Verification of
Welded eaves moment connection of open sections

Ing. Lukáš Gödrich

June 2014

1 Description

The objective of this study: verification of CBFEM IDEARS software with component method. Description of verified connection: welded moment frame, horizontal beam is welded on the column flange, column stiffened with two horizontal stiffeners in levels of the beam flanges. Compressed parts are designed as maximal 3rd class to avoid stability problems (horizontal stiffeners of column, web panel in shear or compression, compressed beam flange). Horizontal beam is considered as both sides fixed beam of length 6m loaded by continuous load over the entire length=>vertical shear force and bending moment in the plane are of the same absolute values.

2 Analytical model

Component method

Six components is examined: fillet weld, web panel in shear, column web in transverse compression, column web in transverse tension, column flange in bending and beam flange in compression.

All components designed according to EN 1993-1-8.

Design loads of component depend on the position:

Web panel in shear– design loads on the vertical axis of the column

Other components- reduced design loads in column flange to which is connected horizontal beam.

3.1 Fillet weld

The weld is closed around a cross-section of the beam.

The thickness of the weld on the flanges can differ from the thickness of the weld on the web.

Vertical shear force is transferred only by welds on the web and plastic stress distribution is considered. Bending moment is transferred by whole weld shape and elastic stress distribution is considered.

Effective weld width depending on the horizontal stiffness of the column is considered (because of bending of the column flange).

Design of the weld is done according to EN1993-1-8 – 4.5.3.2(6).

The assessment is carried out in two major points: on the upper or lower edge of the flange (maximum bending stress) and in the crossing of the flange and the web (combination of shear force and bending moment stresses).

3.2 Web panel in shear

The thickness of the column web is designed to be maximally third class to avoid stability problem see EN1993-1-8 – 6.2.6.1(1).

Two contributions to the load capacity are considered: resistance of the column wall in shear and the contribution from the frame behaviour of the column flanges and horizontal stiffeners see EN1993-1-8 – 6.2.6.1(6.7 and 6.8).

3.3 Column web in transverse compression

Effect of the interaction of the shear load is considered see EN1993-1-8 – 6.2.6.2(tab. 6.3).

Influence of longitudinal stress in the wall of the column is considered see EN1993-1-8 – 6.2.6.2(2).

Horizontal stiffeners prevent from stability problem

The horizontal stiffeners are included in the load capacity of this component with the effective area.

3.4 Column web in transverse tension

Effect of the interaction of the shear load is considered see EN1993-1-8 – 6.2.6.2(tab. 6.3).

The horizontal stiffeners are included in the load capacity of this component with the effective area.

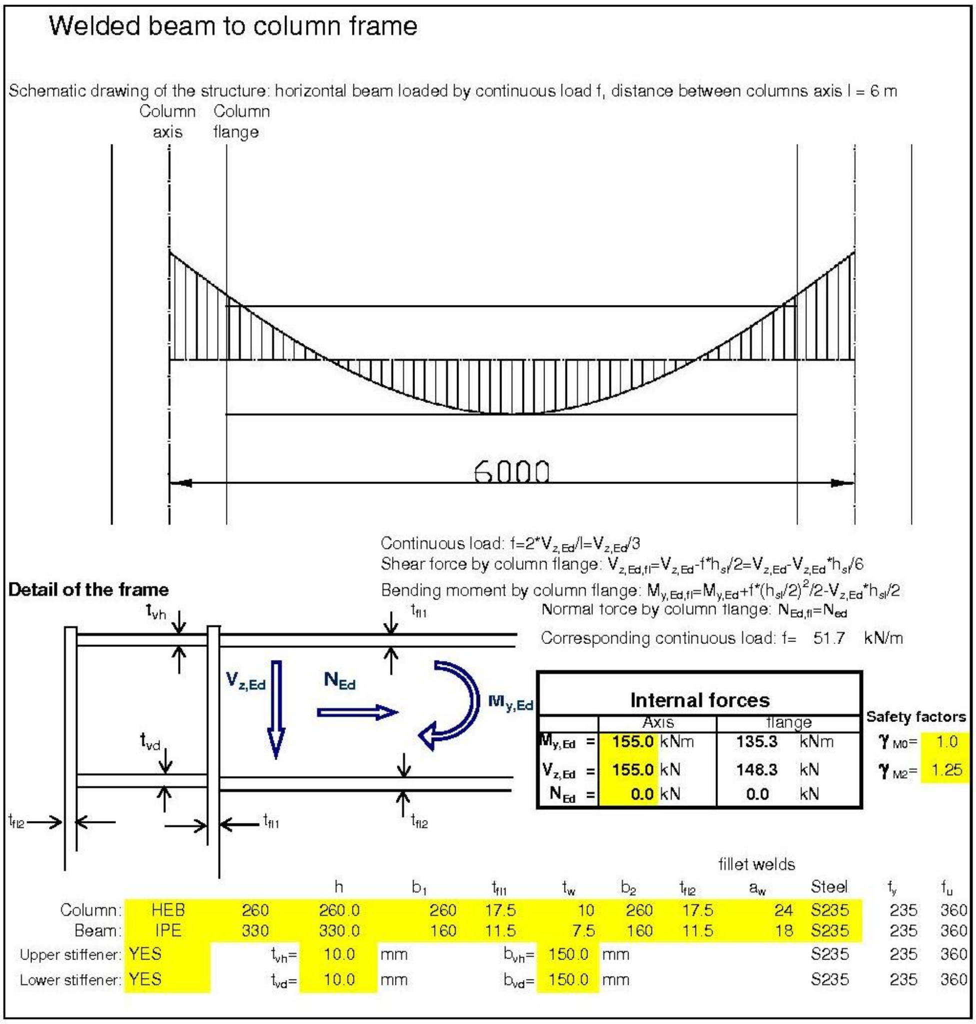
3.5 Column flange in bending

Horizontal stiffeners brace column flange, this component is not considered.

3.6 Beam flange in compression

The horizontal beam is designed to be maximally third class to avoid stability problem.

For better understanding of the component method design of the beam IPE330 to column HEB260 connection is shown below



Welded beam to column frame

Schematic drawing of the structure: horizontal beam loaded by continuous load f, distance between columns axis l = 6 m

Continuous load: $f=2*V_{z,Ed}/l=V_{z,Ed}/3$

Shear force by column flange: $V_{z,Ed,fl}=V_{z,Ed}-f*h_{sl}/2=V_{z,Ed}-V_{z,Ed}*h_{sl}/6$

Bending moment by column flange: $M_{y,Ed,fl}=M_{y,Ed}+f*(h_{sl}/2)^2/2-V_{z,Ed}*h_{sl}/2$

Normal force by column flange: $N_{Ed,fl}=N_{ed}$

Corresponding continuous load: f= 51.7 kN/m

Detail of the frame

Internal forces

	Axis		flange	
$M_{y,Ed}$ =	**155.0**	kNm	**135.3**	kNm
$V_{z,Ed}$ =	**155.0**	kN	**148.3**	kN
N_{Ed} =	**0.0**	kN	**0.0**	kN

Safety factors

γ_{M0}= 1.0

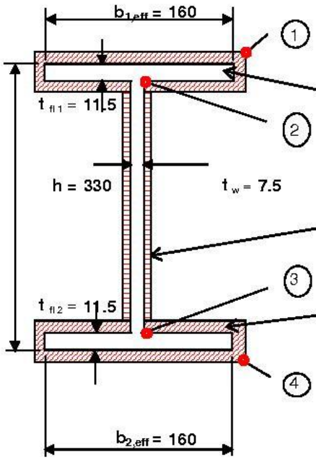
γ_{M2}= 1.25

			h		b_1	t_{fl1}	t_w	b_2	t_{fl2}	fillet welds a_w	Steel	f_y	f_u
Column:	HEB	260	260.0		260	17.5	10	260	17.5	24	S235	235	360
Beam:	IPE	330	330.0		160	11.5	7.5	160	11.5	18	S235	235	360
Upper stiffener:	YES	t_{vh}=	10.0	mm		b_{vh}=	150.0	mm			S235	235	360
Lower stiffener:	YES	t_{vd}=	10.0	mm		b_{vd}=	150.0	mm			S235	235	360

All assessments according to EN 1993-1-8

α= 1.0

$M_{y,Ed}$ = 135.3 kNm
$V_{z,Ed}$ = 148.3 kN
N_{Ed} = 0.0 kN



h = 330 mm
$b_{1,eff}$ = 160 mm
$t_{fl\,1}$ = 11.5 mm
$a_{w,\,fl\,1}$ = 6 mm
t_w = 7.5 mm
$a_{w,w}$ = 5 mm

$f_{y,k}$ = 235 MPa
f_u = 360 MPa
γ_{M2}= 1.25
β_w = 0.8

Distance of critical points to the center of gravity:

$b_{2,eff}$ = 160 mm
$t_{fl\,2}$ = 11.5 mm
$a_{w,\,fl\,2}$ = 6 mm

z_1 = 171.0 mm
z_2 = 153.5 mm
z_3 = 153.5 mm
z_4 = 171.0 mm

Profile:
A_{prof} = 5 983 mm^2
I_{prof} = 111 451 454 mm^4
$W_{h,prof}$ = 675 463 mm^3
$W_{d,prof}$ = 675 463 mm^3

Welds
A_w = 6 700 mm^2
I_w = 117 044 933 mm^4

Resistance of the weld 4.5.3.2(6) **Considered internal forces: by column flange**

Point ①

$\sigma_\perp = \tau_\perp =$	$M_{y,d}\ z_1 / (I_w \sqrt{2}) + N_d / (A_w \sqrt{2})=$	139.8	MPa	<	$0{,}9\ f_u\ / \gamma_{M2}$ =	259.2	MPa	
	Utilization		0.54	<	1.00			OK
	$\sqrt{\sigma_\perp^2 + 3\,\tau_\perp^2}$ =	279.5	MPa	<	$f_u\ / \beta_w / \gamma_{M2}$ =	360.0	MPa	
	Utilization		0.78	<	1.00			OK

Point ②

$\tau_{/\!/}$ =	$V_{z,d} / (2a_{w,w}\,(h - t_{fl\,1} - t_{fl\,2}))$ =	48.3	MPa					
$\sigma_\perp = \tau_\perp =$	$M_{y,d}\ z_2 / (I_w \sqrt{2}) + N_d / (A_w \sqrt{2})=$	125.5	MPa	<	$0{,}9\ f_u\ / \gamma_{M2}$ =	259.2	MPa	
	Utilization		0.48	<	1.00			OK
	$\sqrt{\sigma_\perp^2 + 3\,(\tau_\perp^2 + \tau_{/\!/}^2)}$ =	264.5	MPa	<	$f_u\ / \beta_w / \gamma_{M2}$ =	360.0	MPa	
	Utilization		0.73	<	1.00			OK

Point ③

$\tau_{/\!/}$ =	$V_{z,d} / (2a_{w,w}\,(h - t_{fl\,1} - t_{fl\,2}))$ =	48.3	MPa					
$\sigma_\perp = \tau_\perp =$	$M_{y,d}\ z_3 / (I_w \sqrt{2}) - N_d / (A_w \sqrt{2})=$	125.5	MPa	<	$0{,}9\ f_u\ / \gamma_{M2}$ =	259.2	MPa	
	Utilization		0.48	<	1.00			OK
	$\sqrt{\sigma_\perp^2 + 3\,(\tau_\perp^2 + \tau_{/\!/}^2)}$ =	264.5	MPa	<	$f_u\ / \beta_w / \gamma_{M2}$ =	360.0	MPa	
	Utilization		0.73	<	1.00			OK

Point ④

$\sigma_\perp = \tau_\perp =$	$M_{y,d}\ z_4 / (I_w \sqrt{2}) - N_d / (A_w \sqrt{2})=$	139.8	MPa	<	$0{,}9\ f_u\ / \gamma_{M2}$ =	259.2	MPa	
	Utilization		0.54	<	1.00			OK
	$\sqrt{\sigma_\perp^2 + 3\,\tau_\perp^2}$ =	279.5	MPa	<	$f_u\ / \beta_w / \gamma_{M2}$ =	360.0	MPa	
	Utilization		0.78	<	1.00			OK

Weld is OK

Web panel in shear

6.2.6.1 **Considered internal forces: in column axis**

Slenderness of the panel:

$d/t_w =$ 17.7 $<$ $69\,\varepsilon =$ 69.0 OK 6.2.6.1(1)

Design shear load:

$V_{wp,Ed} = M_{y,Ed}/(h - t_{fl\,1}/2 - t_{fl\,2}/2) =$ 487 kN

Design web panel resistance:

$V_{wp,Rd} = 0{,}9 f_{y,wc} A_{vc}/(\sqrt{3}\,\gamma_{M0}) =$ **454 kN** 6.2.6.1(6.7)

Contribution of stiffners+flanges frame:

Column flanges plastic resistance in bending:

$M_{pl,fc1,Rd} = 0{,}25 b_1 t_{fl,1}^2 f_{y,fc}/\gamma_{M0} =$ 4.7 kNm

$M_{pl,fc2,Rd} = 0{,}25 b_2 t_{fl,2}^2 f_{y,fc}/\gamma_{M0} =$ 4.7 kNm

Stiffners plastic resistance in bending:

$M_{pl,sth,Rd} = 0{,}25 b_{vh} t_{vh}^2 f_{y,vh}/\gamma_{M0} =$ 0.88125 kNm

$M_{pl,std,Rd} = 0{,}25 b_{vd} t_{vd}^2 f_{y,vd}/\gamma_{M0} =$ 0.88125 kNm

Contribution of frame behavior to the total shear resistance:

$V_{wp,add,Rd,1} = 4 M_{pl,fc,Rd}/d_s =$ 59 kN Distance between stiffeners:

$V_{wp,add,Rd,2} = (2 M_{pl,fc,Rd} + 2 M_{pl,st,Rd})/d_s =$ 35 kN $d_s =$ 319 mm

Minimum of both values: $V_{wp,add,Rd,min} =$ **35 kN** 6.2.6.1(6.8)

Assessment:

$V_{wp,Rd} + V_{wp,add,Rd,min} =$ **489** kN **>** $V_{wp,Ed} =$ **487** kN

Utilization **1.00 < 1.00** OK

Column web in compression

6.2.6.2 **Considered internal forces: by column flange**

Design compression load:

$N_{c,wc,Ed} = M_{y,Ed,pásn}/(h - t_{fl\,1}/2 - t_{fl\,2}/2) - N_{Ed} {}^* A_{fb}/A_b =$ 425 kN

$b_{eff,c,wc} = t_{fb} + 2\sqrt{2}\, a_b + 5(t_{fc} + s) =$ 236 mm 6.2.6.2(6.10)

Reduction factor ω considering the possible effect of interaction with shear:

$\beta =$ 1 => $\omega = \omega_1 = 1/\sqrt{(1 + 1{,}3(b_{eff,c,wc}\, t_{wc}/A_{vc})^2)} =$ 0.695 6.2.6.2(tab. 6.3)

Reduction buckling factor 6.2.6.2(6.13):

Plate slenderness: $\lambda_p = 0{,}932\sqrt{(b_{eff,c,wc}\, d_{wc}\, f_{y,wc}/(E t_{wc}^2))} =$ 0.637

Buckling factor: $\rho = (\lambda_p - 0{,}2)/\lambda_p^2 =$ 1.000

Reduction factor k_{wc} 6.2.6.2(2):

Longitudinal compressive stress in column wall: $\sigma_{com,Ed} = M_{y,Ed}/I_c {}^* d_{wc}/2 + V_{z,Ed}/A_c =$ 96 MPa **<** $0{,}7 f_{y,wc} =$ 164.5 MPa

$k_{wc} =$ 1

Design resistance of unstiffened web in compression:

$F_{c,wc,Rd} = \rho\, \omega\, k_{wc}\, b_{eff,c,wc}\, t_{wc}\, f_{y,wc} / \gamma_{M0} =$ **385** **kN** 6.2.6.2(6.9)

Design resistance of stiffened web in compression:

$F_{c,wc,Rd} = \omega\, k_{wc}\, A_{eff,c,wc}\, f_{y,wc} / \gamma_{M0} =$ **630** **kN** $A_{eff,c,wc} = b_{eff,c,wc}\, t_{wc} + b_{vd}\, t_{vd} =$ 3860 mm^2

Assessment:

$F_{c,wc,Rd} =$ **630** kN **>** $N_{c,wc,Ed} =$ **425** kN

Utilization **0.67 < 1.00** OK

Column web in tension

6.2.6.3 **Considered internal forces: by column flange**

Design tension load:

$N_{t,wc,Ed}=M_{y,Ed,pásn}/(h-t_{fl\,1}/2-t_{fl\,2}/2)+N_{Ed}*A_{fb}/A_b=$ 425 kN

$b_{eff,t,wc}=t_{fb}+2\sqrt{2}\,a_b+5(t_{fc}+s)=$ 236 mm 6.2.6.3(6.16)

Reduction factor ω considering the possible effect of interaction with shear:

$\beta=$ 1 => $\omega=\omega_1=1/\sqrt{(1+1{,}3(b_{eff,t,wc}\,t_{wc}/A_{vc})^2)}=$ 0.695 6.2.6.2(tab. 6.3)

Design resistance of unstiffened web in tension:

$F_{t,wc,Rd}=\omega\,b_{eff,t,wc}\,t_{wc}\,f_{y,wc}\,/\,\gamma_{M0}=$ **385** **kN** 6.2.6.3(6.15)

Design resistance of stiffened web in tension:

$F_{t,wc,Rd}=\omega\,A_{eff,t,wc}\,f_{y,wc}\,/\,\gamma_{M0}=$ **630** **kN** $A_{eff,t,wc}=b_{eff,t,wc}\,t_{wc}+b_{vh}\,t_{vh}=$ 3860 mm^2

Assessment:

$F_{t,wc,Rd}=$ **630** kN **>** $N_{t,wc,Ed}=$ **425** kN

Utilization **0.67 < 1.00** **OK**

Column flange in bending

6.2.6.4 **Considered internal forces: by column flange**

By upper beam flange - tension zone:

Design load: $N_{fc,Ed}=N_{t,wc,Ed}=$ 0 kN **The flange is stiffened, is not examined!!**

$b_{eff,b,fc}=b_{1,eff}=$ 160 mm 4.10 (2)

Design resistance of unstiffened flange in bending: 6.2.6.4.3

$F_{fc,Rd}=b_{eff,b,fc}\,t_{fb}\,f_{y,fb}\,/\,\gamma_{M0}=$ **432** **kN**

Assessment:

$F_{fc,Rd}=$ **432** kN **>** $N_{fc,Ed}=$ **0** kN

Utilization **0.00 < 1.00** **OK**

By lower beam flange - compression zone:

Design load: $N_{fc,Ed}=N_{c,wc,Ed}=$ 0 kN **The flange is stiffened, is not examined!!**

$b_{eff,b,fc}=b_{2,eff}=$ 160 mm 4.10 (2)

Design resistance of unstiffened flange in bending: 6.2.6.4.3

$F_{fc,Rd}=b_{eff,b,fc}\,t_{fb}\,f_{y,fb}\,/\,\gamma_{M0}=$ **432** **kN**

Assessment:

$F_{fc,Rd}=$ **432** kN **>** $N_{fc,Ed}=$ **0** kN

Utilization **0.00 < 1.00** **OK**

Beam flange in compression

6.2.6.7 **Considered internal forces: by column flange**

Design load: $N_{c,fb,Ed}=N_{c,wc,Ed}=$ 425 kN

D. res. of beam in bending: $M_{c,Rd}=$ 189 kNm Class of beam: 1

Design resistance: $F_{c,fb,Rd}=M_{c,Rd}\,/(h-t_{fl1}/2-t_{fl2}/2)=$ **593** **kN** 6.2.6.7 (6.21)

Assessment:

$F_{c,fb,Rd}=$ **593** kN **>** $N_{c,fb,Ed}=$ **425** kN

Utilization **0.72 < 1.00** **OK**

4 Results by CBFEM Idea RS software

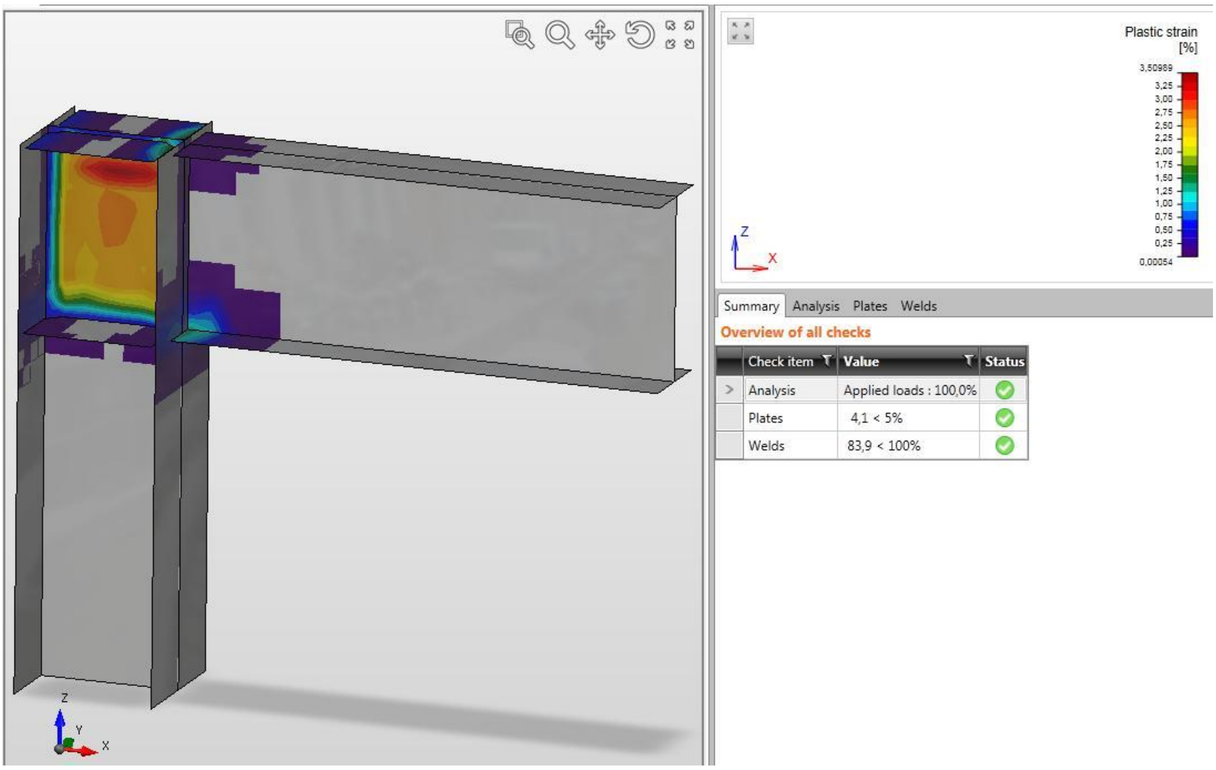
CBFEM - combination of the advantages of finite element method and analytical component method.

Shell elements, special spring and contact elements with characteristics according to the component method.

Elastic-plastic stress-strain diagram for material of shell elements. Assessment is based on the maximum strain given according to EN1993-1-5by value of 5%.

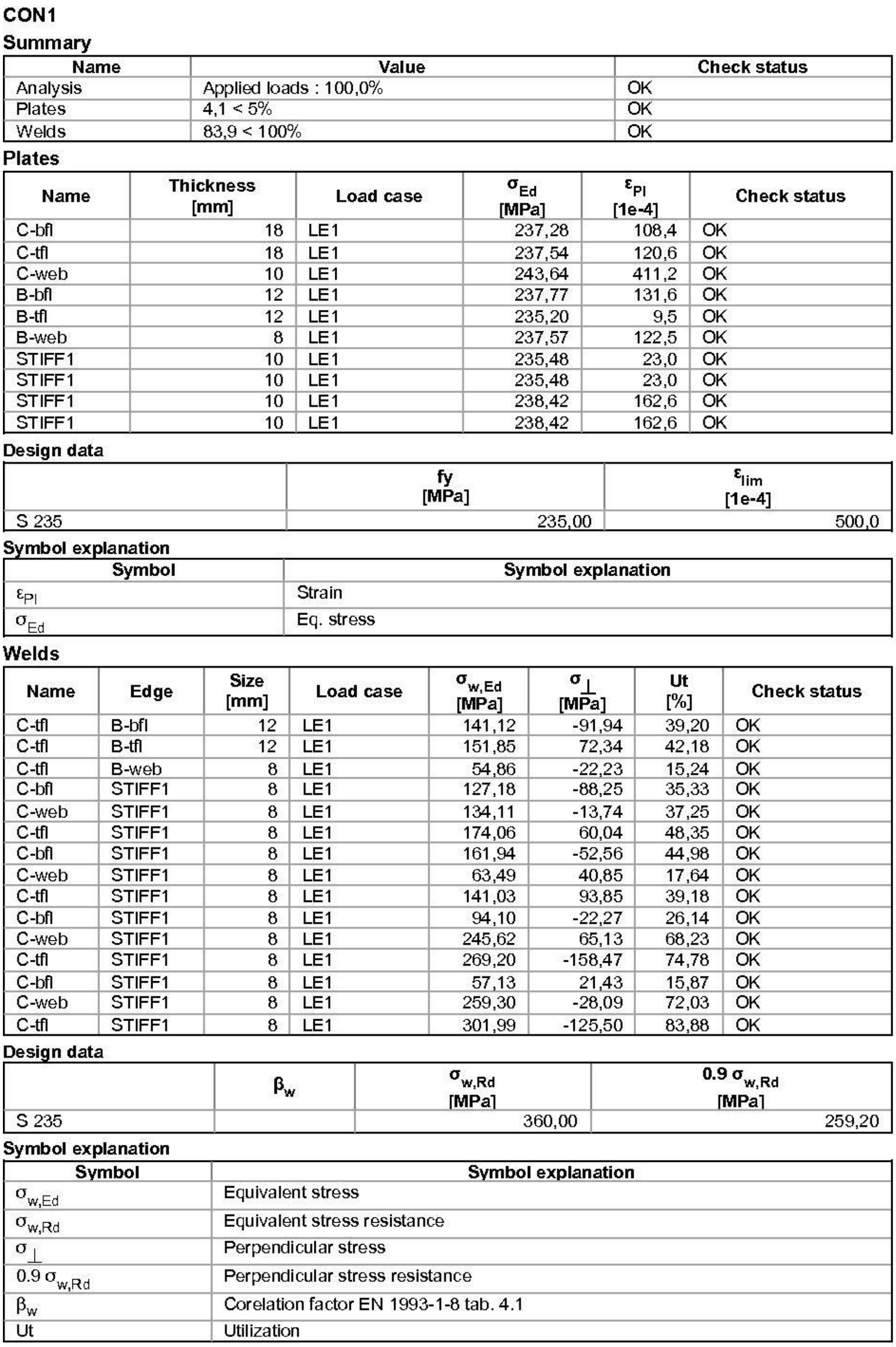
Bolts are modelled using special spring elements and assessment is carried out according to standard procedures described in EN1993-1-8.

Result of Idea RS software for the beam IPE330 to column HEB260 connection is shown below.



Overview of all checks

Check item	Value	Status
Analysis	Applied loads : 100,0%	✓
Plates	4,1 < 5%	✓
Welds	83,9 < 100%	✓



CON1

Summary

Name	Value	Check status
Analysis	Applied loads : 100,0%	OK
Plates	4,1 < 5%	OK
Welds	83,9 < 100%	OK

Plates

Name	Thickness [mm]	Load case	σ_{Ed} [MPa]	ε_{Pl} [1e-4]	Check status
C-bfl	18	LE1	237,28	108,4	OK
C-tfl	18	LE1	237,54	120,6	OK
C-web	10	LE1	243,64	411,2	OK
B-bfl	12	LE1	237,77	131,6	OK
B-tfl	12	LE1	235,20	9,5	OK
B-web	8	LE1	237,57	122,5	OK
STIFF1	10	LE1	235,48	23,0	OK
STIFF1	10	LE1	235,48	23,0	OK
STIFF1	10	LE1	238,42	162,6	OK
STIFF1	10	LE1	238,42	162,6	OK

Design data

	fy [MPa]	ε_{lim} [1e-4]
S 235	235,00	500,0

Symbol explanation

Symbol	Symbol explanation
ε_{Pl}	Strain
σ_{Ed}	Eq. stress

Welds

Name	Edge	Size [mm]	Load case	$\sigma_{w,Ed}$ [MPa]	$\sigma_{\perp}$ [MPa]	Ut [%]	Check status
C-tfl	B-bfl	12	LE1	141,12	-91,94	39,20	OK
C-tfl	B-tfl	12	LE1	151,85	72,34	42,18	OK
C-tfl	B-web	8	LE1	54,86	-22,23	15,24	OK
C-bfl	STIFF1	8	LE1	127,18	-88,25	35,33	OK
C-web	STIFF1	8	LE1	134,11	-13,74	37,25	OK
C-tfl	STIFF1	8	LE1	174,06	60,04	48,35	OK
C-bfl	STIFF1	8	LE1	161,94	-52,56	44,98	OK
C-web	STIFF1	8	LE1	63,49	40,85	17,64	OK
C-tfl	STIFF1	8	LE1	141,03	93,85	39,18	OK
C-bfl	STIFF1	8	LE1	94,10	-22,27	26,14	OK
C-web	STIFF1	8	LE1	245,62	65,13	68,23	OK
C-tfl	STIFF1	8	LE1	269,20	-158,47	74,78	OK
C-bfl	STIFF1	8	LE1	57,13	21,43	15,87	OK
C-web	STIFF1	8	LE1	259,30	-28,09	72,03	OK
C-tfl	STIFF1	8	LE1	301,99	-125,50	83,88	OK

Design data

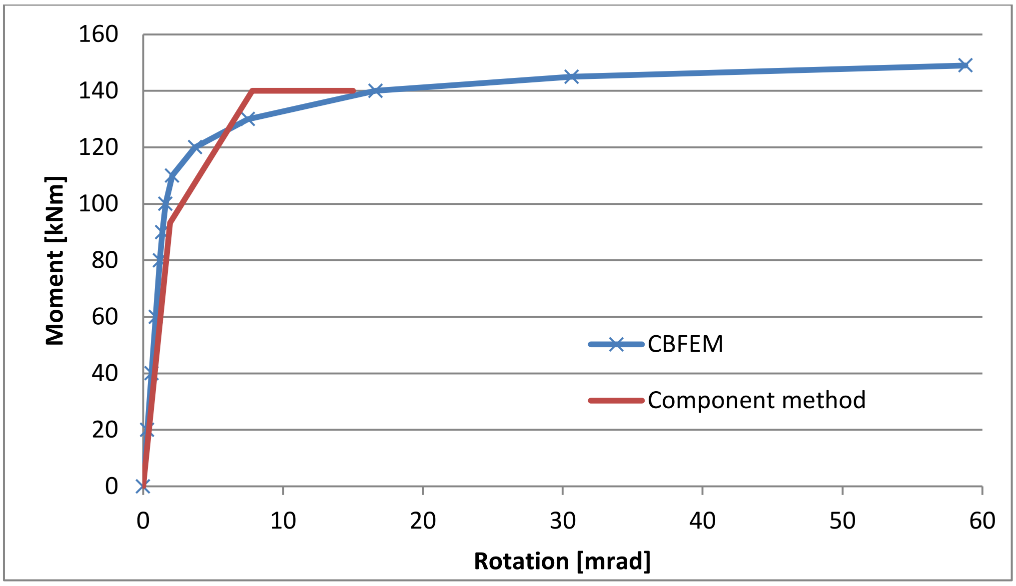
	β_w	$\sigma_{w,Rd}$ [MPa]	$0.9\ \sigma_{w,Rd}$ [MPa]
S 235		360,00	259,20

Symbol explanation

Symbol	Symbol explanation
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$0.9\ \sigma_{w,Rd}$	Perpendicular stress resistance
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization

5 Global behaviour and verification

Comparison of the global behaviour of the joint described by moment-rotation diagrams for both design procedures mentioned above was done. Attention was focused on the main characteristics of the moment-rotation diagram: initial stiffness, elastic resistance and design resistance. Connection of the beam IPE330 to column HEB260 was chosen as a sample. Joint with horizontal stiffeners in column is considered according to component method as a rigid joint with $S_{j,ini}=\infty$. For this reason, a joint without horizontal stiffeners in column is used for this global behaviour study. Results of both design procedures are shown in the graph and the table below. Both procedures give for initial stiffness, elastic resistance and design resistance similar results. In addition, maximal rotation is compared. Component method gives for maximal rotation only guaranteed minimal value 15 mrad see EN 1993-1-8 - 6.4.3(2) and that is the reason of much lower value compared to CBFEM.



		CM	CBFEM	CM/CBFEM
Initial stiffness	[kNm/rad]	48423.7	66889.6	0.72
Elastic resistance	[kNm]	93.3	90.0	1.04
Design resistance	[kNm]	140.0	149.0	0.94
Maximal rotation	[mrad]	15.0	58.8	0.26

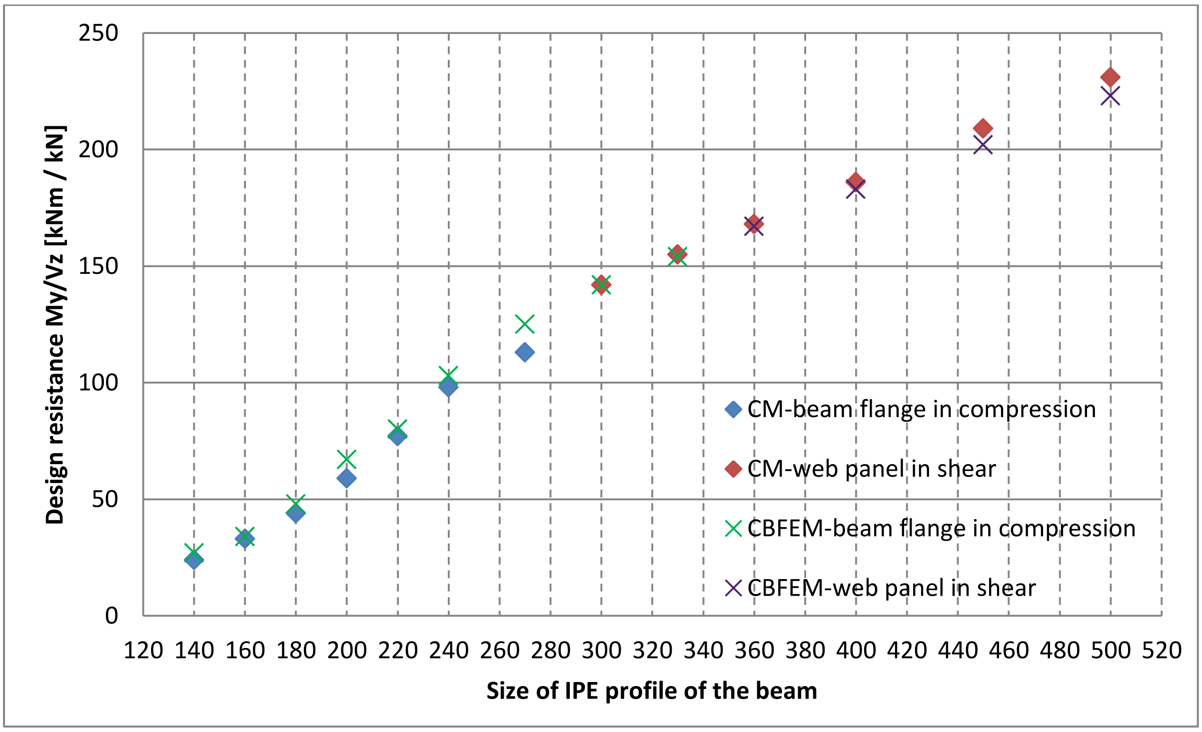
6 Verification of resistance

Design resistance calculated by CBFEM Idea RS software were compared with the results of the component method in the next step. The comparison was focused on capacity and also to determine the critical component.

The study was performed for three different parameters: beam cross-section, column cross section and thickness of the column wall.

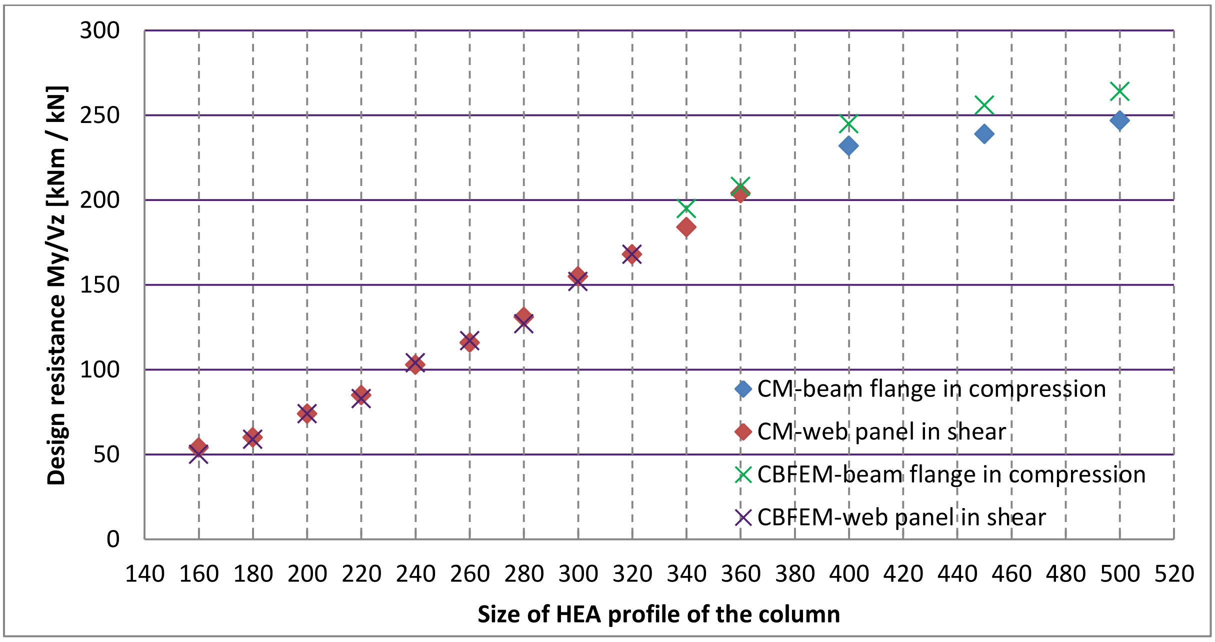
In the first case with parameter beam cross-section was a column cross-section HEB260 and horizontal column stiffener thick was 10 mm and width corresponding to the width of beam flange. IPE sections were selected for horizontal beam from IPE140 to IPE500. The results are shown in table and graph.

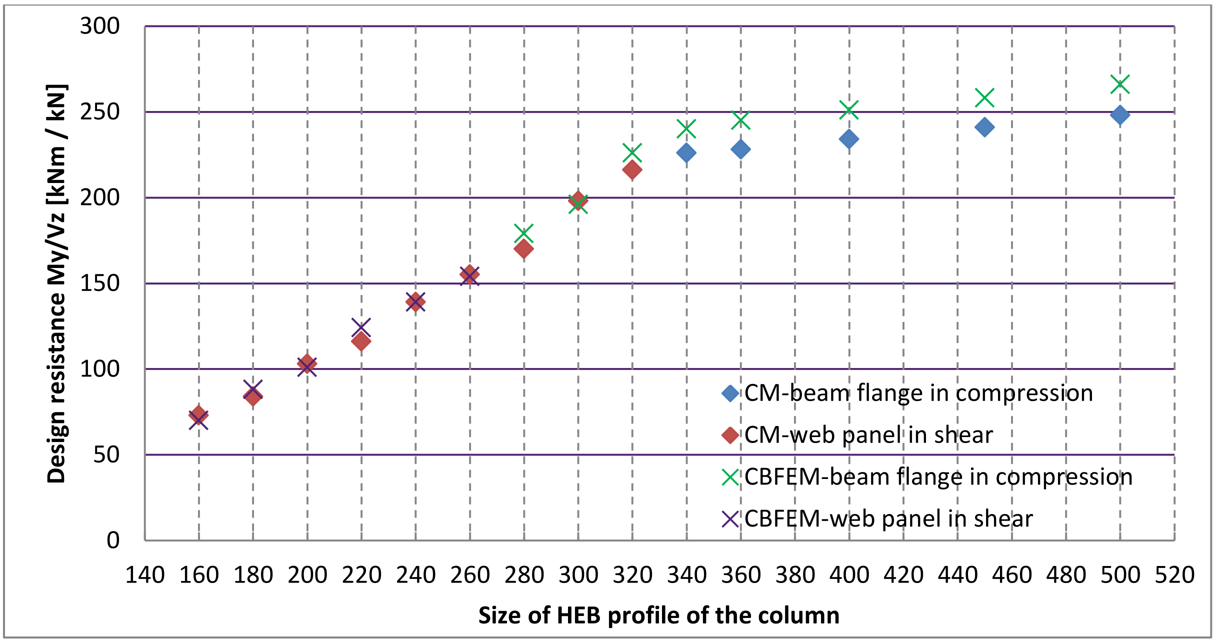
Parameter	Component method		CBFEM-Idea RS	
	Resistance [kN/kNm]	Critical component	Resistance [kN/kNm]	Critical component
IPE140	24	Beam flange in compression	27	Beam flange in compression
IPE160	33	Beam flange in compression	34	Beam flange in compression
IPE180	44	Beam flange in compression	48	Beam flange in compression
IPE200	59	Beam flange in compression	67	Beam flange in compression
IPE220	77	Beam flange in compression	80	Beam flange in compression
IPE240	98	Beam flange in compression	103	Beam flange in compression
IPE270	113	Beam flange in compression	125	Beam flange in compression
IPE300	142	Web panel in shear	142	Beam flange in compression
IPE330	155	Web panel in shear	154	Beam flange in compression
IPE360	168	Web panel in shear	167	Web panel in shear
IPE400	186	Web panel in shear	183	Web panel in shear
IPE450	209	Web panel in shear	202	Web panel in shear
IPE500	231	Web panel in shear	223	Web panel in shear



In the second case with parameter column cross-section was a beam cross-section IPE 330 and horizontal column stiffener thick was 10 mm and width 160 mm. HEA and HEB cross-sections were selected for horizontal beam from HEA 160 to HEA 500 and from HEB 160 to HEB 500. The results are shown in table and graphs.

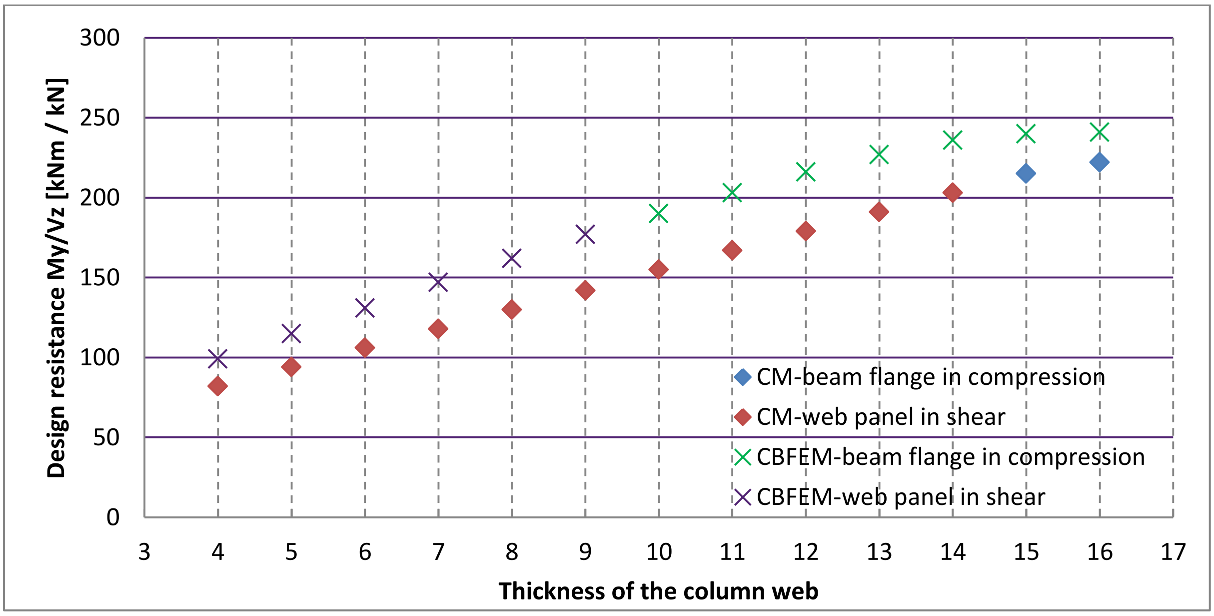
Parameter	Component method		CBFEM-Idea RS	
	Resistance [kN/kNm]	Critical component	Resistance [kN/kNm]	Critical component
HEA160	54	Web panel in shear	50	Web panel in shear
HEA180	60	Web panel in shear	59	Web panel in shear
HEA200	74	Web panel in shear	74	Web panel in shear
HEA220	85	Web panel in shear	83	Web panel in shear
HEA240	103	Web panel in shear	104	Web panel in shear
HEA260	116	Web panel in shear	117	Web panel in shear
HEA280	131	Web panel in shear	127	Web panel in shear
HEA300	155	Web panel in shear	152	Web panel in shear
HEA320	168	Web panel in shear	168	Web panel in shear
HEA340	184	Web panel in shear	195	Beam flange in compression
HEA360	204	Web panel in shear	208	Beam flange in compression
HEA400	232	Beam flange in compression	245	Beam flange in compression
HEA450	239	Beam flange in compression	256	Beam flange in compression
HEA500	247	Beam flange in compression	264	Beam flange in compression
HEB160	73	Web panel in shear	70	Web panel in shear
HEB180	84	Web panel in shear	88	Web panel in shear
HEB200	103	Web panel in shear	101	Web panel in shear
HEB220	116	Web panel in shear	124	Web panel in shear
HEB240	139	Web panel in shear	139	Web panel in shear
HEB260	155	Web panel in shear	154	Web panel in shear
HEB280	170	Web panel in shear	179	Beam flange in compression
HEB300	198	Web panel in shear	196	Beam flange in compression
HEB320	216	Web panel in shear	226	Beam flange in compression
HEB340	226	Beam flange in compression	240	Beam flange in compression
HEB360	228	Beam flange in compression	245	Beam flange in compression
HEB400	234	Beam flange in compression	251	Beam flange in compression
HEB450	241	Beam flange in compression	258	Beam flange in compression
HEB500	248	Beam flange in compression	266	Beam flange in compression



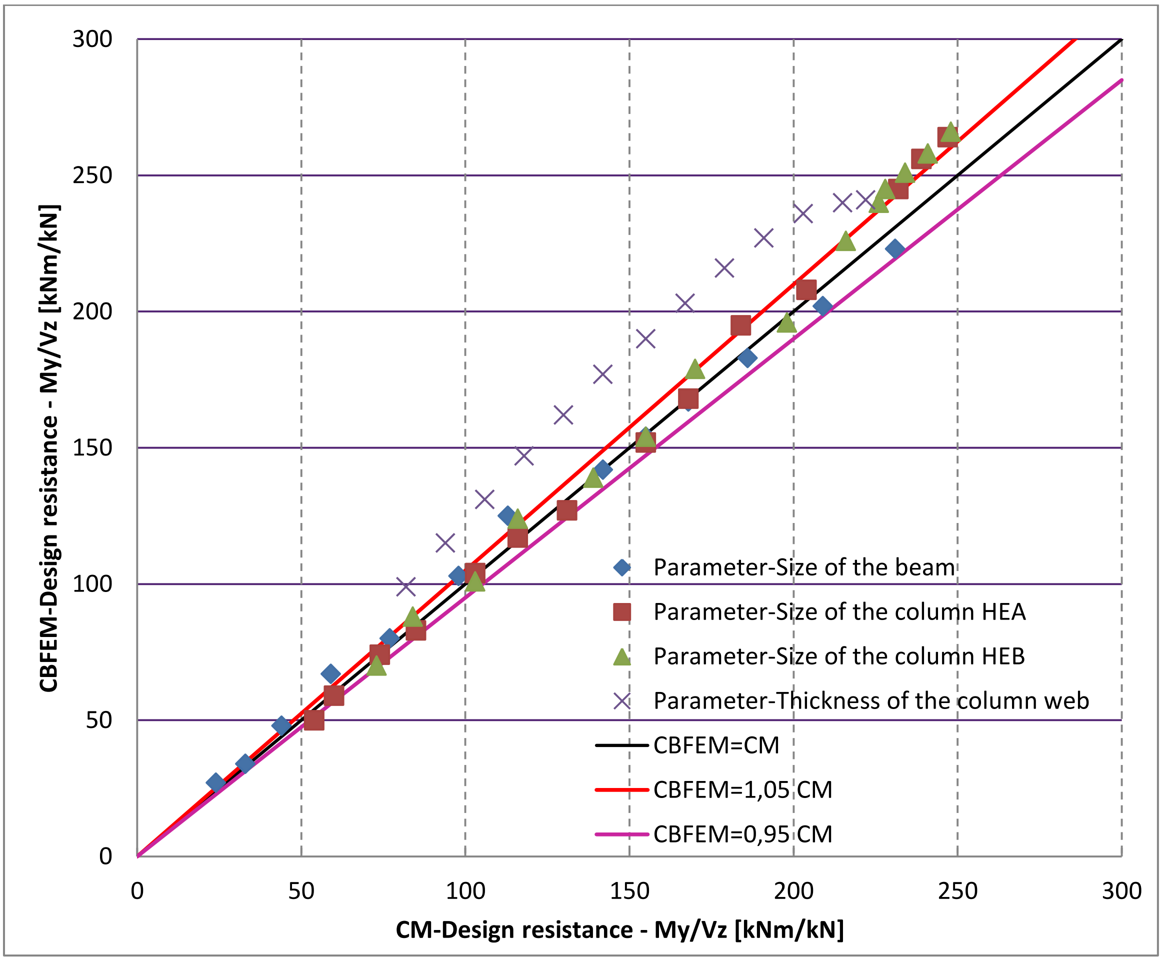


In the third case with parameter thickness of the column wall was a beam cross-section IPE 330 and column cross-section dimensions corresponded to HEA 320 except the wall thickness. Horizontal column stiffener thick was 10 mm and width 160 mm. The wall thickness was chosen from 4 mm to 16 mm with increments of 1 mm. The results are shown in table and graph.

Parameter	Component method		CBFEM-Idea RS	
	Resistance [kN/kNm]	Critical component	Resistance [kN/kNm]	Resistance [kN/kNm]
4	82	Web panel in shear	99	Web panel in shear
5	94	Web panel in shear	115	Web panel in shear
6	106	Web panel in shear	131	Web panel in shear
7	118	Web panel in shear	147	Web panel in shear
8	130	Web panel in shear	162	Web panel in shear
9	142	Web panel in shear	177	Web panel in shear
10	155	Web panel in shear	190	Beam flange in compression
11	167	Web panel in shear	203	Beam flange in compression
12	179	Web panel in shear	216	Beam flange in compression
13	191	Web panel in shear	227	Beam flange in compression
14	203	Web panel in shear	236	Beam flange in compression
15	215	Beam flange in compression	240	Beam flange in compression
16	222	Beam flange in compression	241	Beam flange in compression



To illustrate the accuracy of the CBFEM model, results of the parametric studies were summarized in graph comparing resistance by CBFEM and component method. The results show that the difference of the two calculation methods is up to 5%, which is a generally acceptable value. Except the study with wall thickness parameter where CBFEM model gives higher resistance compared to component method. This difference is caused by considering welded cross-sections. For welded cross-section is in component method for transfer of shear load considered only web and contribution of the flanges is neglected.



7 Reliability

Reliability of CBFEM software is provided in accordance with the strategy of EC considering partial safety factors. Inputs of internal loads are entered as design values with the load factor and combination coefficient. Material safety factors according to EN1993-1-8 are used for design resistance of the connection. For bolts and welds γ_M=1,25 and for plates γ_M=1,0.

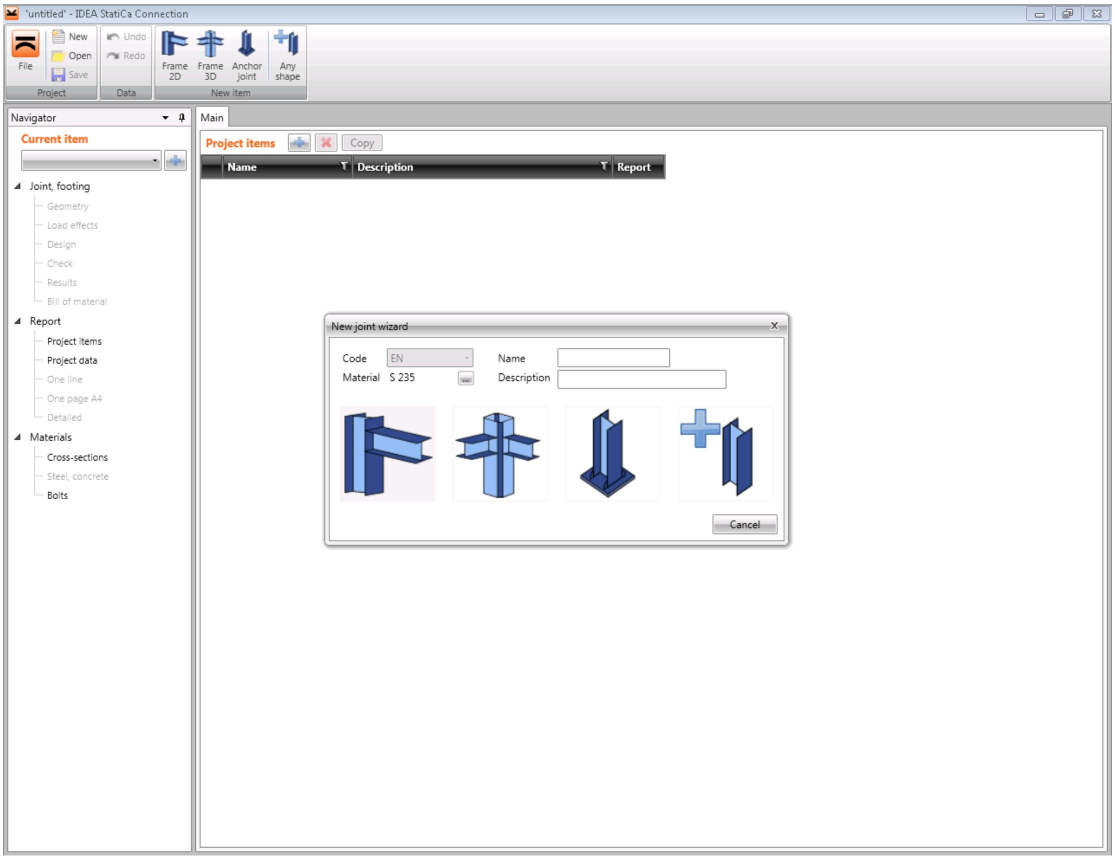
8 Résumé

Verification studies confirmed the accuracy of the CBFEM IDEA RS software. Results of this software were compared with the results of the component method recommended in EN1993-1-8. Both procedures predict similar global behaviour of the joint. Except the study with web thickness parameter is the difference in design resistance of the two calculation methods up to 5%, which is a generally acceptable value. Higher resistance by CBFEM IDEA RS software compared to component method for study with web thickness parameter is caused by conservative calculation of component method for welded cross-sections.

Reliability of CBFEM software is provided in accordance with the strategy of EC considering partial safety factors.

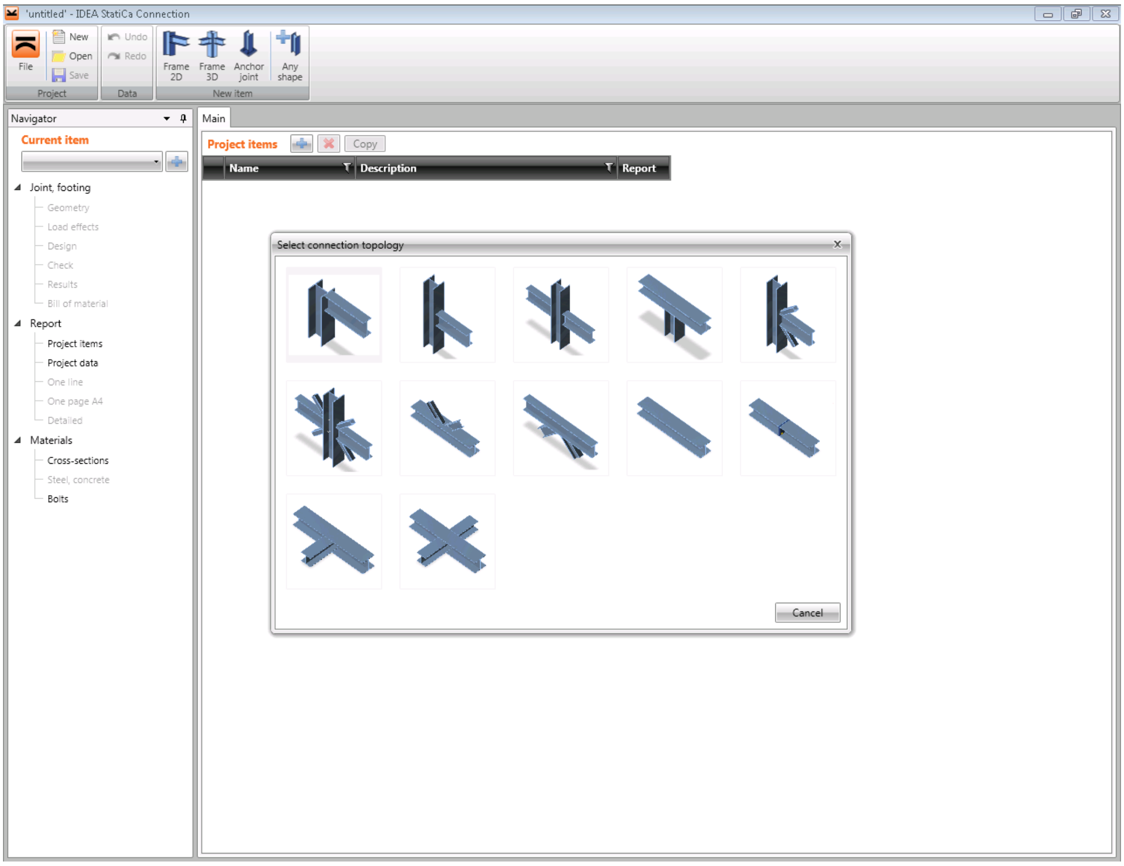
9 Benchmark example

Choise of the geometry:

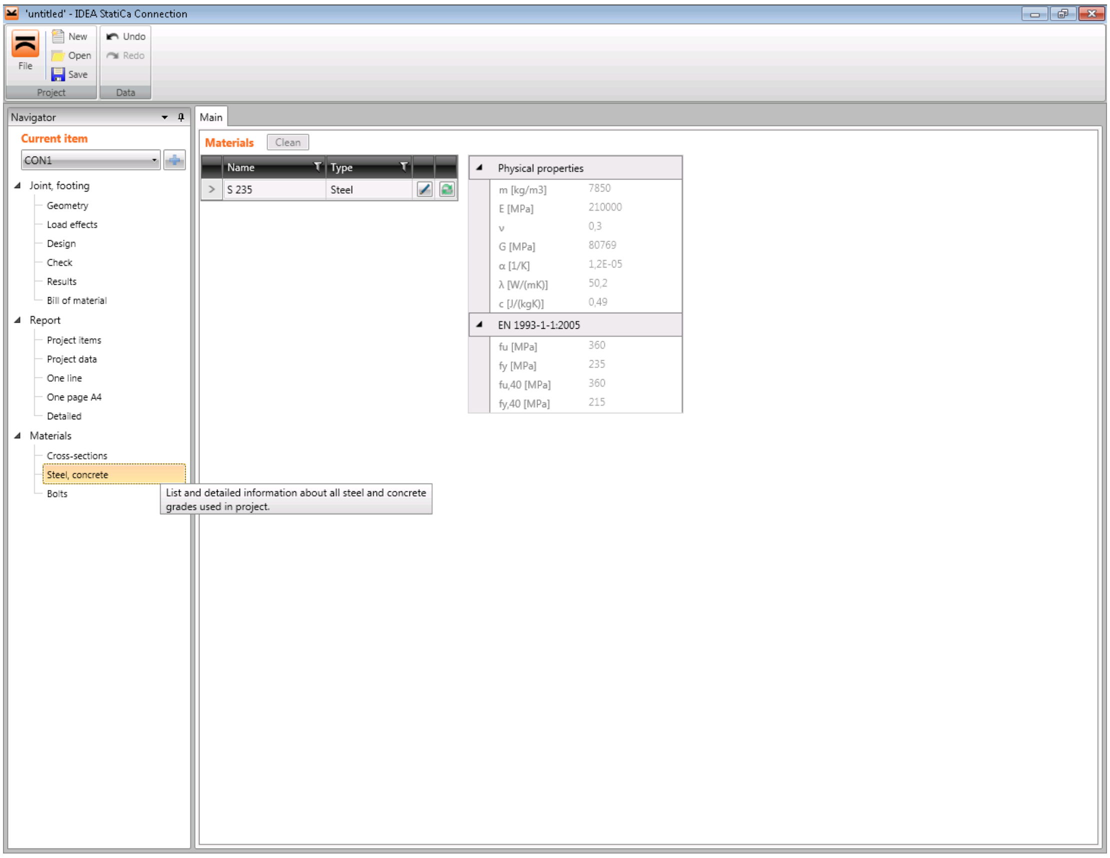


Code EN

Material S 235



Setting of the material:

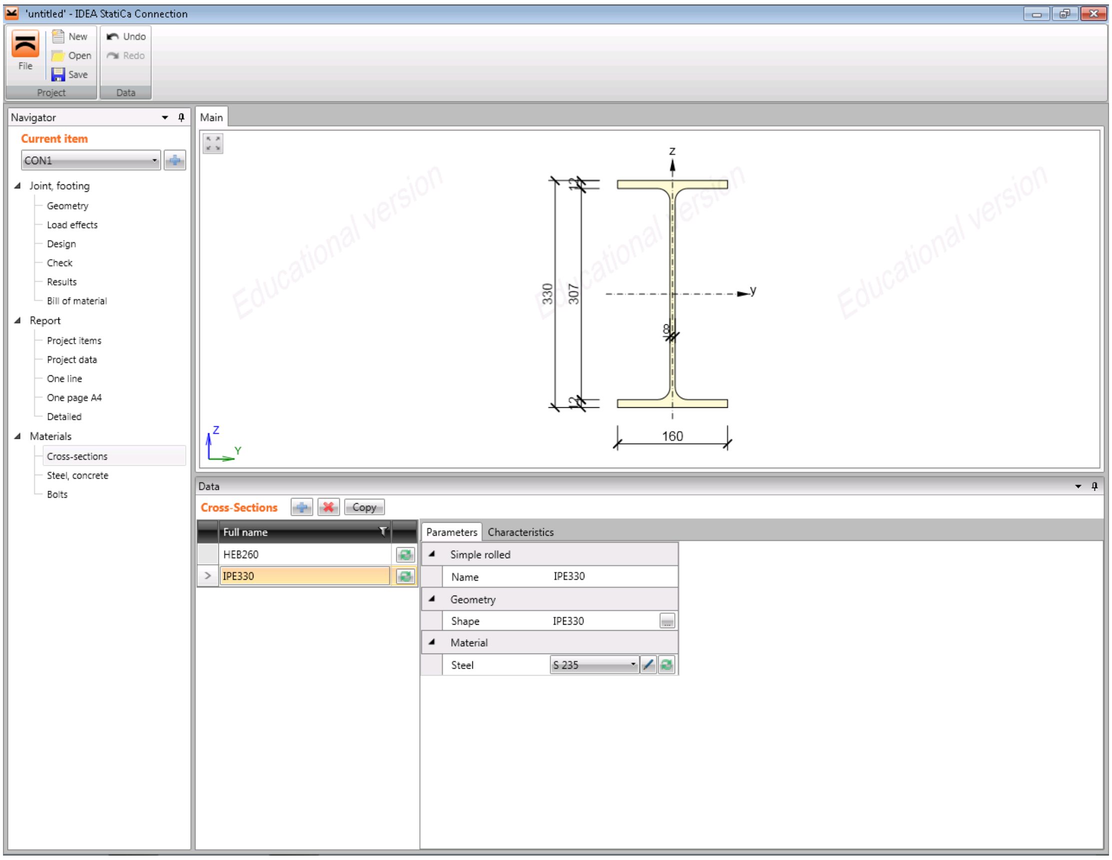


Name	Type
S 235	Steel

Physical properties	
m [kg/m3]	7850
E [MPa]	210000
v	0,3
G [MPa]	80769
α [1/K]	1,2E-05
λ [W/(mK)]	50,2
c [J/(kgK)]	0,49
EN 1993-1-1:2005	
fu [MPa]	360
fy [MPa]	235
fu,40 [MPa]	360
fy,40 [MPa]	215

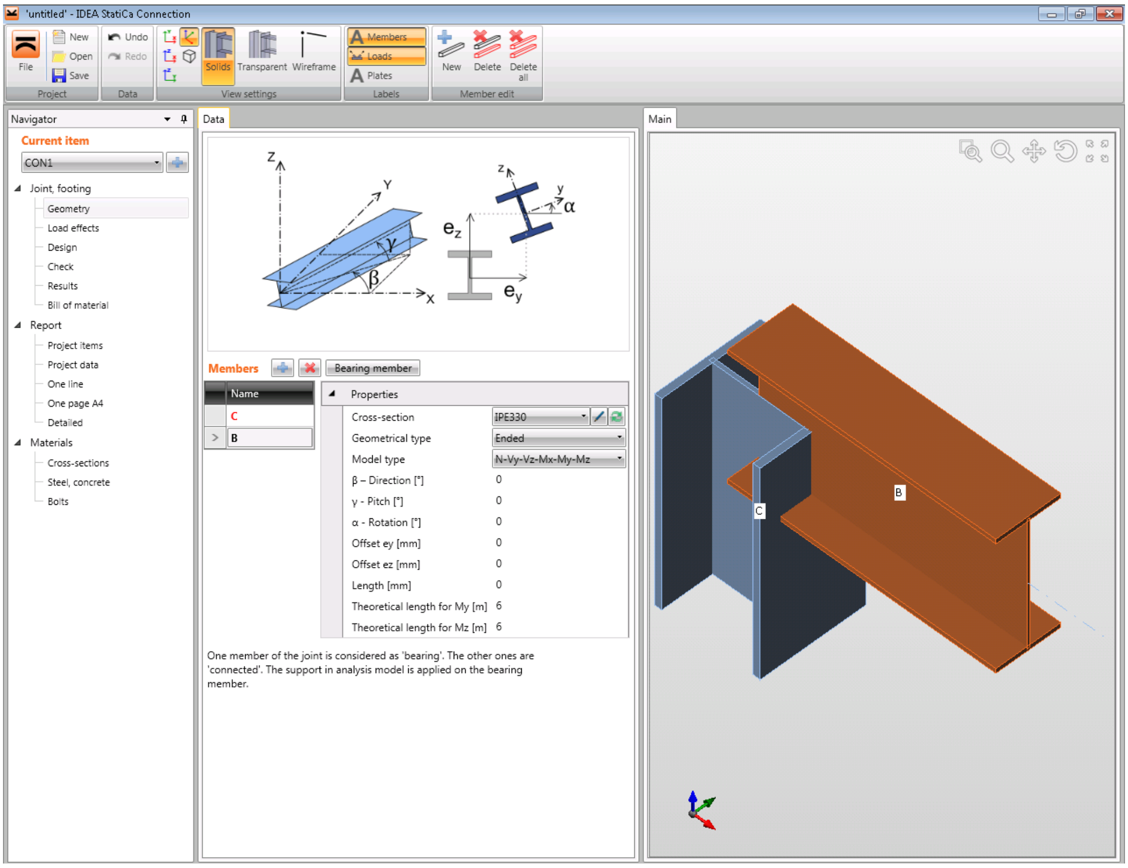
List and detailed information about all steel and concrete grades used in project.

Setting of the cross-sections:



Full name
HEB260
IPE330

Simple rolled	
Name	IPE330
Geometry	
Shape	IPE330
Material	
Steel	S 235



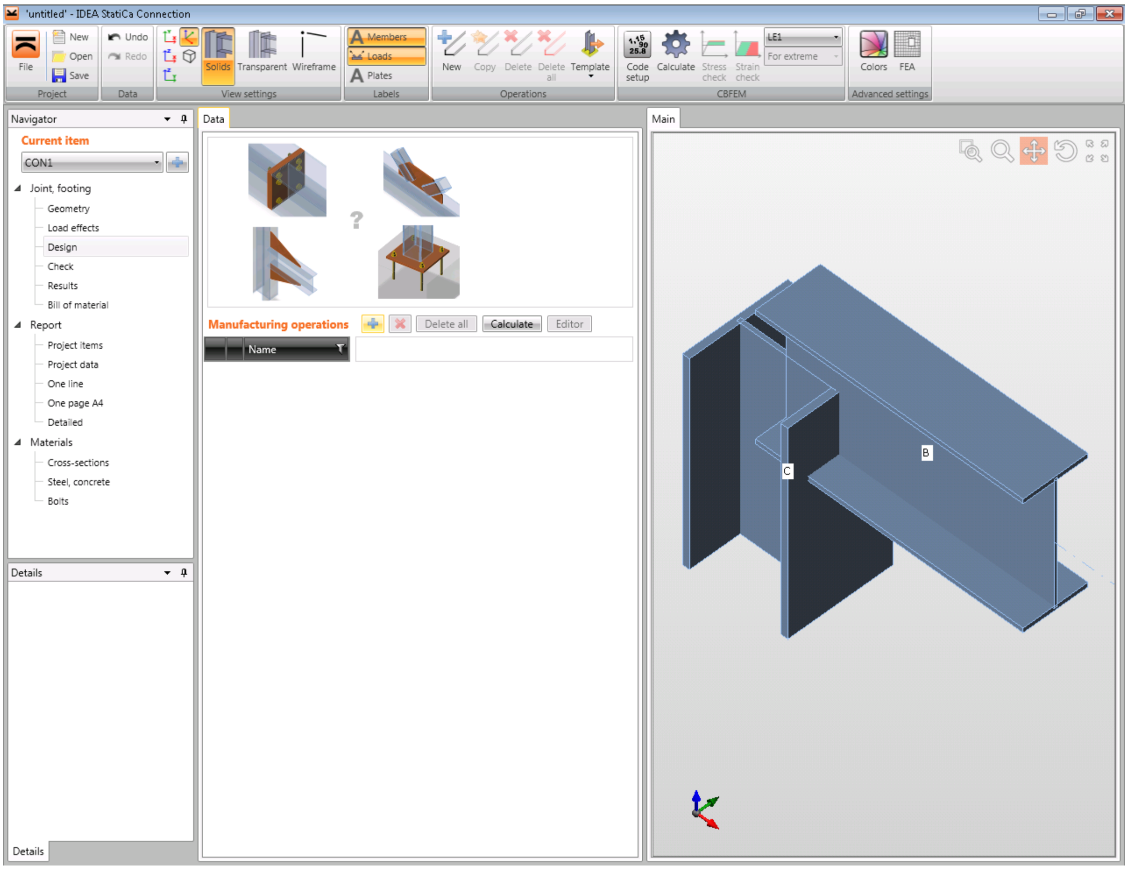
Members Bearing member

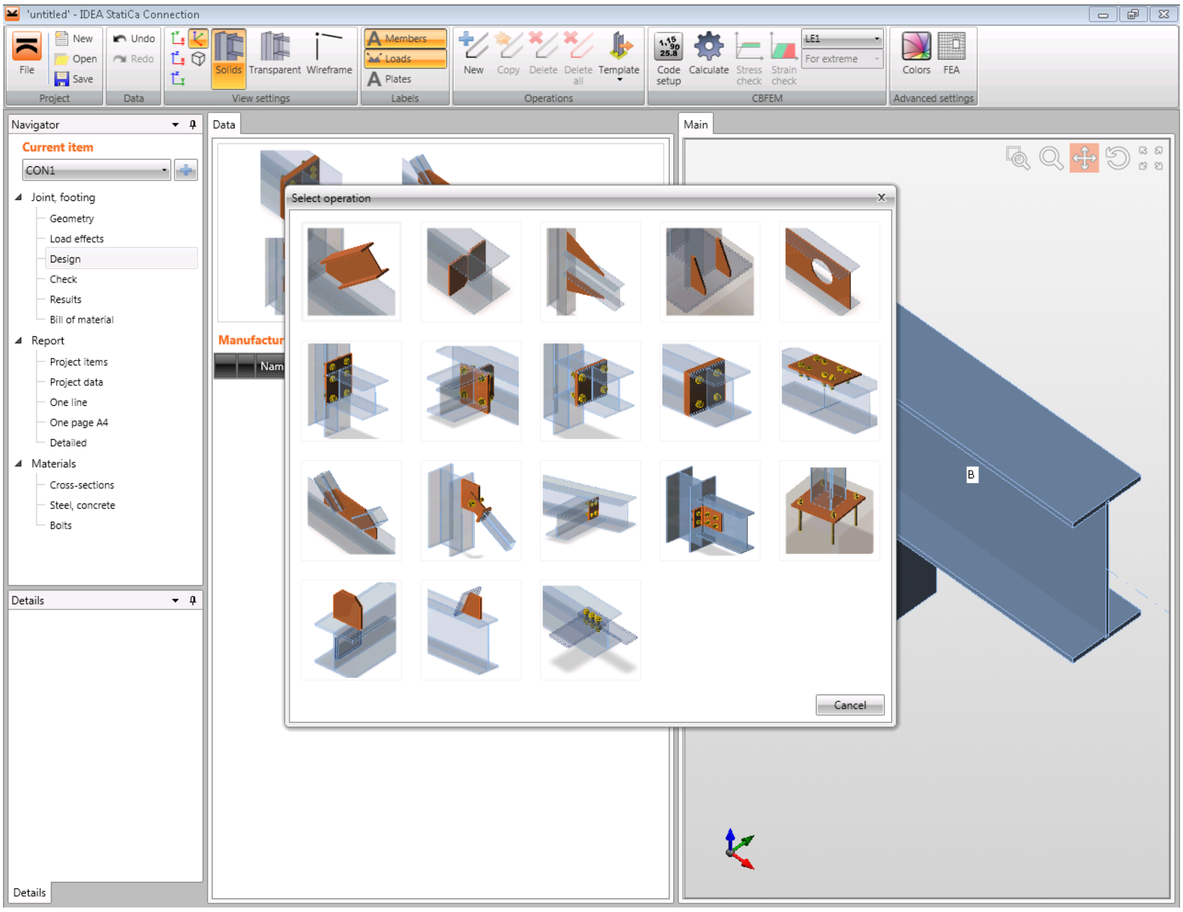
Name
C
B

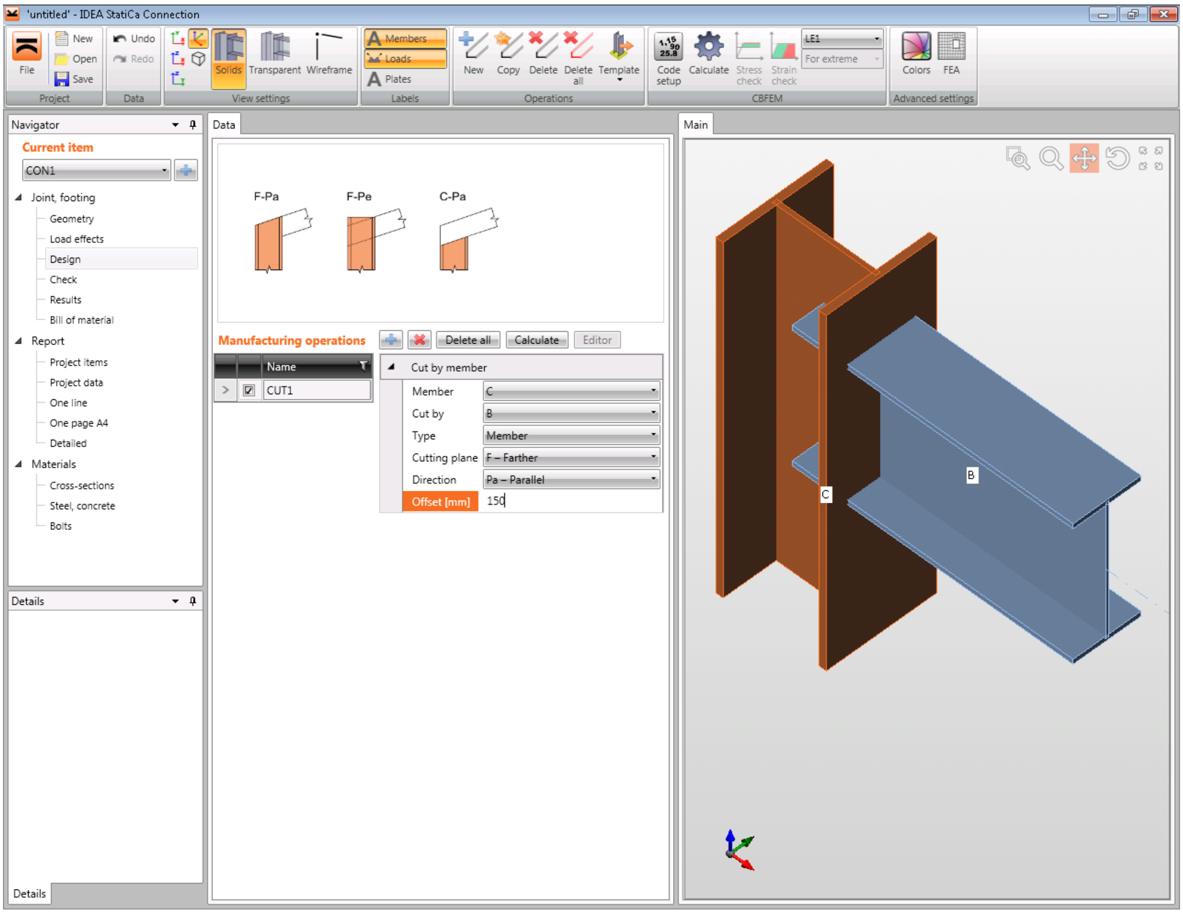
Properties	
Cross-section	IPE330
Geometrical type	Ended
Model type	N-Vy-Vz-Mx-My-Mz
β – Direction [°]	0
γ - Pitch [°]	0
α - Rotation [°]	0
Offset ey [mm]	0
Offset ez [mm]	0
Length [mm]	0
Theoretical length for My [m]	6
Theoretical length for Mz [m]	6

One member of the joint is considered as 'bearing'. The other ones are 'connected'. The support in analysis model is applied on the bearing member.

Cutting of the profiles, setting of the welds:

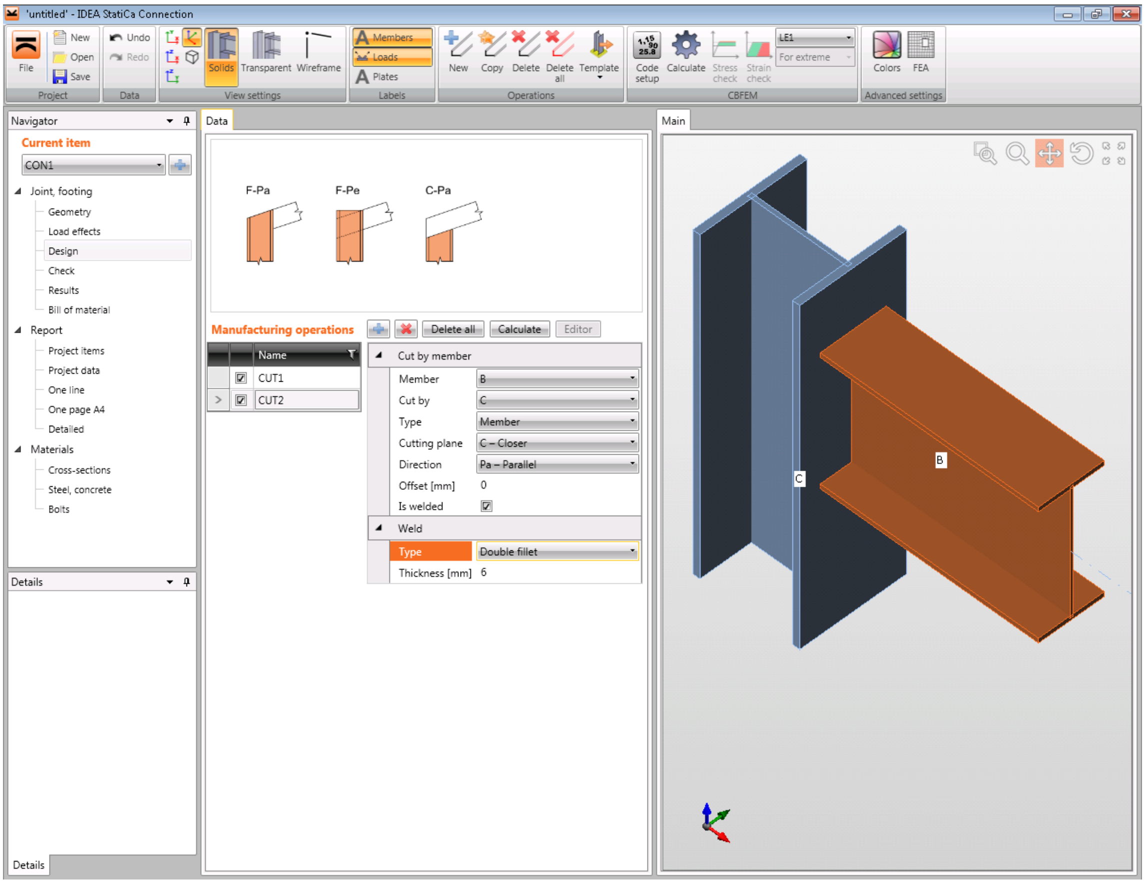






Cut by member

Member	C
Cut by	B
Type	Member
Cutting plane	F – Farther
Direction	Pa – Parallel
Offset [mm]	150



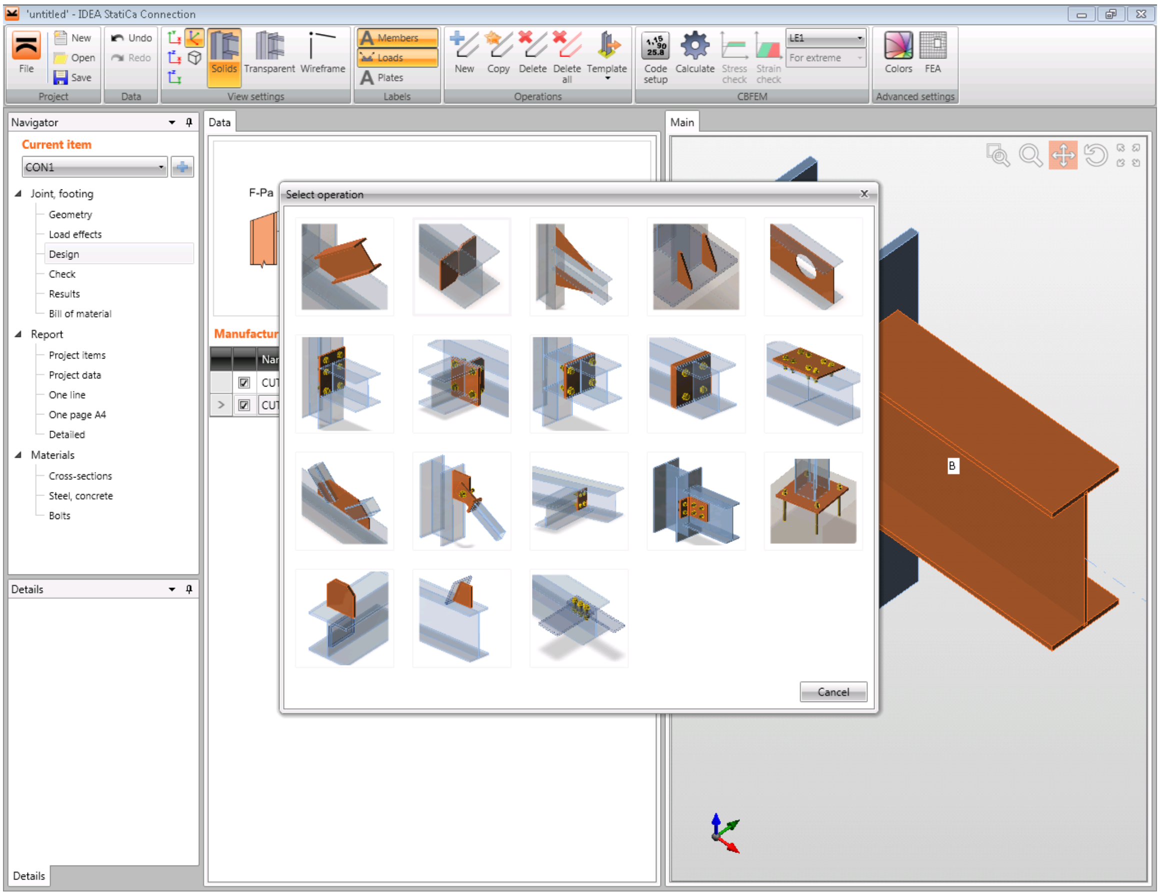
Manufacturing operations

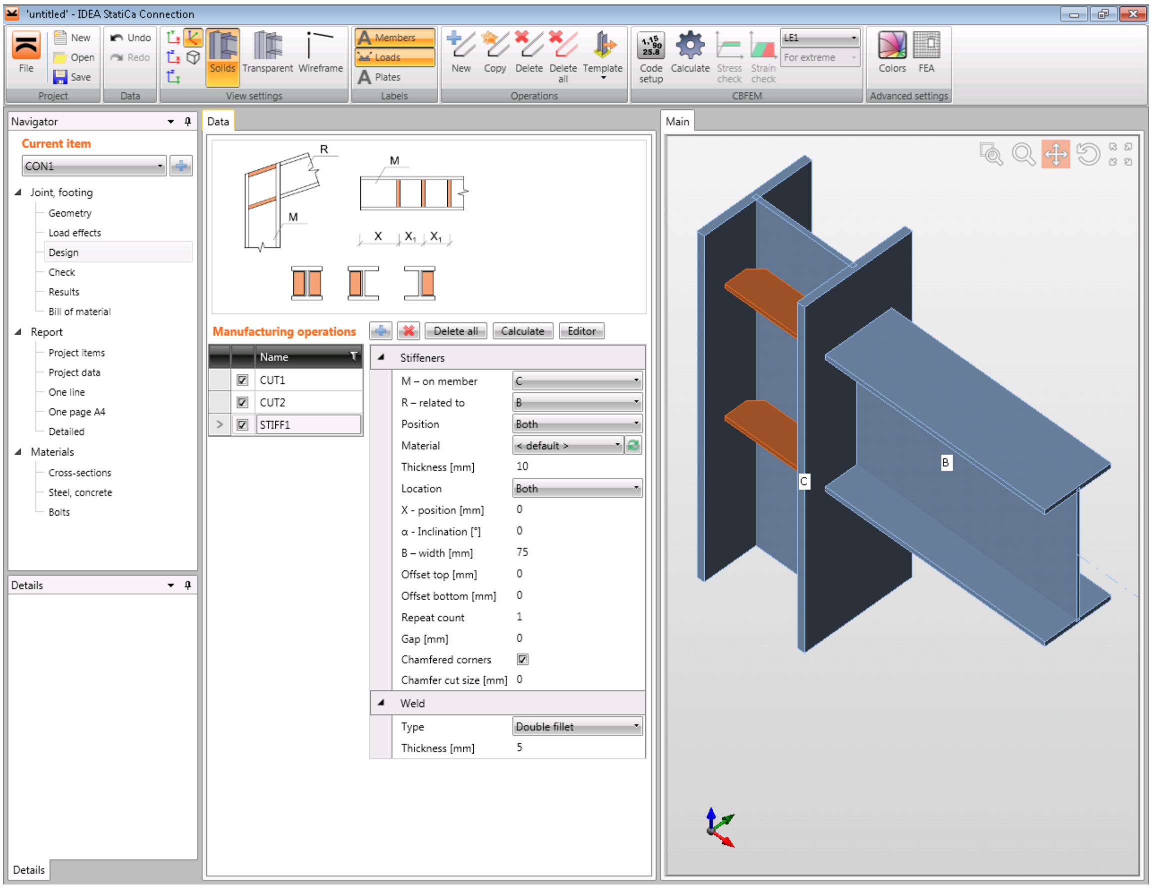
	Name
☑	CUT1
☑	CUT2

Cut by member
- Member: B
- Cut by: C
- Type: Member
- Cutting plane: C – Closer
- Direction: Pa – Parallel
- Offset [mm]: 0
- Is welded: ☑

Weld
- Type: Double fillet
- Thickness [mm]: 6

Adding of the horizontal stiffeners of column:





Manufacturing operations

		Name
	☑	CUT1
	☑	CUT2
>	☑	STIFF1

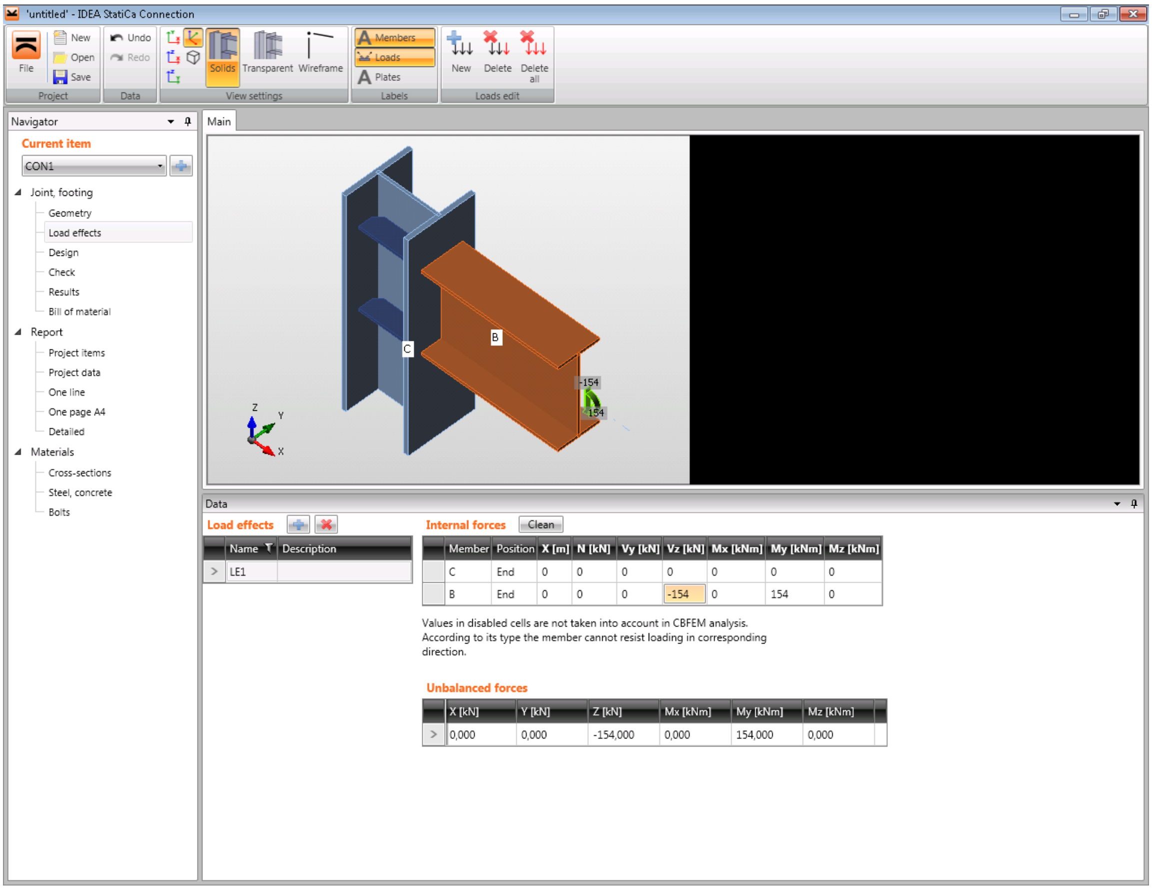
Stiffeners

M – on member	C
R – related to	B
Position	Both
Material	< default >
Thickness [mm]	10
Location	Both
X - position [mm]	0
α - Inclination [°]	0
B – width [mm]	75
Offset top [mm]	0
Offset bottom [mm]	0
Repeat count	1
Gap [mm]	0
Chamfered corners	☑
Chamfer cut size [mm]	0

Weld

Type	Double fillet
Thickness [mm]	5

Setting of the loads:



Load effects

	Name	Description
>	LE1	

Internal forces

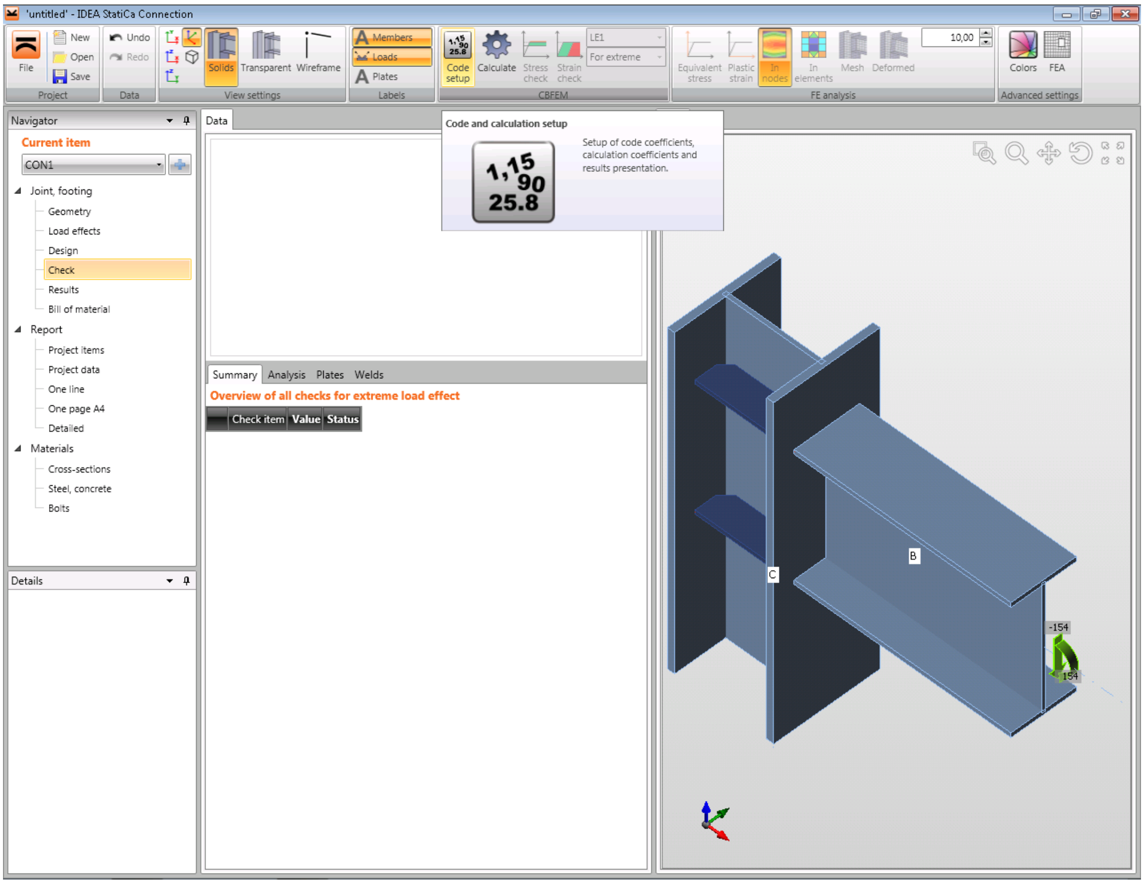
	Member	Position	X [m]	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
	C	End	0	0	0	0	0	0	0
	B	End	0	0	0	-154	0	154	0

Values in disabled cells are not taken into account in CBFEM analysis. According to its type the member cannot resist loading in corresponding direction.

Unbalanced forces

	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
>	0,000	0,000	-154,000	0,000	154,000	0,000

Setting of the calculation:



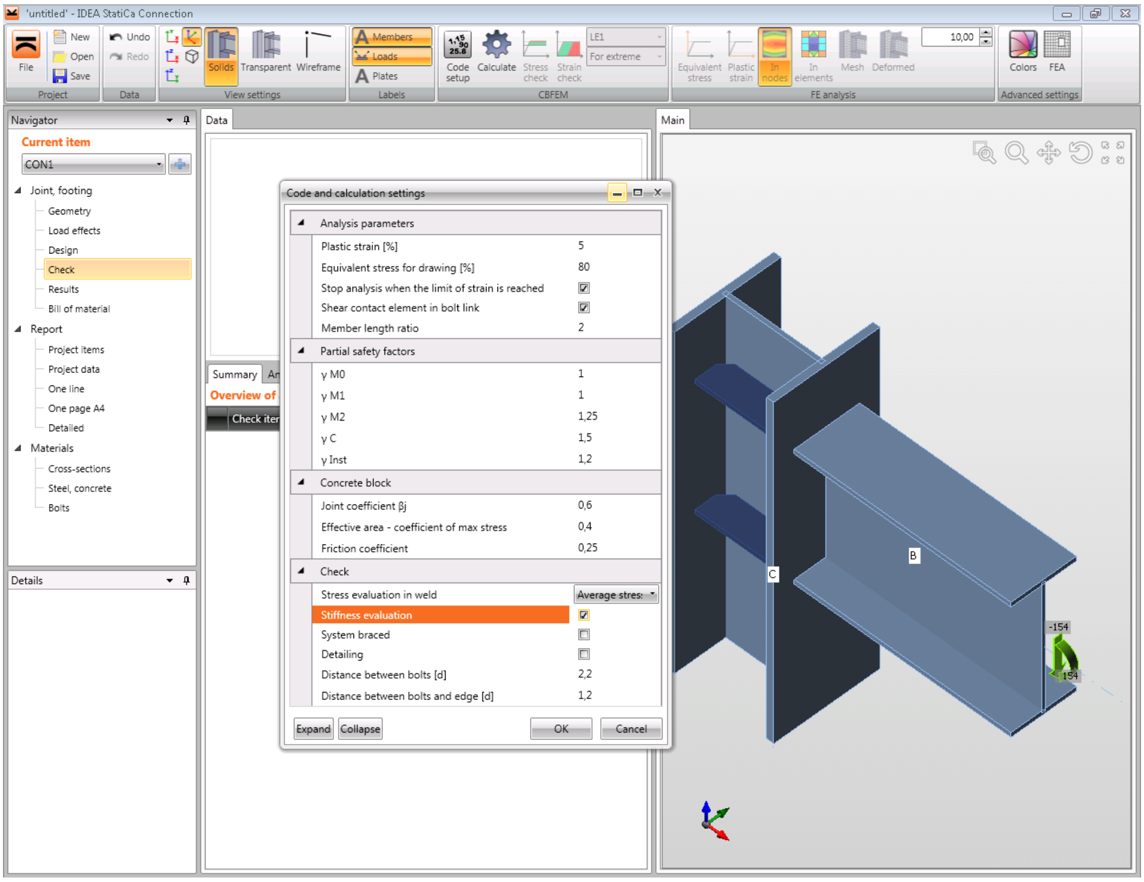
'untitled' - IDEA StatiCa Connection

Code and calculation setup

Setup of code coefficients, calculation coefficients and results presentation.

Overview of all checks for extreme load effect

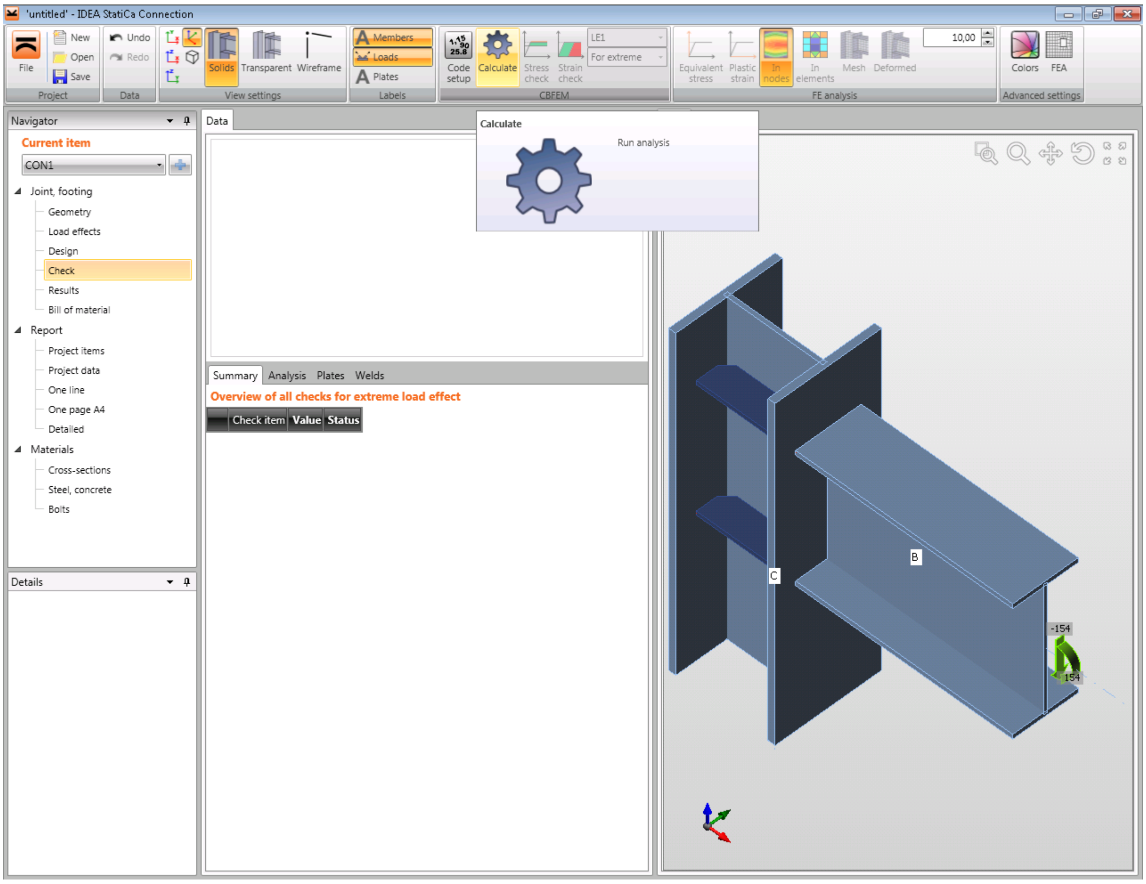
Check item	Value	Status



'untitled' - IDEA StatiCa Connection

Code and calculation settings

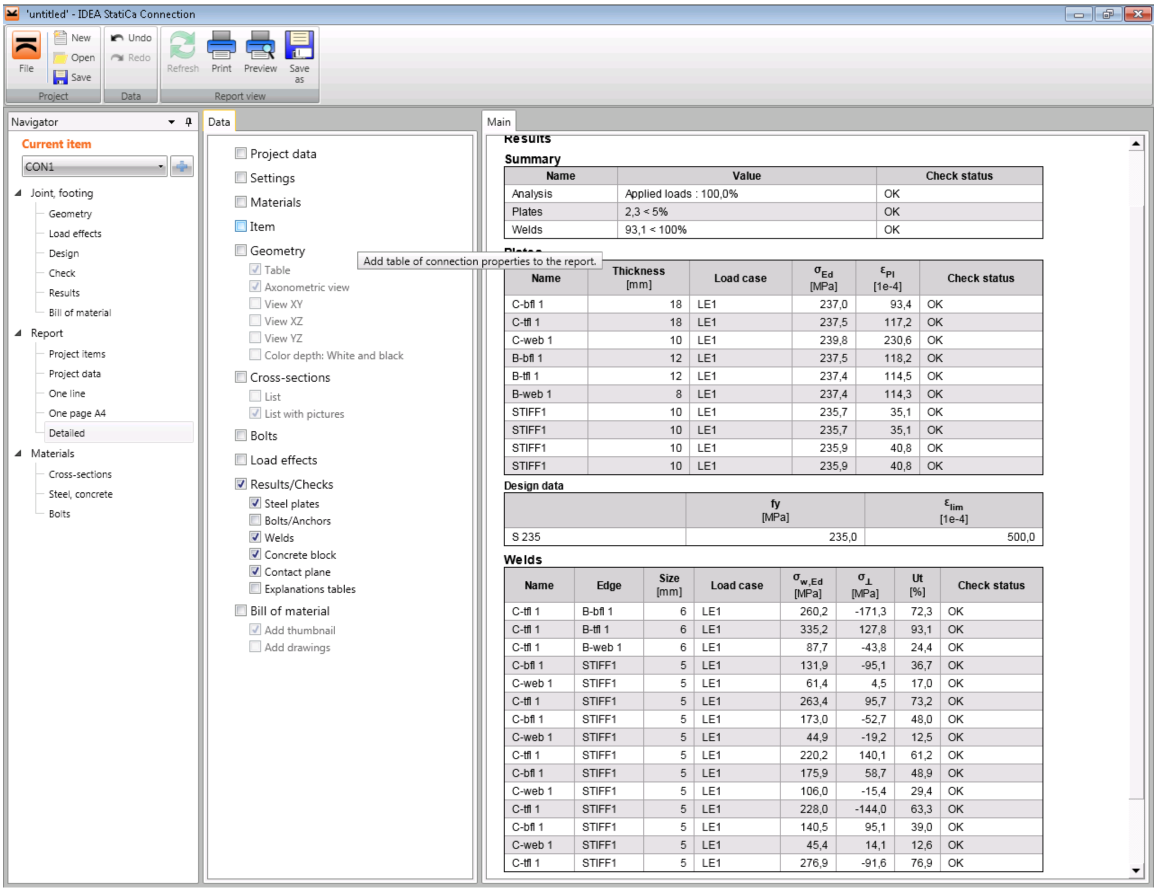
Analysis parameters	
Plastic strain [%]	5
Equivalent stress for drawing [%]	80
Stop analysis when the limit of strain is reached	☑
Shear contact element in bolt link	☑
Member length ratio	2
Partial safety factors	
γ M0	1
γ M1	1
γ M2	1,25
γ C	1,5
γ Inst	1,2
Concrete block	
Joint coefficient βj	0,6
Effective area - coefficient of max stress	0,4
Friction coefficient	0,25
Check	
Stress evaluation in weld	Average stres:
Stiffness evaluation	☑
System braced	☐
Detailing	☐
Distance between bolts [d]	2,2
Distance between bolts and edge [d]	1,2



Overview of all checks for extreme load effect

Check item	Value	Status

Results:



☐ Project data
☐ Settings
☐ Materials
☐ Item
☐ Geometry
  ☑ Table
  ☑ Axonometric view
  ☐ View XY
  ☐ View XZ
  ☐ View YZ
  ☐ Color depth: White and black
☐ Cross-sections
  ☐ List
  ☑ List with pictures
☐ Bolts
☐ Load effects
☑ Results/Checks
  ☑ Steel plates
  ☐ Bolts/Anchors
  ☑ Welds
  ☑ Concrete block
  ☑ Contact plane
  ☐ Explanations tables
☐ Bill of material
  ☑ Add thumbnail
  ☐ Add drawings

Add table of connection properties to the report.

Results

Summary

Name	Value	Check status
Analysis	Applied loads : 100,0%	OK
Plates	2,3 < 5%	OK
Welds	93,1 < 100%	OK

Plates

Name	Thickness [mm]	Load case	σ_{Ed} [MPa]	ε_{Pl} [1e-4]	Check status
C-bfl 1	18	LE1	237,0	93,4	OK
C-tfl 1	18	LE1	237,5	117,2	OK
C-web 1	10	LE1	239,8	230,6	OK
B-bfl 1	12	LE1	237,5	118,2	OK
B-tfl 1	12	LE1	237,4	114,5	OK
B-web 1	8	LE1	237,4	114,3	OK
STIFF1	10	LE1	235,7	35,1	OK
STIFF1	10	LE1	235,7	35,1	OK
STIFF1	10	LE1	235,9	40,8	OK
STIFF1	10	LE1	235,9	40,8	OK

Design data

	fy [MPa]	ε_{lim} [1e-4]
S 235	235,0	500,0

Welds

Name	Edge	Size [mm]	Load case	$\sigma_{w,Ed}$ [MPa]	$\sigma_{\perp}$ [MPa]	Ut [%]	Check status
C-tfl 1	B-bfl 1	6	LE1	260,2	-171,3	72,3	OK
C-tfl 1	B-tfl 1	6	LE1	335,2	127,8	93,1	OK
C-tfl 1	B-web 1	6	LE1	87,7	-43,8	24,4	OK
C-bfl 1	STIFF1	5	LE1	131,9	-95,1	36,7	OK
C-web 1	STIFF1	5	LE1	61,4	4,5	17,0	OK
C-tfl 1	STIFF1	5	LE1	263,4	95,7	73,2	OK
C-bfl 1	STIFF1	5	LE1	173,0	-52,7	48,0	OK
C-web 1	STIFF1	5	LE1	44,9	-19,2	12,5	OK
C-tfl 1	STIFF1	5	LE1	220,2	140,1	61,2	OK
C-bfl 1	STIFF1	5	LE1	175,9	58,7	48,9	OK
C-web 1	STIFF1	5	LE1	106,0	-15,4	29,4	OK
C-tfl 1	STIFF1	5	LE1	228,0	-144,0	63,3	OK
C-bfl 1	STIFF1	5	LE1	140,5	95,1	39,0	OK
C-web 1	STIFF1	5	LE1	45,4	14,1	12,6	OK
C-tfl 1	STIFF1	5	LE1	276,9	-91,6	76,9	OK