	0.00	kNm

Scaffolding coupler resistances
According to Z-8.22-64:2018 Table 5

Scaffolding Coupler H1300		
N_{xk}	34.10	kN
V_{yk}	11.00	kN
V_{zk}	29.04	kN
M_{xk}	0.58	kNm
M_{yk}	1.11	kNm
M_{zk}	0.41	kNm

Scaffolding coupler check
According to EN 12811-1

Normal force check N

$$UC_{Fx} = \frac{|N_{Ed}|}{\frac{N_{xk}}{\gamma_{M0}}} = \frac{|14.43[kN]|}{\frac{34.10[kN]}{1.10}} = 0.47 \le 1.00 \qquad (\S10.3.3.1)$$

Shear force check Vy

$$UC_{Fy} = \frac{|V_{y,Ed}|}{\frac{V_{yk}}{\gamma_{M0}}} = \frac{|0.20[kN]|}{\frac{11.00[kN]}{1.10}} = 0.02 \le 1.00 \qquad (\S10.3.3.1)$$

Shear force check Vz

$$UC_{Fz} = \frac{|V_{z,Ed}|}{\frac{V_{zk}}{\gamma_{M0}}} = \frac{|2.95[kN]|}{\frac{29.04[kN]}{1.10}} = 0.11 \le 1.00 \qquad (\S10.3.3.1)$$

Torsional moment check Mx

$$UC_{Mx} = \frac{|M_{x,Ed}|}{\frac{M_{xk}}{\gamma_{M0}}} = \frac{|0.00[kNm]|}{\frac{0.58[kNm]}{1.10}} = 0.00 \le 1.00 \qquad (\S10.3.3.1)$$

Bending moment check My

$$UC_{My} = \frac{|M_{y,Ed}|}{\frac{M_{yk}}{\gamma_{M0}}} = \frac{|0.09[kNm]|}{\frac{1.11[kNm]}{1.10}} = 0.09 \le 1.00 \qquad (\S10.3.3.1)$$

Torsional moment check Mz

$$UC_{Mz} = \frac{|M_{z,Ed}|}{\frac{M_{zk}}{\gamma_{M0}}} = \frac{|0.00[kNm]|}{\frac{0.41[kNm]}{1.10}} = 0.01 \le 1.00 \qquad (\S10.3.3.1)$$

Interaction checks
According to Z-88.22-64:2018

Interaction check 1

$$UC_{Interaction1} = \frac{N_{Ed}^+}{\frac{N_{xk}}{\gamma_{M0}}} + \frac{|M_{y,Ed}|}{\frac{M_{yk}}{\gamma_{M0}}} + \frac{max(|V_{z,Ed}| - V_{z,Ed,min}, 0)}{\frac{V_{zk}}{\gamma_{M0}}} + \frac{|M_{z,Ed}|}{\frac{M_{zk}}{\gamma_{M0}}} + \frac{|V_{y,Ed}|}{V_{y,Rd}} + \frac{|M_{x,Ed}|}{\frac{M_{xk}}{\gamma_{M0}}}$$

$$= \frac{14.43[kN]}{\frac{34.10[kN]}{1.10}} + \frac{|0.09[kNm]|}{\frac{1.11[kNm]}{1.10}} + \frac{max(|2.95[kN]| - 2.10[kN], 0[kN])}{\frac{29.04[kN]}{1.10}} + \frac{|0.00[kNm]|}{\frac{0.41[kNm]}{1.10}} + \frac{|0.20[kN]|}{27.10[kN]} + \frac{|0.00[kNm]|}{\frac{0.58[kNm]}{1.10}} = \mathbf{0.60} \leq \mathbf{1.00}$$

(6)

Interaction check 2

$$nA = \frac{N_{Ed}^+ + \frac{|M_{y,Ed}|}{e}}{\xi \times \frac{N_{xk}}{\gamma_{M0}}} = \frac{14.43[kN] + \frac{|0.09[kNm]|}{33[mm]}}{1.85 \times \frac{34.10[kN]}{1.10}} = 0.30$$

(§3.2.6.1 Table 11)

$$nB = \frac{0.707 \times \sum(sin(\alpha) \times N_{v,Ed}^+) + \frac{e_D}{e} \times \sum(cos(\alpha) \times |N_{v,Ed}|)}{\xi \times \frac{N_{xk}}{\gamma_{M0}}} = \frac{0.707 \times 0.00[kN] + \frac{57[mm]}{33[mm]} \times 0.00[kN]}{1.85 \times \frac{34.10[kN]}{1.10}} = 0.00$$

(§3.2.6.1 Table 11)

$$vA = \frac{V_{z,Ed}}{\frac{V_{zk}}{\gamma_{M0}}} = \frac{2.95[kN]}{\frac{29.04[kN]}{1.10}} = 0.11$$

(§3.2.6.1 Table 11)

$$vB = \frac{\sum(cos(\alpha) \times N_{v,Ed})}{\frac{V_{zk}}{\gamma_{M0}}} = \frac{0.00[kN]}{\frac{29.04[kN]}{1.10}} = 0.00$$

(§3.2.6.1 Table 11)

$$UC_{Interaction2} = (nA + nB)^2 + (vA + vB)^2 = (0.30 + 0.00)^2 + (0.11 + 0.00)^2 = \mathbf{0.10} \leq \mathbf{1.00}$$

(14)

Interaction check 3

Column data		
Member	B116	
Section	2.000	m
$N_{st,Ed}$	-14.03	kN
$V_{st,Ed}$	-0.27	kN
$M_{st,Ed}$	-0.03	kNm
A_{st}	453	mm²
$A_{v,st}$	288	mm²
$W_{el,st}$	4800	mm³
$W_{pl,st}$	6509	mm³
f_{yk}	320.0	MPa

$$I_A = \frac{|M_{y,Ed}|}{\frac{M_{yk}}{\gamma_{M0}}} = \frac{|0.09[kNm]|}{\frac{1.11[kNm]}{1.10}} = 0.09$$

$$N_{st,Rd} = \frac{A_{st} \times f_{yk}}{\gamma_{M0}} = \frac{453[mm^2] \times 320.0[MPa]}{1.10} = 131.78[kN]$$

$$n_{act} = \frac{|N_{st,Ed}|}{N_{st,Rd}} = \frac{|-14.03[kN]|}{131.78[kN]} = 0.11$$

$$V_{st,Rd} = \frac{A_{v,st} \times f_{yk}}{\sqrt{3} \times \gamma_{M0}} = \frac{288[mm^2] \times 320.0[MPa]}{\sqrt{3.00} \times 1.10} = 48.44[kN]$$

$$v_{act} = \frac{|V_{st,Ed}|}{V_{st,Rd}} = \frac{|-0.27[kN]|}{48.44[kN]} = 0.01$$

$$\alpha_{pl} = min\left(\frac{W_{pl,st}}{W_{el,st}}, 1, 25\right) = min\left(\frac{6509[mm^3]}{4800[mm^3]}, 1.25\right) = min(1.36, 1.25) = 1.25$$

$$M_{st,Rd} = \frac{\alpha_{pl} \times W_{el,st} \times f_{yk}}{\gamma_{M0}} = \frac{1.25 \times 4800[mm^3] \times 320.0[MPa]}{1.10} = 1.75[kNm]$$

$$m_{act} = \frac{|M_{st,Ed}|}{M_{st,Rd}} = \frac{|-0.03[kNm]|}{1.75[kNm]} = 0.02$$

$$m = 0.14$$

$$n = \frac{n_{act}}{m_{act}} \times m = \frac{0.11}{0.02} \times 0.14 = 0.91$$

$$a = \sqrt{m_{act}^2 + n_{act}^2} = \sqrt{0.02^{2.00} + 0.11^{2.00}} = 0.11$$

$$b = \sqrt{m^2 + n^2} = \sqrt{0.14^{2.00} + 0.91^{2.00}} = 0.92$$

$$I_S = \frac{a}{b} = \frac{0.11}{0.92} = 0.12$$

$$UC_{Interaction3} = I_S + 0,316 \times I_A = 0.12 + 0.32 \times 0.09 = \mathbf{0.15} \leq \mathbf{1.00}$$

(§3.2.2.2 Table 6)

You can also check the table results (these can be copy-pasted to Excel) and of course there is the opportunity to add the results to the Engineering report.