ΤΕΥΧΟΣ ΣΤΑΤΙΚΩΝ ΥΠΟΛΟΓΙΣΜΩΝ ΣΥΝΔΕΣΕΩΝ

Στατική Μελέτη Νέας Αποθήκης Χημικών από Δομικό Χάλυβα και Θεμελίωση Σκυροδέματος

ΕΡΓΟ:	Κατασκευή Νέας Αποθήκης Χημικών από Δομικό Χάλυβα και Θεμελίωση Σκυροδέματος
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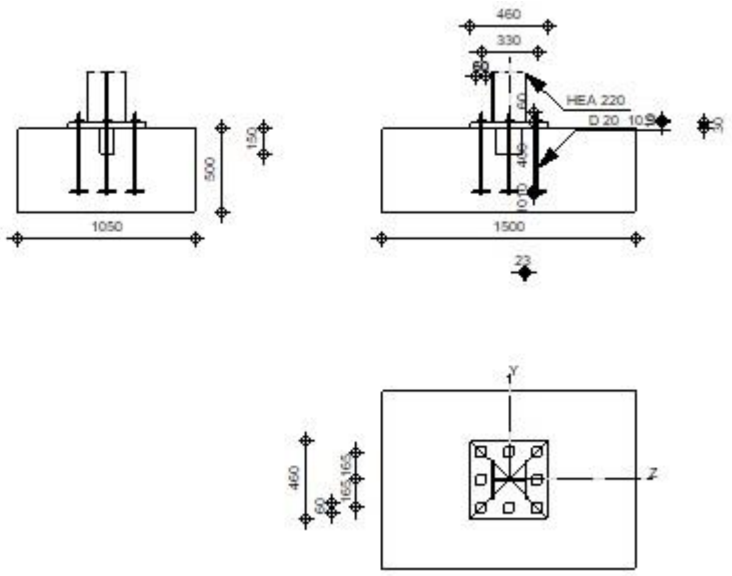
ΒΑΣΗ ΕΔΡΑΣΗΣ



GENERAL

Connection no.: 1
Connection name: Fixed column base

GEOMETRY

COLUMN

Section: HEA 220

L_c =	0.00	[m]	Column length
α =	0.0	[Deg]	Inclination angle
h_c =	210	[mm]	Height of column section
b_{fc} =	220	[mm]	Width of column section
t_{wc} =	7	[mm]	Thickness of the web of column section
t_{fc} =	11	[mm]	Thickness of the flange of column section
r_c =	18	[mm]	Radius of column section fillet
A_c =	64.34	[cm^2]	Cross-sectional area of a column
I_{yc} =	5409.70	[cm^4]	Moment of inertia of the column section

Material: S235

f_{yc} =	235.00	[MPa]	Resistance
f_{uc} =	360.00	[MPa]	Yield strength of a material

COLUMN BASE

l_{pd} =	460	[mm]	Length
b_{pd} =	460	[mm]	Width
t_{pd} =	30	[mm]	Thickness

Material: S235

f_{ypd} =	235.00	[MPa]	Resistance
f_{upd} =	360.00	[MPa]	Yield strength of a material

ANCHORAGE

The shear plane passes through the UNTHREADED portion of the bolt.

Class =	10.9		Anchor class
f_{yb} =	900.00	[MPa]	Yield strength of the anchor material
f_{ub} =	1000.00	[MPa]	Tensile strength of the anchor material
d =	20	[mm]	Bolt diameter
A_s =	2.45	[cm^2]	Effective section area of a bolt
A_v =	3.14	[cm^2]	Area of bolt section
n_H =	3		Number of bolt columns
n_V =	3		Number of bolt rows

Horizontal spacing e_{Hi} = 165 [mm]

Vertical spacing e_{Vi} = 165 [mm]

Anchor dimensions

L_1 = 60 [mm]

L_2 = 400 [mm]

L_3 = 10 [mm]

Anchor plate

d =	100	[mm]	Diameter
t_p =	10	[mm]	Thickness
Material:	S235		
f_y =	235.00	[MPa]	Resistance

Washer

l_{wd} =	60	[mm]	Length
b_{wd} =	60	[mm]	Width
t_{wd} =	10	[mm]	Thickness

WEDGE

Section:	IPE 160		
l_w =	150	[mm]	Length
Material:	S235		
f_{yw} =	235.00	[MPa]	Resistance

MATERIAL FACTORS

γ_{M0} =	1.00	Partial safety factor
γ_{M2} =	1.25	Partial safety factor
γ_C =	1.50	Partial safety factor

SPREAD FOOTING

L =	1500	[mm]	Spread footing length
B =	1050	[mm]	Spread footing width
H =	500	[mm]	Spread footing height

Concrete

Class C25/30

f_{ck} = 25.00 [MPa] Characteristic resistance for compression

Grout layer

t_g =	0	[mm]	Thickness of leveling layer (grout)
$f_{ck,g}$ =	12.00	[MPa]	Characteristic resistance for compression
$C_{f,d}$ =	0.30		Coeff. of friction between the base plate and concrete

WELDS

a_p =	5	[mm]	Footing plate of the column base
a_w =	4	[mm]	Wedge

LOADS

Case: Manual calculations.

$N_{j,Ed}$ =	-50.62	[kN]	Axial force
$V_{j,Ed,y}$ =	-0.81	[kN]	Shear force
$V_{j,Ed,z}$ =	-37.01	[kN]	Shear force
$M_{j,Ed,y}$ =	52.21	[kN*m]	Bending moment
$M_{j,Ed,z}$ =	0.74	[kN*m]	Bending moment

RESULTS

COMPRESSION ZONE

COMPRESSION OF CONCRETE

f_{cd} =	16.67	[MPa]	Design compressive resistance	EN 1992-1:[3.1.6.(1)]
f_j =	23.19	[MPa]	Design bearing resistance under the base plate	[6.2.5.(7)]

$c = t_p \sqrt{(f_{yp}/(3*f_j*\gamma_{M0}))}$

c =	55	[mm]	Additional width of the bearing pressure zone	[6.2.5.(4)]
b_{eff} =	121	[mm]	Effective width of the bearing pressure zone under the flange	[6.2.5.(3)]
l_{eff} =	330	[mm]	Effective length of the bearing pressure zone under the flange	[6.2.5.(3)]
A_{c0} =	400.55	[cm^2]	Area of the joint between the base plate and the foundation	EN 1992-1:[6.7.(3)]
A_{c1} =	3020.84	[cm^2]	Maximum design area of load distribution	EN 1992-1:[6.7.(3)]

$F_{rdu} = A_{c0}*f_{cd}*\sqrt{(A_{c1}/A_{c0})} \leq 3*A_{c0}*f_{cd}$

F_{rdu} =	1833.34	[kN]	Bearing resistance of concrete	EN 1992-1:[6.7.(3)]
β_j =	0.67		Reduction factor for compression	[6.2.5.(7)]

$f_{jd} = \beta_j*F_{rdu}/(b_{eff}*l_{eff})$

f_{jd} =	30.51	[MPa]	Design bearing resistance	[6.2.5.(7)]

$A_{c,n}$ =	892.26	[cm^2]	Bearing area for compression	[6.2.8.2.(1)]
$A_{c,y}$ =	400.55	[cm^2]	Bearing area for bending My	[6.2.8.3.(1)]
$A_{c,z}$ =	400.55	[cm^2]	Bearing area for bending Mz	[6.2.8.3.(1)]

$F_{c,Rd,i} = A_{C,i}*f_{jd}$

$F_{c,Rd,n}$ =	2722.59	[kN]	Bearing resistance of concrete for compression	[6.2.8.2.(1)]
$F_{c,Rd,y}$ =	1222.23	[kN]	Bearing resistance of concrete for bending My	[6.2.8.3.(1)]
$F_{c,Rd,z}$ =	1222.23	[kN]	Bearing resistance of concrete for bending Mz	[6.2.8.3.(1)]

COLUMN FLANGE AND WEB IN COMPRESSION

CL =	1.00		Section class	EN 1993-1-1:[5.5.2]
$W_{pl,y}$ =	568.50	[cm^3]	Plastic section modulus	EN1993-1-1:[6.2.5.(2)]
$M_{c,Rd,y}$ =	133.60	[kN*m]	Design resistance of the section for bending	EN1993-1-1:[6.2.5]
$h_{f,y}$ =	199	[mm]	Distance between the centroids of flanges	[6.2.6.7.(1)]

$F_{c,fc,Rd,y} = M_{c,Rd,y} / h_{f,y}$

$F_{c,fc,Rd,y}$ =	671.34	[kN]	Resistance of the compressed flange and web	[6.2.6.7.(1)]

$W_{pl,z}$ =	270.60	[cm^3]	Plastic section modulus	EN1993-1-1:[6.2.5.(2)]
$M_{c,Rd,z}$ =	63.59	[kN*m]	Design resistance of the section for bending	EN1993-1-1:[6.2.5]
$h_{f,z}$ =	165	[mm]	Distance between the centroids of flanges	[6.2.6.7.(1)]

$F_{c,fc,Rd,z} = M_{c,Rd,z} / h_{f,z}$

$F_{c,fc,Rd,z}$ =	385.07	[kN]	Resistance of the compressed flange and web	[6.2.6.7.(1)]

RESISTANCES OF SPREAD FOOTING IN THE COMPRESSION ZONE

$N_{j,Rd} = F_{c,Rd,n}$

$N_{j,Rd} =$ 2722.59 [kN] Resistance of a spread footing for axial compression [6.2.8.2.(1)]

$F_{C,Rd,y} = \min(F_{c,Rd,y},F_{c,fc,Rd,y})$

$F_{C,Rd,y} =$ 671.34 [kN] Resistance of spread footing in the compression zone [6.2.8.3]

$F_{C,Rd,z} = \min(F_{c,Rd,z},F_{c,fc,Rd,z})$

$F_{C,Rd,z} =$ 385.07 [kN] Resistance of spread footing in the compression zone [6.2.8.3]

TENSION ZONE

STEEL FAILURE

$A_b =$	2.45	[cm^2]	Effective anchor area	[Table 3.4]
$f_{ub} =$	1000.00	[MPa]	Tensile strength of the anchor material	[Table 3.4]
Beta =	0.85		Reduction factor of anchor resistance	[3.6.1.(3)]

$F_{t,Rd,s1} = beta*0.9*f_{ub}*A_b/\gamma_{M2}$

$F_{t,Rd,s1} =$ 149.94 [kN] Anchor resistance to steel failure [Table 3.4]

$\gamma_{Ms} =$	1.20		Partial safety factor	CEB [3.2.3.2]
$f_{yb} =$	900.00	[MPa]	Yield strength of the anchor material	CEB [9.2.2]

$F_{t,Rd,s2} = f_{yb}*A_b/\gamma_{Ms}$

$F_{t,Rd,s2} =$ 183.75 [kN] Anchor resistance to steel failure CEB [9.2.2]

$F_{t,Rd,s} = \min(F_{t,Rd,s1},F_{t,Rd,s2})$

$F_{t,Rd,s} =$ 149.94 [kN] Anchor resistance to steel failure

PULL-OUT FAILURE

$f_{ck} =$	25.00	[MPa]	Characteristic compressive strength of concrete	EN 1992-1:[3.1.2]
$A_h =$	75.40	[cm^2]	Bearing area of the head	CEB [15.1.2.3]
$p_k =$	175.00	[MPa]	Characteristic strength of concrete (pull-out)	CEB [15.1.2.3]
$\gamma_{Mp} =$	2.16		Partial safety factor	CEB [3.2.3.1]

$F_{t,Rd,p} = p_k*A_h/\gamma_{Mp}$

$F_{t,Rd,p} =$ 261.80 [kN] Design uplift capacity CEB [9.2.3]

CONCRETE CONE FAILURE

$h_{ef} =$ 390 [mm] Effective anchorage depth CEB [9.2.4]

$N_{Rk,c}^0 = 7.5[N^{0.5}/mm^{0.5}]*f_{ck}*h_{ef}^{1.5}$

$N_{Rk,c}^0 =$	288.82	[kN]	Characteristic resistance of an anchor	CEB [9.2.4]
$s_{cr,N} =$	1170	[mm]	Critical width of the concrete cone	CEB [9.2.4]
$c_{cr,N} =$	585	[mm]	Critical edge distance	CEB [9.2.4]
$A_{c,N0} =$	22500.00	[cm^2]	Maximum area of concrete cone	CEB [9.2.4]
$A_{c,N} =$	15750.00	[cm^2]	Actual area of concrete cone	CEB [9.2.4]

$\psi_{A,N} = A_{c,N}/A_{c,N0}$

$\psi_{A,N} =$	0.70		Factor related to anchor spacing and edge distance	CEB [9.2.4]
c =	360	[mm]	Minimum edge distance from an anchor	CEB [9.2.4]

$\psi_{s,N} = 0.7 + 0.3*c/c_{cr.N} \le 1.0$

$\psi_{s,N} =$	0.88	Factor taking account the influence of edges of the concrete member on the distribution of stresses in the concrete	CEB [9.2.4]
$\psi_{ec,N} =$	1.00	Factor related to distribution of tensile forces acting on anchors	CEB [9.2.4]

$\psi_{re,N} = 0.5 + h_{ef}[mm]/200 \le 1.0$

$\psi_{re,N} =$	1.00	Shell spalling factor	CEB [9.2.4]
$\psi_{ucr,N} =$	1.00	Factor taking into account whether the anchorage is in cracked or non-cracked concrete	CEB [9.2.4]
$\gamma_{Mc} =$	2.16	Partial safety factor	CEB [3.2.3.1]

$F_{t,Rd,c} = N_{Rk,c}^0*\psi_{A,N}*\psi_{s,N}*\psi_{ec,N}*\psi_{re,N}*\psi_{ucr,N}/\gamma_{Mc}$

$F_{t,Rd,c}$ = 82.80 [kN] Design anchor resistance to concrete cone failure EN 1992-1:[8.4.2.(2)]

SPLITTING FAILURE

h_{ef} =	400	[mm]	Effective anchorage depth	CEB [9.2.5]

$N_{Rk,c}^0 = 7.5[N^{0.5}/mm^{0.5}]*f_{ck}*h_{ef}^{1.5}$

$N_{Rk,c}^0$ =	300.00	[kN]	Design uplift capacity	CEB [9.2.5]
$s_{cr,N}$ =	800	[mm]	Critical width of the concrete cone	CEB [9.2.5]
$c_{cr,N}$ =	400	[mm]	Critical edge distance	CEB [9.2.5]
$A_{c,N0}$ =	12769.00	[cm^2]	Maximum area of concrete cone	CEB [9.2.5]
$A_{c,N}$ =	11865.00	[cm^2]	Actual area of concrete cone	CEB [9.2.5]

$\psi_{A,N} = A_{c,N}/A_{c,N0}$

$\psi_{A,N}$ =	0.93		Factor related to anchor spacing and edge distance	CEB [9.2.5]
c =	360	[mm]	Minimum edge distance from an anchor	CEB [9.2.5]

$\psi_{s,N} = 0.7 + 0.3*c/c_{cr.N} \le 1.0$

$\psi_{s,N}$ =	0.97		Factor taking account the influence of edges of the concrete member on the distribution of stresses in the concrete	CEB [9.2.5]
$\psi_{ec,N}$ =	1.00		Factor related to distribution of tensile forces acting on anchors	CEB [9.2.5]

$\psi_{re,N} = 0.5 + h_{ef}[mm]/200 \le 1.0$

$\psi_{re,N}$ =	1.00		Shell spalling factor	CEB [9.2.5]
$\psi_{ucr,N}$ =	1.00		Factor taking into account whether the anchorage is in cracked or non-cracked concrete	CEB [9.2.5]

$\psi_{h,N} = (h/(2*h_{ef}))^{2/3} \le 1.2$

$\psi_{h,N}$ =	0.73		Coeff. related to the foundation height	CEB [9.2.5]
$\gamma_{M,sp}$ =	2.16		Partial safety factor	CEB [3.2.3.1]

$F_{t,Rd,sp} = N_{Rk,c}^0*\psi_{A,N}*\psi_{s,N}*\psi_{ec,N}*\psi_{re,N}*\psi_{ucr,N}*\psi_{h,N}/\gamma_{M,sp}$

$F_{t,Rd,sp}$ = 91.51 [kN] Design anchor resistance to splitting of concrete CEB [9.2.5]

TENSILE RESISTANCE OF AN ANCHOR

$F_{t,Rd} = \min(F_{t,Rd,s} , F_{t,Rd,p} , F_{t,Rd,c} , F_{t,Rd,sp})$

$F_{t,Rd}$ = 82.80 [kN] Tensile resistance of an anchor

BENDING OF THE BASE PLATE

Bending moment $M_{j,Ed,y}$

$l_{eff,1}$ =	230	[mm]	Effective length for a single bolt for mode 1	[6.2.6.5]
$l_{eff,2}$ =	230	[mm]	Effective length for a single bolt for mode 2	[6.2.6.5]
m =	54	[mm]	Distance of a bolt from the stiffening edge	[6.2.6.5]
$M_{pl,1,Rd}$ =	12.16	[kN*m]	Plastic resistance of a plate for mode 1	[6.2.4]
$M_{pl,2,Rd}$ =	12.16	[kN*m]	Plastic resistance of a plate for mode 2	[6.2.4]
$F_{T,1,Rd}$ =	895.15	[kN]	Resistance of a plate for mode 1	[6.2.4]
$F_{T,2,Rd}$ =	339.09	[kN]	Resistance of a plate for mode 2	[6.2.4]
$F_{T,3,Rd}$ =	248.40	[kN]	Resistance of a plate for mode 3	[6.2.4]

$F_{t,pl,Rd,y} = \min(F_{T,1,Rd} , F_{T,2,Rd} , F_{T,3,Rd})$

$F_{t,pl,Rd,y}$ = 248.40 [kN] Tension resistance of a plate [6.2.4]

Bending moment $M_{j,Ed,z}$

$l_{eff,1}$ =	230	[mm]	Effective length for a single bolt for mode 1	[6.2.6.5]
$l_{eff,2}$ =	230	[mm]	Effective length for a single bolt for mode 2	[6.2.6.5]
m =	156	[mm]	Distance of a bolt from the stiffening edge	[6.2.6.5]
$M_{pl,1,Rd}$ =	12.16	[kN*m]	Plastic resistance of a plate for mode 1	[6.2.4]
$M_{pl,2,Rd}$ =	12.16	[kN*m]	Plastic resistance of a plate for mode 2	[6.2.4]
$F_{T,1,Rd}$ =	312.14	[kN]	Resistance of a plate for mode 1	[6.2.4]
$F_{T,2,Rd}$ =	183.24	[kN]	Resistance of a plate for mode 2	[6.2.4]
$F_{T,3,Rd}$ =	248.40	[kN]	Resistance of a plate for mode 3	[6.2.4]

$F_{t,pl,Rd,z} = \min(F_{T,1,Rd} , F_{T,2,Rd} , F_{T,3,Rd})$

$F_{t,pl,Rd,z}$ = 183.24 [kN] Tension resistance of a plate [6.2.4]

TENSILE RESISTANCE OF A COLUMN WEB

Bending moment $M_{j,Ed,z}$

t_{wc} =	7	[mm]	Effective thickness of the column web	[6.2.6.3.(8)]
$b_{eff,t,wc}$ =	230	[mm]	Effective width of the web for tension	[6.2.6.3.(2)]
A_{vc} =	20.67	[cm^2]	Shear area	EN1993-1-1:[6.2.6.(3)]
ω =	0.75		Reduction factor for interaction with shear	[6.2.6.3.(4)]

$F_{t,wc,Rd,z} = \omega\ b_{eff,t,wc}\ t_{wc}\ f_{yc} / \gamma_{M0}$

$F_{t,wc,Rd,z}$ = 282.90 [kN] Column web resistance [6.2.6.3.(1)]

RESISTANCES OF SPREAD FOOTING IN THE TENSION ZONE

$F_{T,Rd,y} = F_{t,pl,Rd,y}$

$F_{T,Rd,y}$ = 248.40 [kN] Resistance of a column base in the tension zone [6.2.8.3]

$F_{T,Rd,z} = \min(F_{t,pl,Rd,z},F_{t,wc,Rd,z})$

$F_{T,Rd,z}$ = 183.24 [kN] Resistance of a column base in the tension zone [6.2.8.3]

CONNECTION CAPACITY CHECK

$N_{j,Ed} / N_{j,Rd} \leq 1,0$ (6.24)	0.02 < 1.00	verified	(0.02)

e_y =	1031	[mm]	Axial force eccentricity	[6.2.8.3]
$z_{c,y}$ =	100	[mm]	Lever arm $F_{C,Rd,y}$	[6.2.8.1.(2)]
$z_{t,y}$ =	165	[mm]	Lever arm $F_{T,Rd,y}$	[6.2.8.1.(3)]
$M_{j,Rd,y}$ =	72.72	[kN*m]	Connection resistance for bending	[6.2.8.3]

$M_{j,Ed,y} / M_{j,Rd,y} \leq 1,0$ (6.23)	0.72 < 1.00	verified	(0.72)

e_z =	15	[mm]	Axial force eccentricity	[6.2.8.3]
$z_{c,z}$ =	83	[mm]	Lever arm $F_{C,Rd,z}$	[6.2.8.1.(2)]
$z_{t,z}$ =	165	[mm]	Lever arm $F_{T,Rd,z}$	[6.2.8.1.(3)]
$M_{j,Rd,z}$ =	9.57	[kN*m]	Connection resistance for bending	[6.2.8.3]

$M_{j,Ed,z} / M_{j,Rd,z} \leq 1,0$ (6.23)	0.08 < 1.00	verified	(0.08)
$M_{j,Ed,y} / M_{j,Rd,y} + M_{j,Ed,z} / M_{j,Rd,z} \leq 1,0$	0.80 < 1.00	verified	(0.80)

SHEAR

BEARING PRESSURE OF AN ANCHOR BOLT ONTO THE BASE PLATE

Shear force $V_{j,Ed,y}$

$\alpha_{d,y}$ =	0.98	Coeff. taking account of the bolt position - in the direction of shear	[Table 3.4]
$\alpha_{b,y}$ =	0.98	Coeff. for resistance calculation $F_{1,vb,Rd}$	[Table 3.4]
$k_{1,y}$ =	2.50	Coeff. taking account of the bolt position - perpendicularly to the direction of shear	[Table 3.4]

$F_{1,vb,Rd,y} = k_{1,y}*\alpha_{b,y}*f_{up}*d*t_p / \gamma_{M2}$

$F_{1,vb,Rd,y}$ = 425.45 [kN] Resistance of an anchor bolt for bearing pressure onto the base plate [6.2.2.(7)]

Shear force $V_{j,Ed,z}$

$\alpha_{d,z}$ =	0.98	Coeff. taking account of the bolt position - in the direction of shear	[Table 3.4]
$\alpha_{b,z}$ =	0.98	Coeff. for resistance calculation $F_{1,vb,Rd}$	[Table 3.4]
$k_{1,z}$ =	2.50	Coeff. taking account of the bolt position - perpendicularly to the direction of shear	[Table 3.4]

$F_{1,vb,Rd,z} = k_{1,z}*\alpha_{b,z}*f_{up}*d*t_p / \gamma_{M2}$

$F_{1,vb,Rd,z} =$ 425.45 [kN] Resistance of an anchor bolt for bearing pressure onto the base plate [6.2.2.(7)]

SHEAR OF AN ANCHOR BOLT

$\alpha_b =$	0.25		Coeff. for resistance calculation $F_{2,vb,Rd}$	[6.2.2.(7)]
$A_{vb} =$	3.14	[cm^2]	Area of bolt section	[6.2.2.(7)]
$f_{ub} =$	1000.00	[MPa]	Tensile strength of the anchor material	[6.2.2.(7)]
$\gamma_{M2} =$	1.25		Partial safety factor	[6.2.2.(7)]

$F_{2,vb,Rd} = \alpha_b*f_{ub}*A_{vb}/\gamma_{M2}$

$F_{2,vb,Rd} =$ 62.33 [kN] Shear resistance of a bolt - without lever arm [6.2.2.(7)]

CONCRETE PRY-OUT FAILURE

$N_{Rk,c} =$	178.85	[kN]	Design uplift capacity	CEB [9.2.4]
$k_3 =$	2.00		Factor related to the anchor length	CEB [9.3.3]
$\gamma_{Mc} =$	2.16		Partial safety factor	CEB [3.2.3.1]

$F_{v,Rd,cp} = k_3*N_{Rk,c}/\gamma_{Mc}$

$F_{v,Rd,cp} =$ 165.60 [kN] Concrete resistance for pry-out failure CEB [9.3.1]

CONCRETE EDGE FAILURE

Shear force $V_{j,Ed,y}$

$V_{Rk,c,y}{}^0 =$	528.08	[kN]	Characteristic resistance of an anchor	CEB [9.3.4.(a)]
$\psi_{A,V,y} =$	0.93		Factor related to anchor spacing and edge distance	CEB [9.3.4]
$\psi_{h,V,y} =$	1.03		Factor related to the foundation thickness	CEB [9.3.4.(c)]
$\psi_{s,V,y} =$	1.00		Factor related to the influence of edges parallel to the shear load direction	CEB [9.3.4.(d)]
$\psi_{ec,V,y} =$	1.00		Factor taking account a group effect when different shear loads are acting on the individual anchors in a group	CEB [9.3.4.(e)]
$\psi_{\alpha,V,y} =$	1.00		Factor related to the angle at which the shear load is applied	CEB [9.3.4.(f)]
$\psi_{ucr,V,y} =$	1.00		Factor related to the type of edge reinforcement used	CEB [9.3.4.(g)]
$\gamma_{Mc} =$	2.16		Partial safety factor	CEB [3.2.3.1]

$F_{v,Rd,c,y} = V_{Rk,c,y}{}^0*\psi_{A,V,y}*\psi_{h,V,y}*\psi_{s,V,y}*\psi_{ec,V,y}*\psi_{\alpha,V,y}*\psi_{ucr,V,y}/\gamma_{Mc}$

$F_{v,Rd,c,y} =$ 232.26 [kN] Concrete resistance for edge failure CEB [9.3.1]

Shear force $V_{j,Ed,z}$

$V_{Rk,c,z}{}^0 =$	1093.91	[kN]	Characteristic resistance of an anchor	CEB [9.3.4.(a)]
$\psi_{A,V,z} =$	0.23		Factor related to anchor spacing and edge distance	CEB [9.3.4]
$\psi_{h,V,z} =$	1.21		Factor related to the foundation thickness	CEB [9.3.4.(c)]
$\psi_{s,V,z} =$	0.82		Factor related to the influence of edges parallel to the shear load direction	CEB [9.3.4.(d)]
$\psi_{ec,V,z} =$	1.00		Factor taking account a group effect when different shear loads are acting on the individual anchors in a group	CEB [9.3.4.(e)]
$\psi_{\alpha,V,z} =$	1.00		Factor related to the angle at which the shear load is applied	CEB [9.3.4.(f)]
$\psi_{ucr,V,z} =$	1.00		Factor related to the type of edge reinforcement used	CEB [9.3.4.(g)]
$\gamma_{Mc} =$	2.16		Partial safety factor	CEB [3.2.3.1]

$F_{v,Rd,c,z} = V_{Rk,c,z}{}^0*\psi_{A,V,z}*\psi_{h,V,z}*\psi_{s,V,z}*\psi_{ec,V,z}*\psi_{\alpha,V,z}*\psi_{ucr,V,z}/\gamma_{Mc}$

$F_{v,Rd,c,z} =$ 117.54 [kN] Concrete resistance for edge failure CEB [9.3.1]

SPLITTING RESISTANCE

$C_{f,d}$ = 0.30 Coeff. of friction between the base plate and concrete [6.2.2.(6)]

$N_{c,Ed}$ = 50.62 [kN] Compressive force [6.2.2.(6)]

$F_{f,Rd} = C_{f,d}*N_{c,Ed}$

$F_{f,Rd}$ = 15.19 [kN] Slip resistance [6.2.2.(6)]

BEARING PRESSURE OF THE WEDGE ONTO CONCRETE

$F_{v,Rd,wg,y} = 1.4*l_w*b_{wy}*f_{ck}/\gamma_c$

$F_{v,Rd,wg,y}$ = 560.00 [kN] Resistance for bearing pressure of the wedge onto concrete

$F_{v,Rd,wg,z} = 1.4*l_w*b_{wz}*f_{ck}/\gamma_c$

$F_{v,Rd,wg,z}$ = 287.00 [kN] Resistance for bearing pressure of the wedge onto concrete

SHEAR CHECK

$V_{j,Rd,y} = n_b*\min(F_{1,vb,Rd,y}, F_{2,vb,Rd}, F_{v,Rd,cp}, F_{v,Rd,c,y}) + F_{v,Rd,wg,y} + F_{f,Rd}$

$V_{j,Rd,y}$ = 1073.82 [kN] Connection resistance for shear CEB [9.3.1]

$V_{j,Ed,y} / V_{j,Rd,y} \leq 1,0$ 0.00 < 1.00 verified (0.00)

$V_{j,Rd,z} = n_b*\min(F_{1,vb,Rd,z}, F_{2,vb,Rd}, F_{v,Rd,cp}, F_{v,Rd,c,z}) + F_{v,Rd,wg,z} + F_{f,Rd}$

$V_{j,Rd,z}$ = 800.82 [kN] Connection resistance for shear CEB [9.3.1]

$V_{j,Ed,z} / V_{j,Rd,z} \leq 1,0$ 0.05 < 1.00 verified (0.05)

$V_{j,Ed,y} / V_{j,Rd,y} + V_{j,Ed,z} / V_{j,Rd,z} \leq 1,0$ 0.05 < 1.00 verified (0.05)

WELDS BETWEEN THE COLUMN AND THE BASE PLATE

$\sigma_\perp$ = 90.91 [MPa] Normal stress in a weld [4.5.3.(7)]

$\tau_\perp$ = 90.91 [MPa] Perpendicular tangent stress [4.5.3.(7)]

τ_{yII} = -0.19 [MPa] Tangent stress parallel to $V_{j,Ed,y}$ [4.5.3.(7)]

τ_{zII} = -19.69 [MPa] Tangent stress parallel to $V_{j,Ed,z}$ [4.5.3.(7)]

β_W = 0.80 Resistance-dependent coefficient [4.5.3.(7)]

$\sigma_\perp / (0.9*f_u/\gamma_{M2}) \leq 1.0$ (4.1) 0.35 < 1.00 verified (0.35)

$\sqrt{(\sigma_\perp^2 + 3.0 (\tau_{yII}^2 + \tau_\perp^2))} / (f_u/(\beta_W*\gamma_{M2})) \leq 1.0$ (4.1) 0.51 < 1.00 verified (0.51)

$\sqrt{(\sigma_\perp^2 + 3.0 (\tau_{zII}^2 + \tau_\perp^2))} / (f_u/(\beta_W*\gamma_{M2})) \leq 1.0$ (4.1) 0.43 < 1.00 verified (0.43)

CONNECTION STIFFNESS

Bending moment $M_{j,Ed,y}$

b_{eff} = 121 [mm] Effective width of the bearing pressure zone under the flange [6.2.5.(3)]

l_{eff} = 330 [mm] Effective length of the bearing pressure zone under the flange [6.2.5.(3)]

$k_{13,y} = E_c*\sqrt{(b_{eff}*l_{eff})}/(1.275*E)$

$k_{13,y}$ = 23 [mm] Stiffness coeff. of compressed concrete [Table 6.11]

l_{eff} = 230 [mm] Effective length for a single bolt for mode 2 [6.2.6.5]

m = 54 [mm] Distance of a bolt from the stiffening edge [6.2.6.5]

$k_{15,y} = 0.850*l_{eff}*t_p^3/(m^3)$

$k_{15,y}$ = 16 [mm] Stiffness coeff. of the base plate subjected to tension [Table 6.11]

L_b = 210 [mm] Effective anchorage depth [Table 6.11]

$k_{16,y} = 1.6*A_b/L_b$

$k_{16,y}$ = 2 [mm] Stiffness coeff. of an anchor subjected to tension [Table 6.11]

$\lambda_{0,y}$ = 0.00 Column slenderness [5.2.2.5.(2)]

$S_{j,ini,y}$ = 20415.17 [kN*m] Initial rotational stiffness [Table 6.12]

$S_{j,rig,y}$ = 113603700.00 [kN*m] Stiffness of a rigid connection [5.2.2.5]

$S_{j,ini,y} < S_{j,rig,y}$ SEMI-RIGID [5.2.2.5.(2)]

Bending moment $M_{j,Ed,z}$

$k_{13,z} = E_c*\sqrt{(A_{c,z})}/(1.275*E)$

$k_{13,z}$ = 23 [mm] Stiffness coeff. of compressed concrete [Table 6.11]

l_{eff} = 230 [mm] Effective length for a single bolt for mode 2 [6.2.6.5]

m = 156 [mm] Distance of a bolt from the stiffening edge [6.2.6.5]

$k_{15,z} = 0.850*l_{eff}*t_p^3/(m^3)$

$k_{15,z}$ = 1 [mm] Stiffness coeff. of the base plate subjected to tension [Table 6.11]

L_b = 210 [mm] Effective anchorage depth [Table 6.11]

$k_{16,z} = 1.6*A_b/L_b$

$k_{16,z}$ = 2 [mm] Stiffness coeff. of an anchor subjected to tension [Table 6.11]

$\lambda_{0,z}$ = 0.00 Column slenderness [5.2.2.5.(2)]

$S_{j,ini,z}$ = 66351.68 [kN*m] Initial rotational stiffness [6.3.1.(4)]

$S_{j,rig,z}$ = 41045760.00 [kN*m] Stiffness of a rigid connection [5.2.2.5]

$S_{j,ini,z} < S_{j,rig,z}$ SEMI-RIGID [5.2.2.5.(2)]

WEAKEST COMPONENT:

FOUNDATION - CONCRETE CONE PULL-OUT FAILURE

Connection conforms to the code Ratio 0.80

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

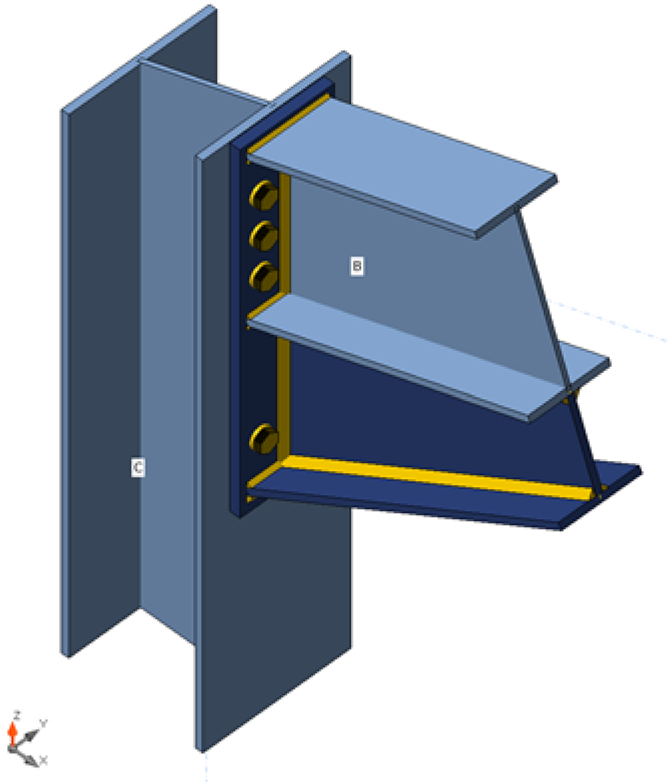
Project item CON1

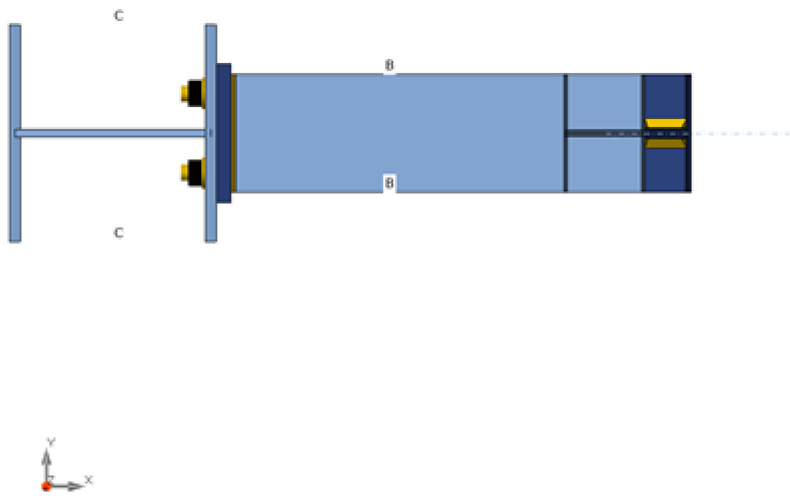
Design

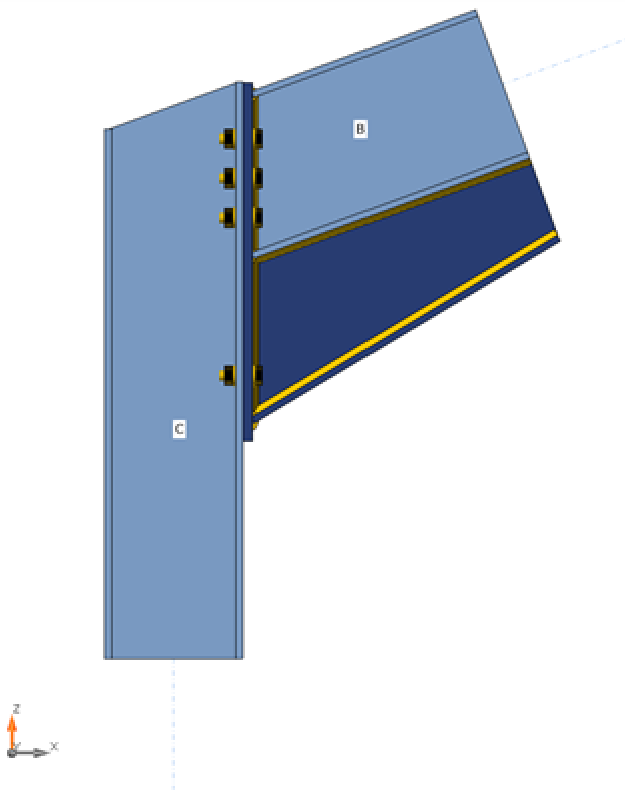
Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

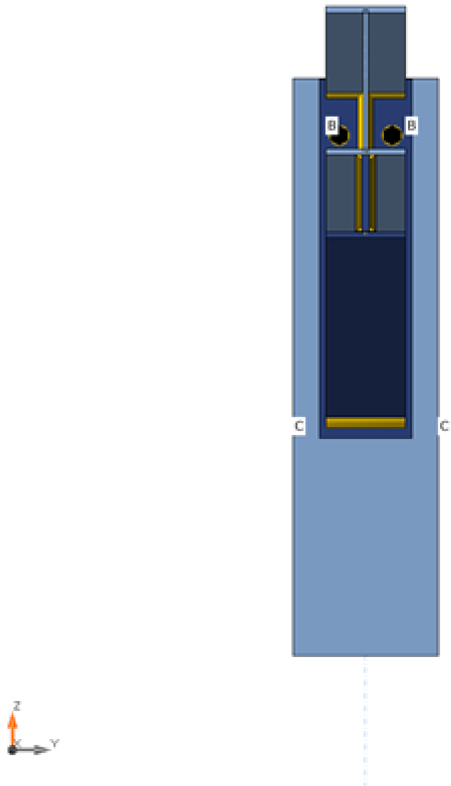
Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
C	1 - HEA220	0.0	90.0	0.0	0	0	0	Node
B	2 - IPE240	0.0	-20.0	0.0	0	0	0	Node




C
B
B
C
Y
X

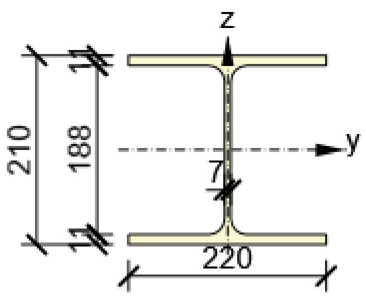
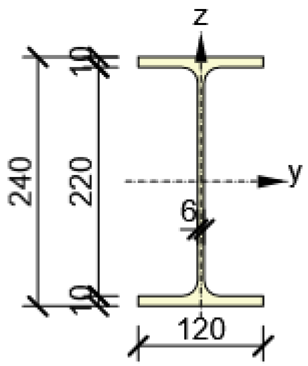

B
C
Z
X



Cross-sections

Name	Material
1 - HEA220	S 235
2 - IPE240	S 235

Cross-sections

Name	Material	Drawing
1 - HEA220	S 235	
2 - IPE240	S 235	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M16 10.9	M16 10.9	16	1000.0	201

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	C	42.5	-0.1	24.0	0.0	-50.5	0.0
	B	36.4	0.1	-30.3	0.0	50.4	-0.1
LE2	C	-42.1	0.1	-24.0	0.0	-50.5	0.0
	B	-36.4	-0.1	30.3	0.0	50.4	0.1

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.1 < 5.0%	OK
Bolts	51.5 < 100%	OK
Welds	71.0 < 100%	OK
Buckling	Not calculated	

Plates

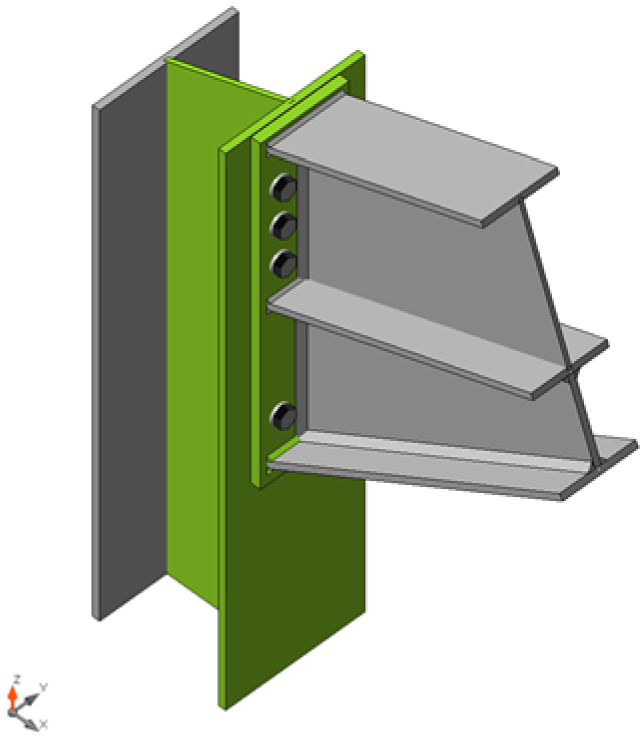
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	11.0	LE1	171.0	0.0	0.0	OK
C-tfl 1	11.0	LE1	235.2	0.1	29.8	OK
C-w 1	7.0	LE1	229.9	0.0	0.0	OK
B-bfl 1	9.8	LE1	28.9	0.0	0.0	OK
B-tfl 1	9.8	LE2	108.5	0.0	0.0	OK
B-w 1	6.2	LE2	165.6	0.0	0.0	OK
EP1	15.0	LE1	211.8	0.0	29.8	OK
WID1a	10.0	LE2	96.5	0.0	0.0	OK
WID1b	10.0	LE1	133.2	0.0	0.0	OK

Design data

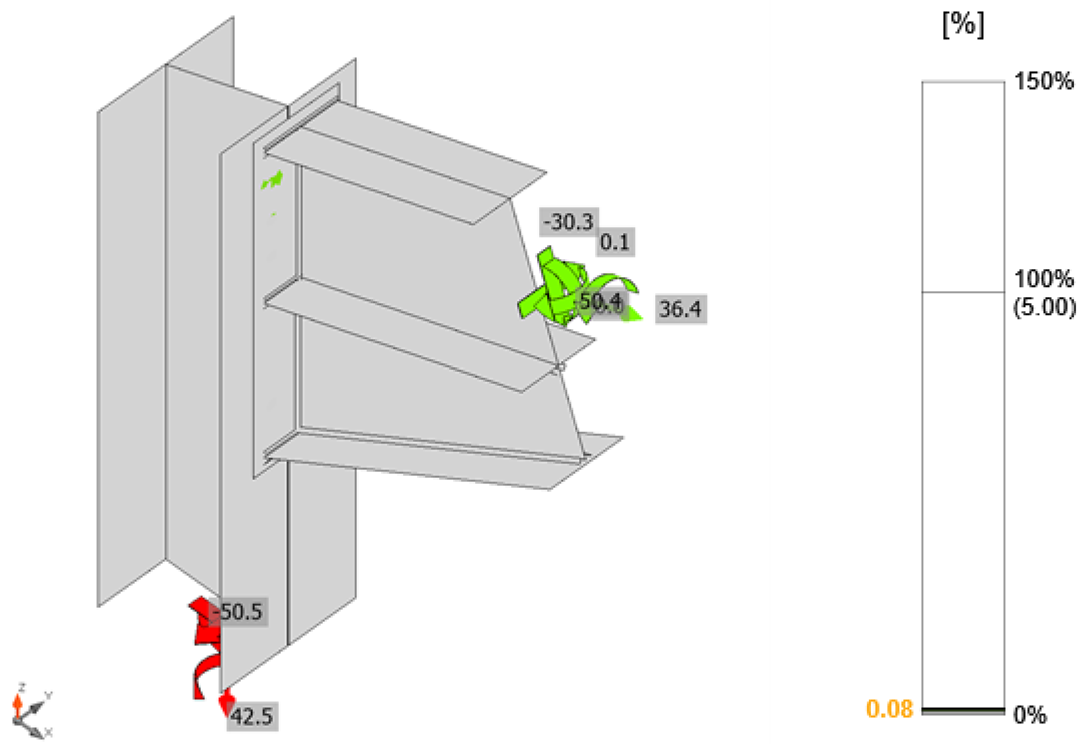
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

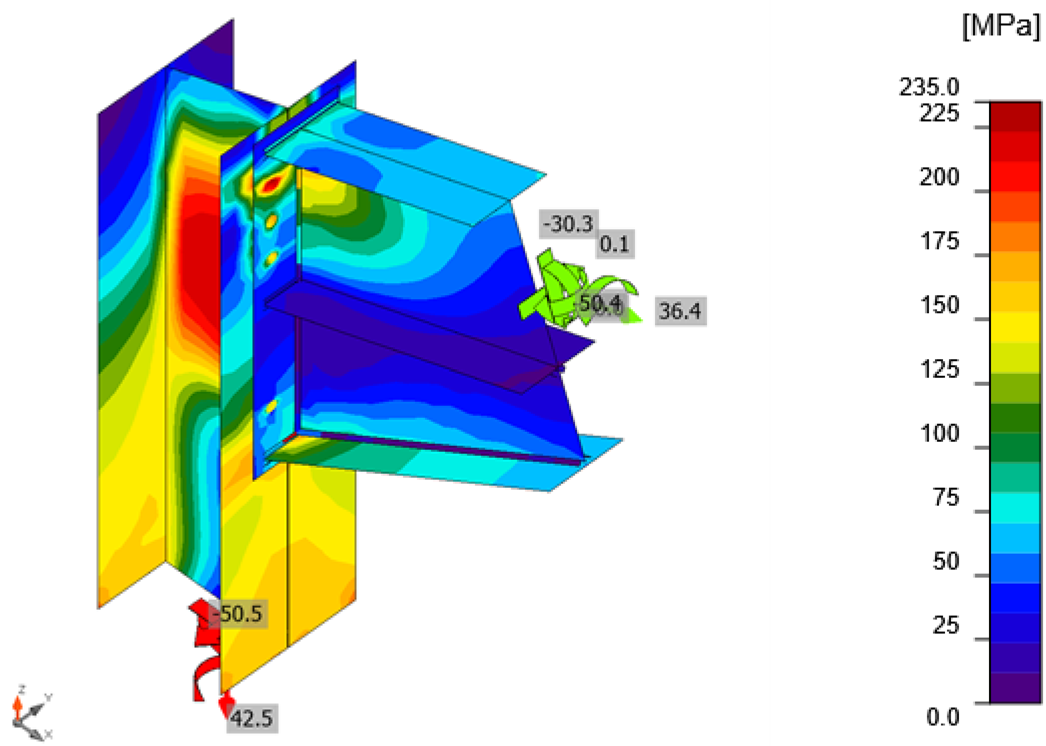
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

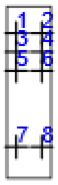


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	58.1	1.4	51.4	126.7	2.3	39.0	OK
	B2	LE1	58.3	1.4	51.5	126.7	2.3	39.1	OK
	B3	LE1	37.1	1.3	32.8	126.7	2.1	25.5	OK
	B4	LE1	37.3	1.3	33.0	126.7	2.0	25.6	OK
	B5	LE1	29.4	1.3	26.0	126.7	2.0	20.6	OK
	B6	LE1	29.6	1.3	26.2	126.7	2.0	20.7	OK
	B7	LE1	2.1	6.7	1.9	126.7	10.6	12.0	OK
	B8	LE1	2.2	6.7	2.0	126.7	10.6	12.0	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M16 10.9 - 1	113.0	168.9	62.8

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\|\|}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
EP1	B-bfl 1	◢4.5◣	120	LE1	33.9	0.0	21.0	0.8	15.4	9.4	7.2	OK
		◢4.5◣	120	LE1	20.0	0.0	9.7	-3.5	-9.5	5.5	3.4	OK
EP1	B-tfl 1	◢4.5◣	120	LE2	83.3	0.0	-23.1	46.2	-1.0	23.1	20.0	OK
		◢4.5◣	120	LE1	97.2	0.0	54.4	-30.8	-34.9	27.0	19.8	OK
EP1	B-w 1	◢6.0◣	245	LE1	153.5	0.0	76.8	2.2	76.7	42.6	24.0	OK
		◢6.0◣	245	LE1	153.2	0.0	76.5	-1.9	-76.6	42.6	23.9	OK
EP1	WID1a	◢7.0◣	240	LE2	49.2	0.0	-23.8	7.0	-23.9	13.7	7.1	OK
		◢7.0◣	240	LE2	51.0	0.0	-25.1	0.1	25.7	14.2	7.1	OK
B-bfl 1	WID1a	◢7.0◣	445	LE1	27.4	0.0	13.3	3.6	13.3	7.6	4.5	OK
		◢7.0◣	445	LE2	27.4	0.0	4.5	-14.9	-4.7	7.6	4.7	OK
WID1b	WID1a	◢7.0◣	541	LE2	70.5	0.0	-15.5	36.6	-15.5	19.6	4.8	OK
		◢7.0◣	541	LE2	70.6	0.0	-15.5	-36.6	15.5	19.6	4.8	OK
EP1	WID1b	◢7.0◣	120	LE1	255.6	0.0	-43.8	-71.9	-126.4	71.0	43.3	OK
		◢7.0◣	120	LE1	152.1	0.0	-84.9	30.9	66.0	42.3	32.7	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

Project:
Project no:
Author:

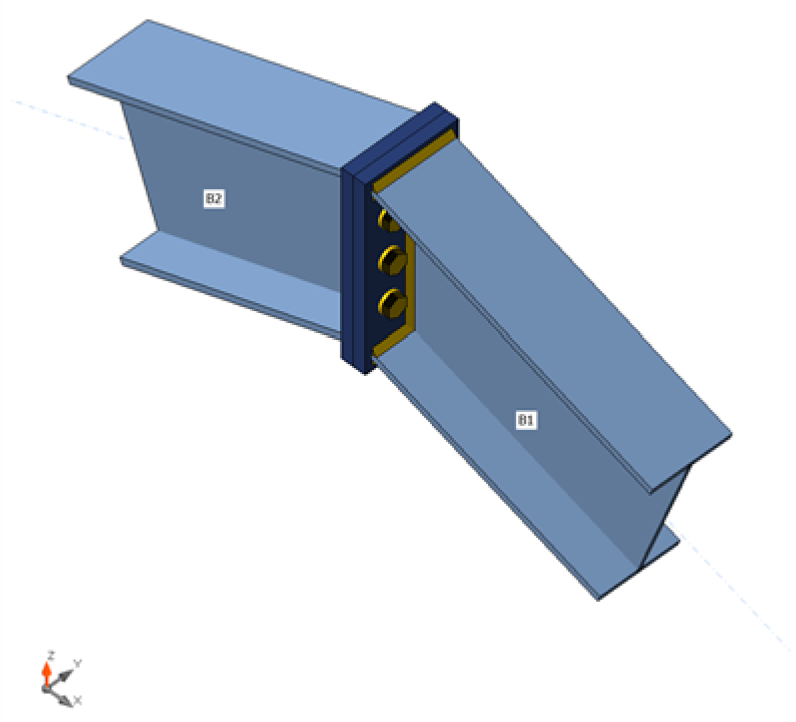
Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
B1	1 - IPE240	0.0	20.0	0.0	0	0	0	Node
B2	1 - IPE240	180.0	20.0	0.0	0	0	0	Node



Cross-sections

Name	Material
1 - IPE240	S 235

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M16 10.9	M16 10.9	16	1000.0	201

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B1	26.8	0.0	-16.0	0.0	-15.1	0.0
LE2	B1	-26.8	0.0	-16.0	0.0	-15.1	0.0
LE3	B1	26.8	0.0	-16.0	0.0	-15.1	0.0
LE4	B1	-26.8	0.0	-16.0	0.0	15.1	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	41.0 < 100%	OK
Welds	50.1 < 100%	OK
Buckling	Not calculated	

Plates

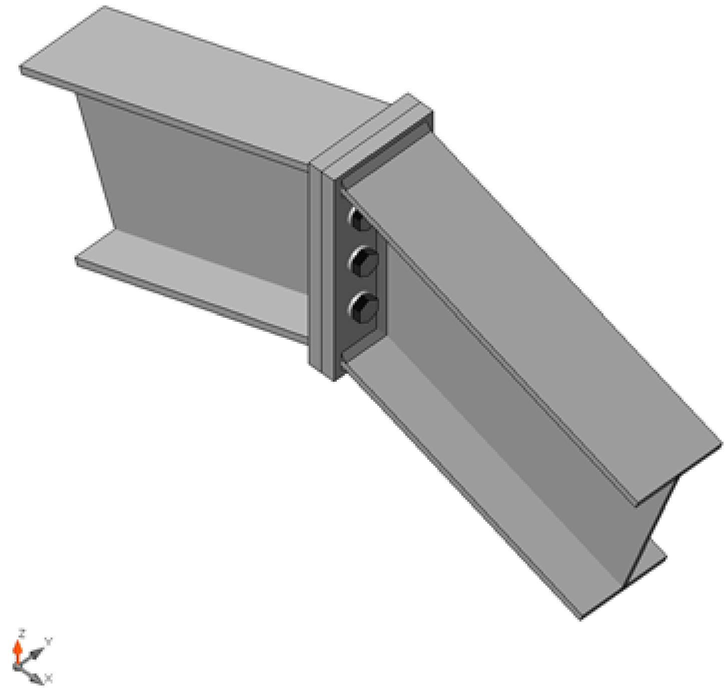
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
B1-bfl 1	9.8	LE4	97.5	0.0	0.0	OK
B1-tfl 1	9.8	LE2	80.0	0.0	0.0	OK
B1-w 1	6.2	LE3	161.6	0.0	0.0	OK
B2-bfl 1	9.8	LE4	96.3	0.0	0.0	OK
B2-tfl 1	9.8	LE3	78.2	0.0	0.0	OK
B2-w 1	6.2	LE3	125.1	0.0	0.0	OK
PP1a	18.0	LE3	187.2	0.0	10.4	OK
PP1b	18.0	LE3	174.4	0.0	10.4	OK

Design data

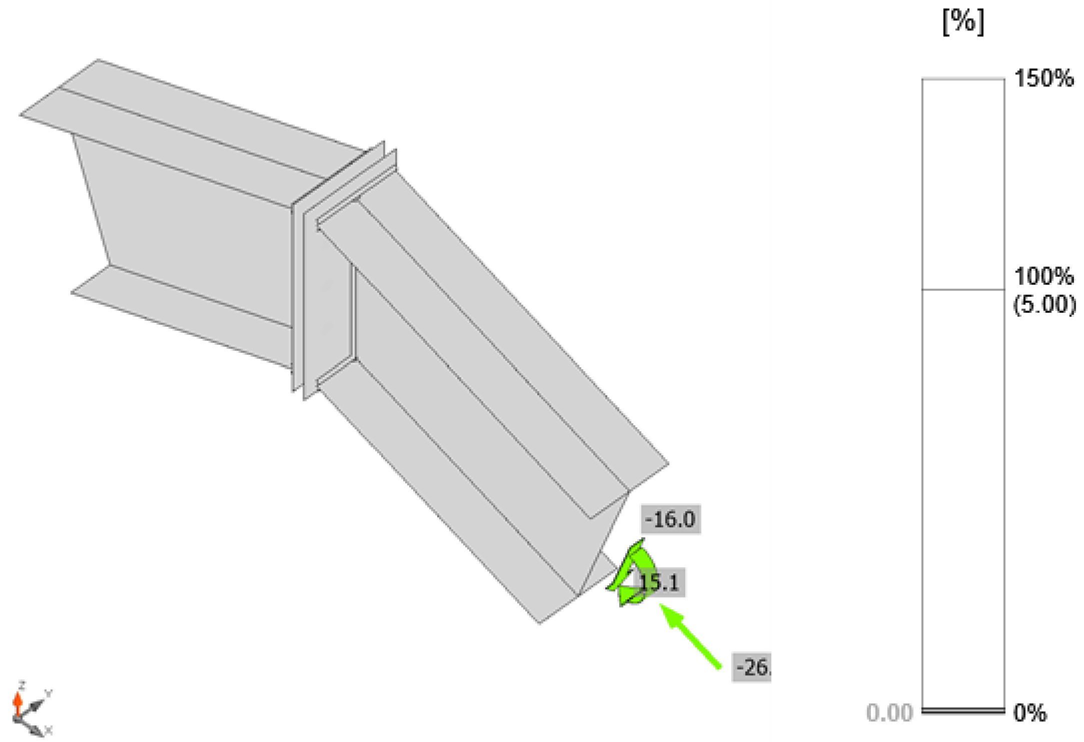
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

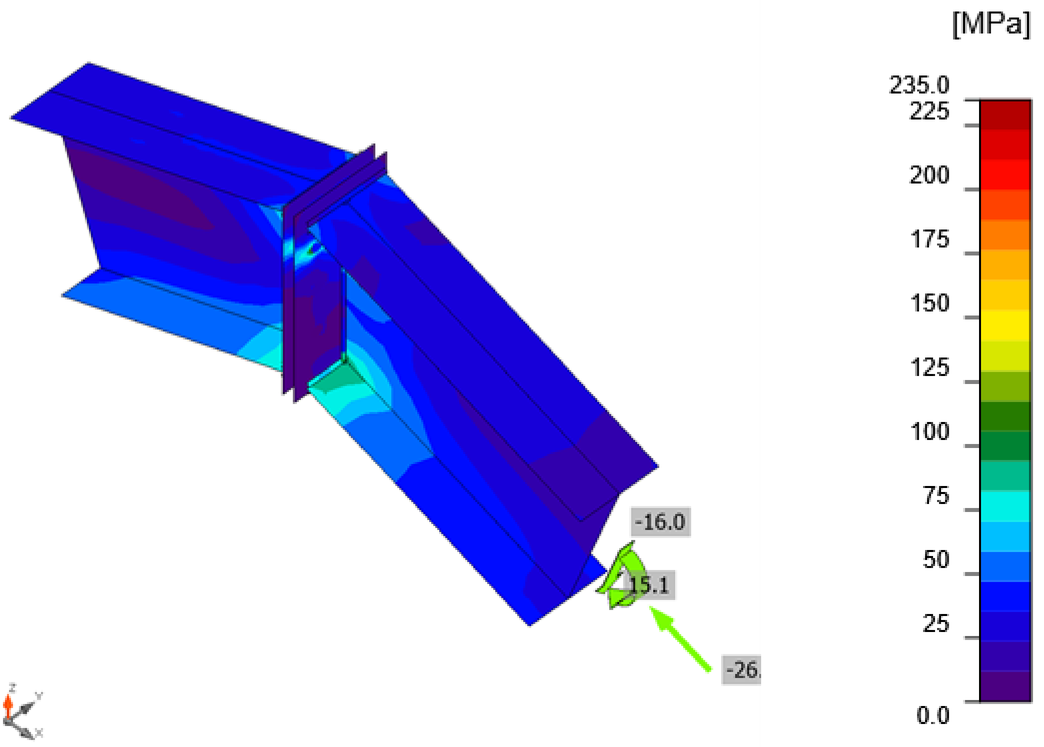
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE4

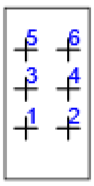


Strain check, LE4



Equivalent stress, LE4

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	46.4	4.2	41.0	197.8	6.7	36.0	OK
	B2	LE1	46.4	4.2	41.0	197.8	6.7	36.0	OK
	B3	LE1	10.3	4.0	9.1	197.8	6.4	12.9	OK
	B4	LE1	10.3	4.0	9.1	197.8	6.4	12.9	OK
	B5	LE4	27.9	0.9	24.7	197.8	1.5	19.1	OK
	B6	LE4	27.9	0.9	24.7	197.8	1.5	19.1	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M16 10.9 - 1	113.0	276.3	62.8

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
PP1a	B1-bfl 1	◢5.0◣	120	LE1	111.5	0.0	50.8	45.6	34.8	31.0	21.0	OK
		◢5.0◣	120	LE4	123.9	0.0	-50.0	5.4	65.2	34.4	32.4	OK
PP1a	B1-tfl 1	◢5.0◣	120	LE2	110.0	0.0	-50.0	40.4	-39.7	30.6	25.1	OK
		◢5.0◣	120	LE2	132.6	0.0	-45.4	0.5	71.9	36.8	33.2	OK
PP1a	B1-w 1	◢5.0◣	245	LE1	168.9	0.0	85.2	9.3	83.7	46.9	19.0	OK
		◢5.0◣	245	LE1	168.9	0.0	82.9	-9.1	-84.5	46.9	19.0	OK
PP1b	B2-bfl 1	◢5.0◣	120	LE4	102.2	0.0	-39.8	-0.1	-54.4	28.4	22.5	OK
		◢5.0◣	120	LE4	127.6	0.0	-49.8	3.9	67.7	35.4	32.9	OK
PP1b	B2-tfl 1	◢5.0◣	120	LE2	110.1	0.0	-50.0	-40.4	-39.6	30.6	25.2	OK
		◢5.0◣	120	LE2	130.8	0.0	-44.1	-0.5	71.1	36.3	32.9	OK
PP1b	B2-w 1	◢5.0◣	245	LE1	180.5	0.0	85.2	30.6	86.6	50.1	18.7	OK
		◢5.0◣	245	LE1	180.5	0.0	87.5	-30.7	-85.8	50.1	18.8	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4

Item	Value	Unit	Reference
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

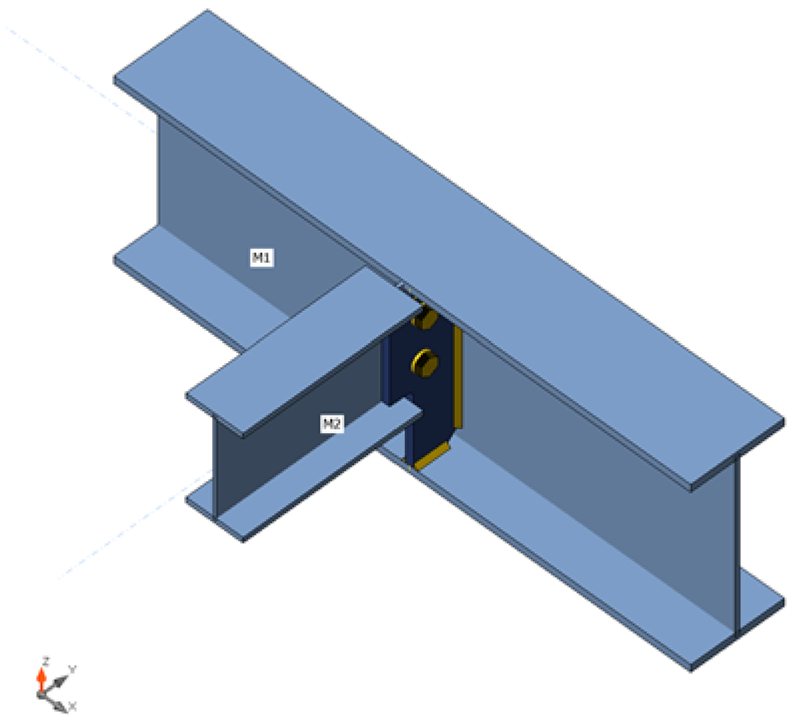
Project item CON1

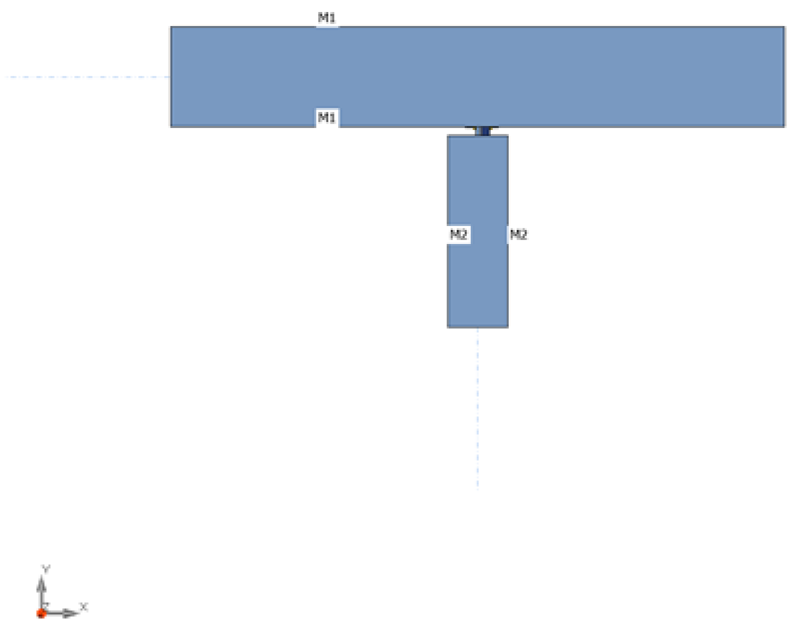
Design

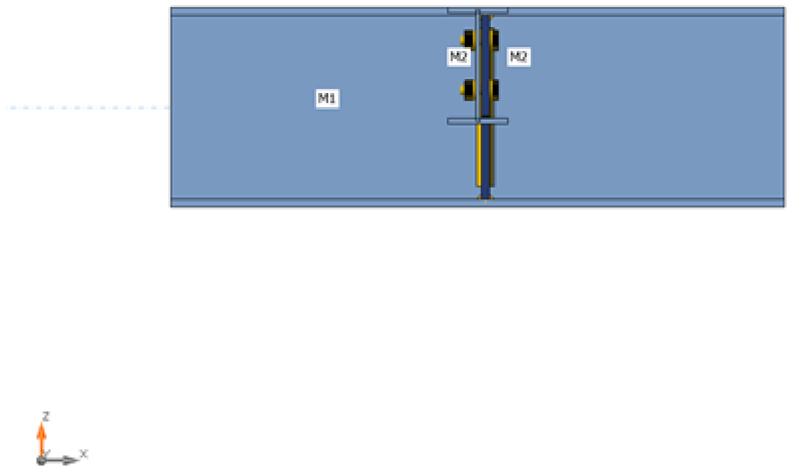
Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

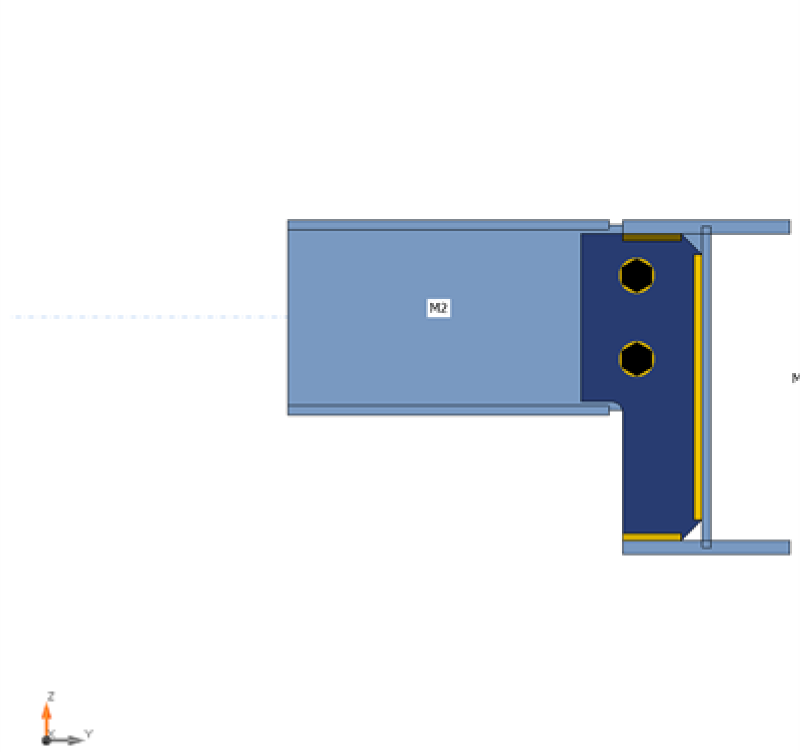
Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
M1	1 - CON1(IPE240)	0.0	0.0	0.0	0	0	0	Node	0
M2	2 - CON1(IPE140)	-90.0	0.0	0.0	0	0	50	Bolts	50




M1
M1
M2
M2
Y
X

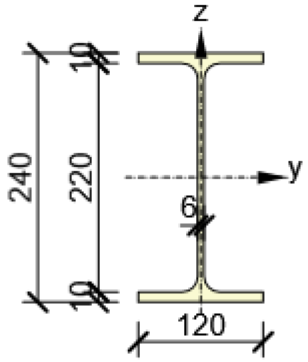
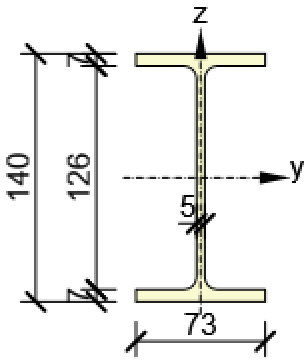

M2
M2
M1
Z
X



Cross-sections

Name	Material
1 - CON1(IPE240)	S 235
2 - CON1(IPE140)	S 235

Cross-sections

Name	Material	Drawing
1 - CON1(IPE240)	S 235	
2 - CON1(IPE140)	S 235	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 10.9	M12 10.9	12	1000.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	M2	-17.7	0.1	-0.2	0.0	0.1	0.0
LE2	M2	17.7	-0.1	-0.2	0.0	0.1	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	36.3 < 100%	OK
Welds	32.7 < 100%	OK
Buckling	Not calculated	

Plates

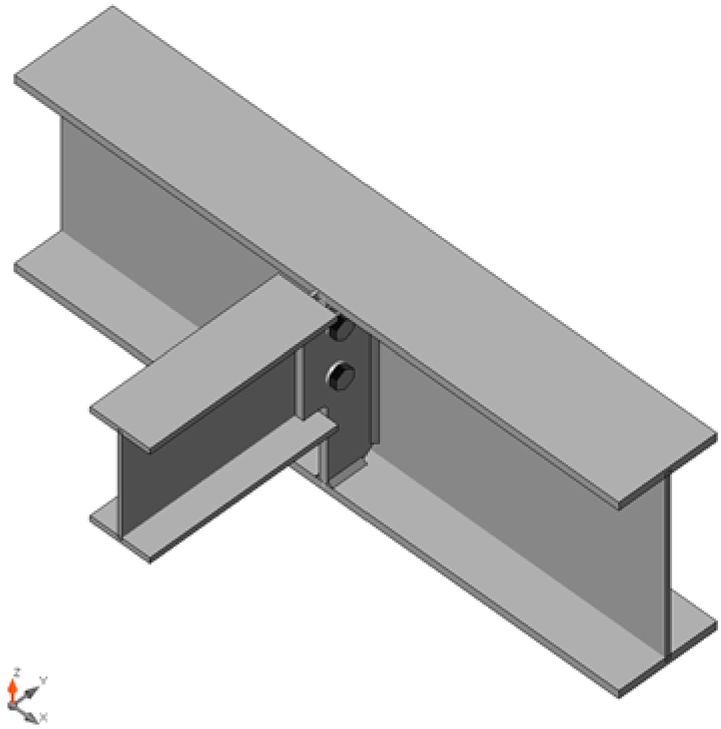
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
M1-bfl 1	9.8	LE1	19.0	0.0	0.0	OK
M1-tfl 1	9.8	LE2	49.2	0.0	0.0	OK
M1-w 1	6.2	LE1	21.7	0.0	0.0	OK
M2-bfl 1	6.9	LE1	14.2	0.0	0.0	OK
M2-tfl 1	6.9	LE2	19.9	0.0	0.0	OK
M2-w 1	4.7	LE2	169.8	0.0	10.5	OK
STIFF1	10.0	LE2	114.3	0.0	10.5	OK

Design data

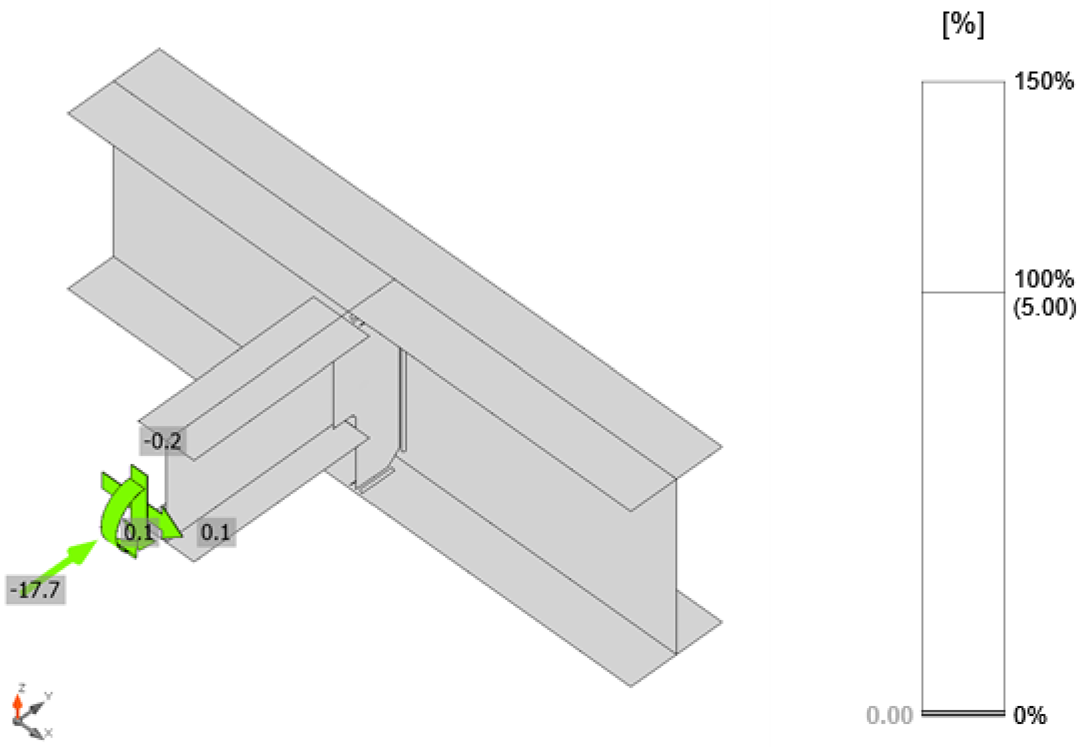
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

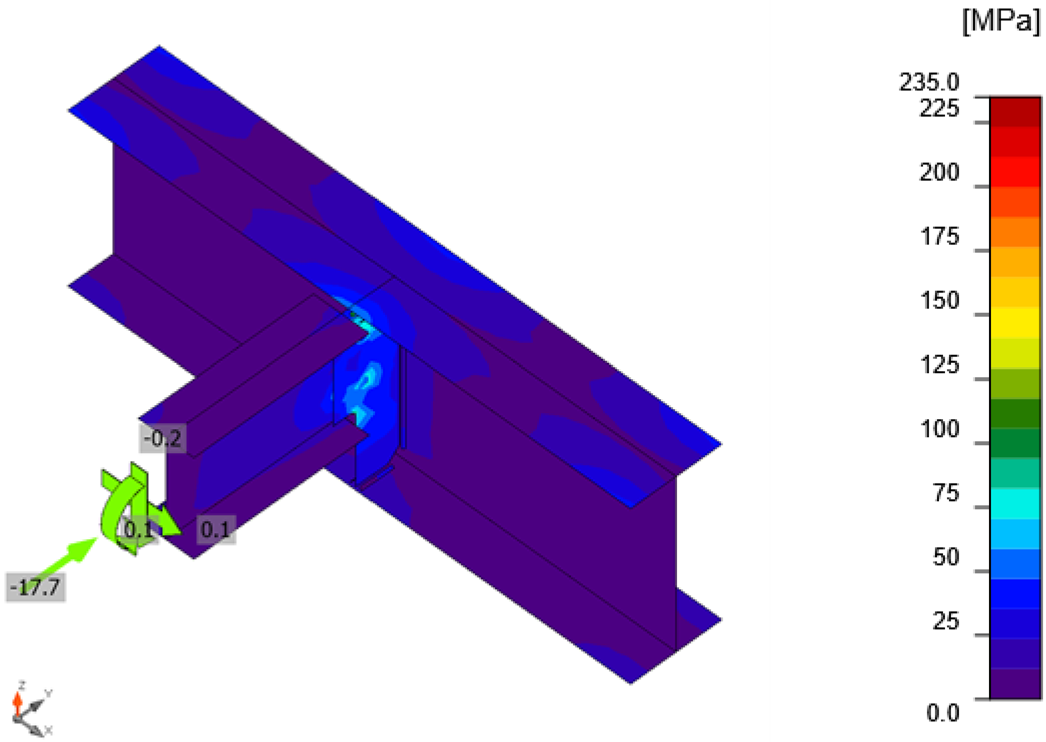
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

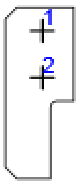


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE2	4.2	10.5	7.2	40.6	31.3	36.3	OK
	B2	LE1	3.4	10.5	5.8	40.6	31.3	35.3	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 10.9 - 1	60.5	58.7	33.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
M1-bfl 1	STIFF1	◢4.0◣	42	LE1	44.6	0.0	-5.8	-25.2	-3.7	12.4	8.9	OK
		◢4.0◣	42	LE1	34.5	0.0	1.2	19.9	0.9	9.6	6.1	OK
M1-w 1	STIFF1	◢4.0◣	190	LE1	44.1	0.0	-2.5	-25.3	-2.6	12.2	7.7	OK
		◢4.0◣	190	LE1	30.9	0.0	0.8	17.8	-1.0	8.6	4.9	OK
M1-tfl 1	STIFF1	◢4.0◣	42	LE2	117.7	0.0	25.7	-64.0	17.5	32.7	26.2	OK
		◢4.0◣	42	LE2	52.7	0.0	2.6	30.3	-2.1	14.6	10.4	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\|\|}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

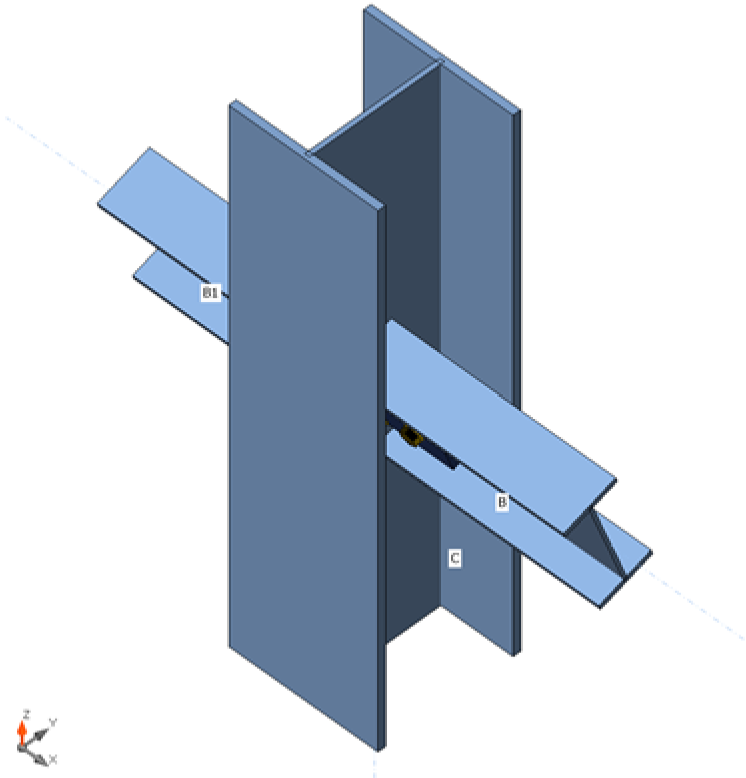
Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
C	4 - HEA220	0.0	-90.0	90.0	0	0	0	Node	0
B	5 - IPE160	0.0	0.0	20.0	0	0	0	Bolts	59
B1	5 - IPE160	180.0	0.0	-20.0	0	0	0	Bolts	58



Cross-sections

Name	Material
4 - HEA220	S 235
5 - IPE160	S 235

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 10.9	M12 10.9	12	1000.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	-11.8	0.1	-0.2	0.0	0.1	0.1
	B1	-4.3	0.1	-0.2	0.0	0.1	0.1
LE2	B	11.8	-0.1	0.2	0.0	-0.1	-0.1
	B1	4.3	-0.1	0.2	0.0	-0.1	-0.1
LE3	B	11.8	0.1	0.2	0.0	0.1	-0.1
	B1	-4.3	-0.1	-0.2	0.0	-0.1	0.1

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	26.4 < 100%	OK
Welds	41.6 < 100%	OK
Buckling	Not calculated	

Plates

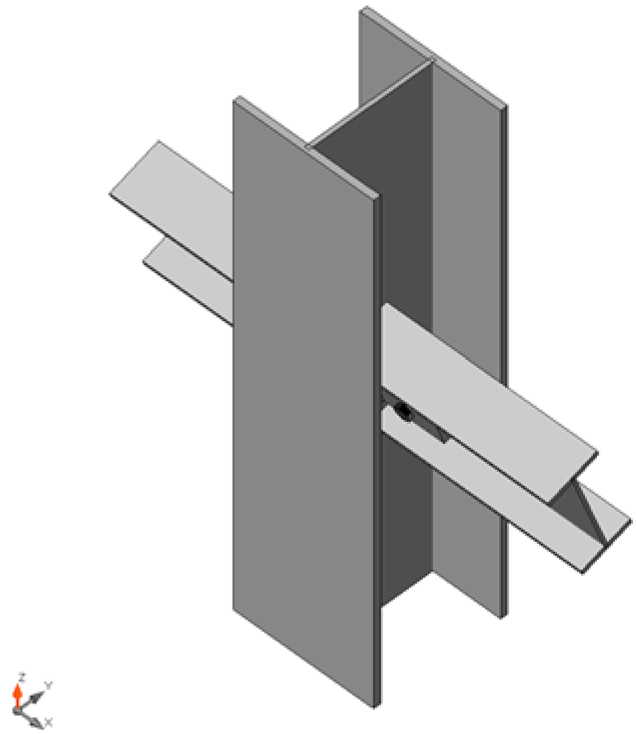
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	11.0	LE3	30.9	0.0	0.0	OK
C-tfl 1	11.0	LE3	33.8	0.0	0.0	OK
C-w 1	7.0	LE3	170.6	0.0	0.0	OK
B-bfl 1	7.4	LE3	19.0	0.0	0.0	OK
B-tfl 1	7.4	LE3	17.8	0.0	0.0	OK
B-w 1	5.0	LE1	147.0	0.0	10.8	OK
B1-bfl 1	7.4	LE2	15.9	0.0	0.0	OK
B1-tfl 1	7.4	LE3	17.5	0.0	0.0	OK
B1-w 1	5.0	LE2	94.3	0.0	10.1	OK
FP1	10.0	LE3	133.8	0.0	9.4	OK
FP2	10.0	LE3	92.1	0.0	5.2	OK

Design data

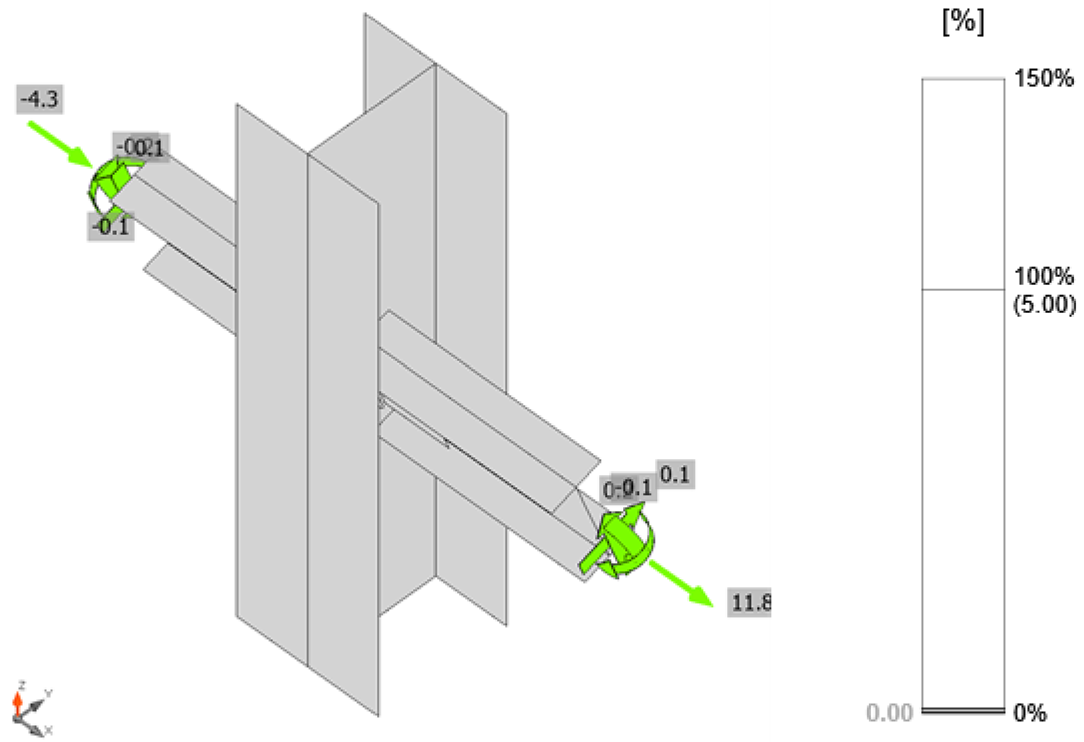
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

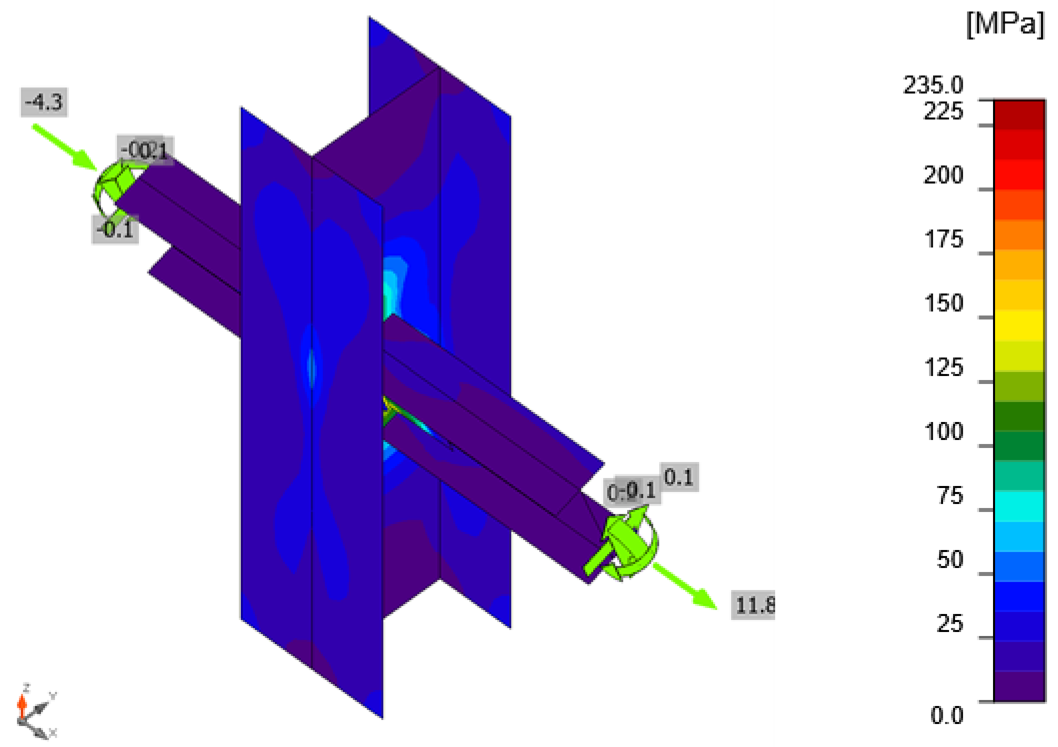
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE3

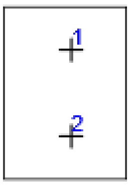
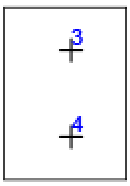


Strain check, LE3



Equivalent stress, LE3

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE3	3.8	7.3	6.3	43.2	21.8	26.3	OK
	B2	LE2	3.9	7.3	6.4	43.2	21.8	26.4	OK
	B3	LE3	2.1	3.6	3.6	43.2	10.7	13.2	OK
	B4	LE2	2.2	3.6	3.6	43.2	10.7	13.3	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 10.9 - 1	60.5	62.4	33.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\|\|}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
C-w 1	FP1	◢4.0◣	140	LE3	99.0	0.0	51.5	36.5	32.4	27.5	13.7	OK
		◢4.0◣	140	LE3	149.8	0.0	65.0	57.7	-52.4	41.6	18.3	OK
C-w 1	FP2	◢4.0◣	140	LE3	131.2	0.0	-60.8	-43.1	51.5	36.4	11.7	OK
		◢4.0◣	140	LE3	106.6	0.0	-47.6	-48.9	-25.3	29.6	12.6	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\|\|}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2

Item	Value	Unit	Reference
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

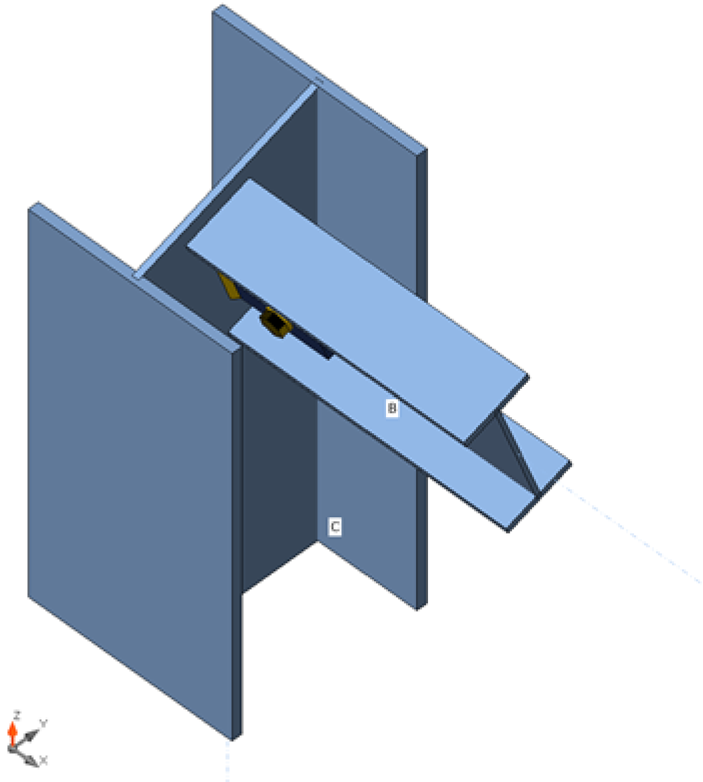
Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
C	4 - HEA220	0.0	90.0	90.0	0	0	0	Node	0
B	5 - IPE140	0.0	0.0	20.0	0	0	0	Bolts	58



Cross-sections

Name	Material
4 - HEA220	S 235
5 - IPE140	S 235

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 10.9	M12 10.9	12	1000.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	-11.8	0.1	-0.2	0.0	0.0	0.1
LE2	B	11.8	0.1	0.2	0.0	0.0	0.1

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	22.0 < 100%	OK
Welds	48.0 < 100%	OK
Buckling	Not calculated	

Plates

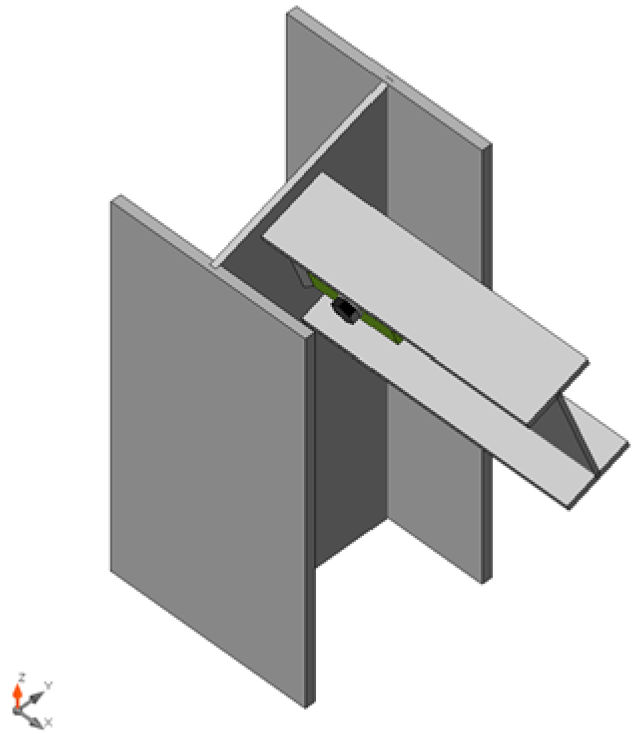
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	11.0	LE1	59.5	0.0	0.0	OK
C-tfl 1	11.0	LE2	62.8	0.0	0.0	OK
C-w 1	7.0	LE1	234.0	0.0	0.0	OK
B-bfl 1	6.9	LE1	36.2	0.0	0.0	OK
B-tfl 1	6.9	LE2	29.9	0.0	0.0	OK
B-w 1	4.7	LE1	140.6	0.0	10.0	OK
FP1	10.0	LE1	221.1	0.0	10.0	OK

Design data

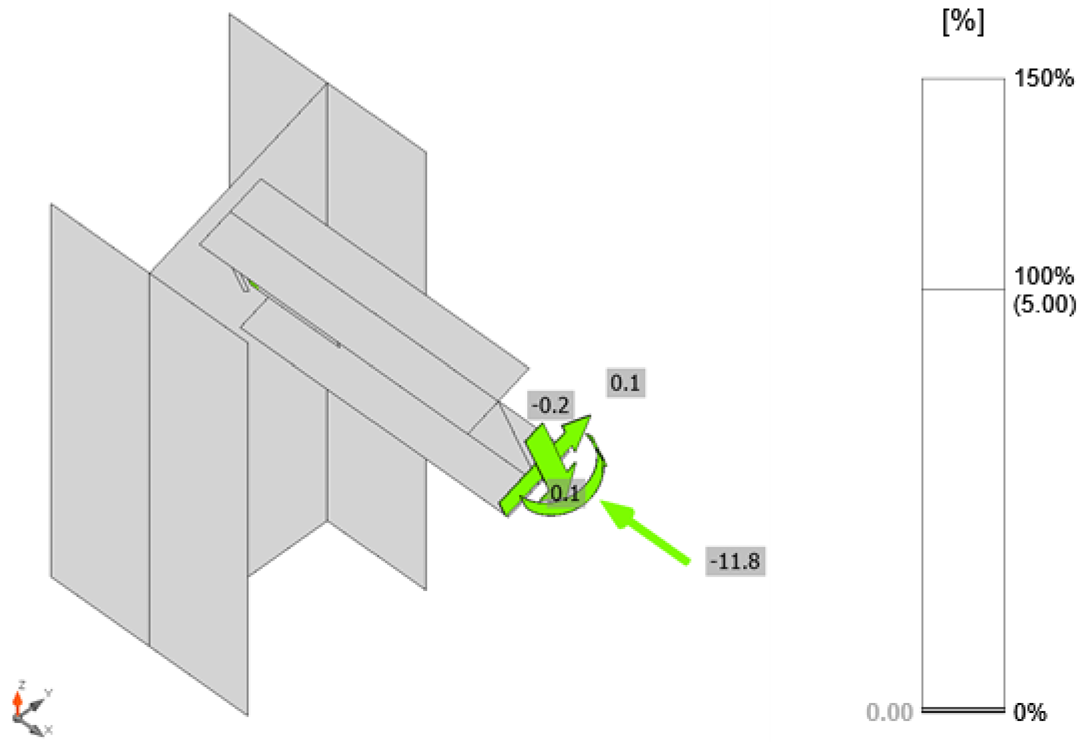
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

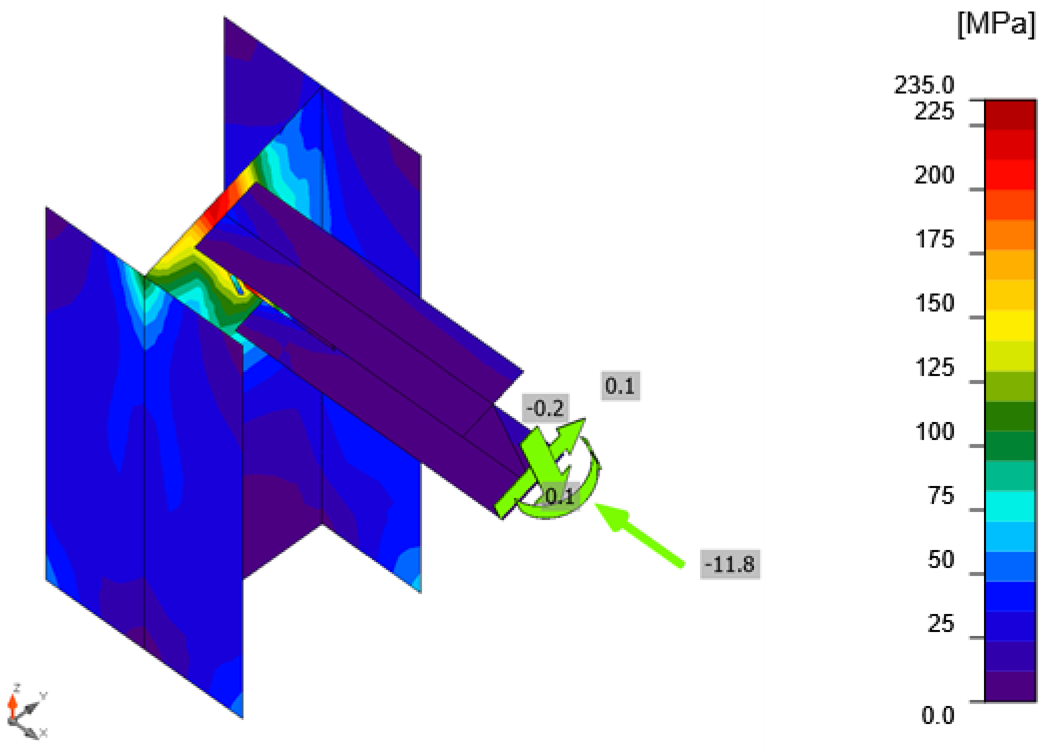
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

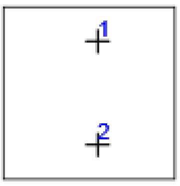


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	3.1	5.9	5.2	40.6	17.6	21.2	OK
	B2	LE1	3.8	5.9	6.4	40.6	17.6	22.0	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 10.9 - 1	60.5	58.7	33.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
C-w 1	FP1	◢4.0◣	100	LE1	163.9	0.0	26.0	-83.8	41.3	45.5	19.8	OK
		◢4.0◣	100	LE1	172.6	0.0	-44.5	-88.6	37.9	48.0	27.7	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5

Item	Value	Unit	Reference
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

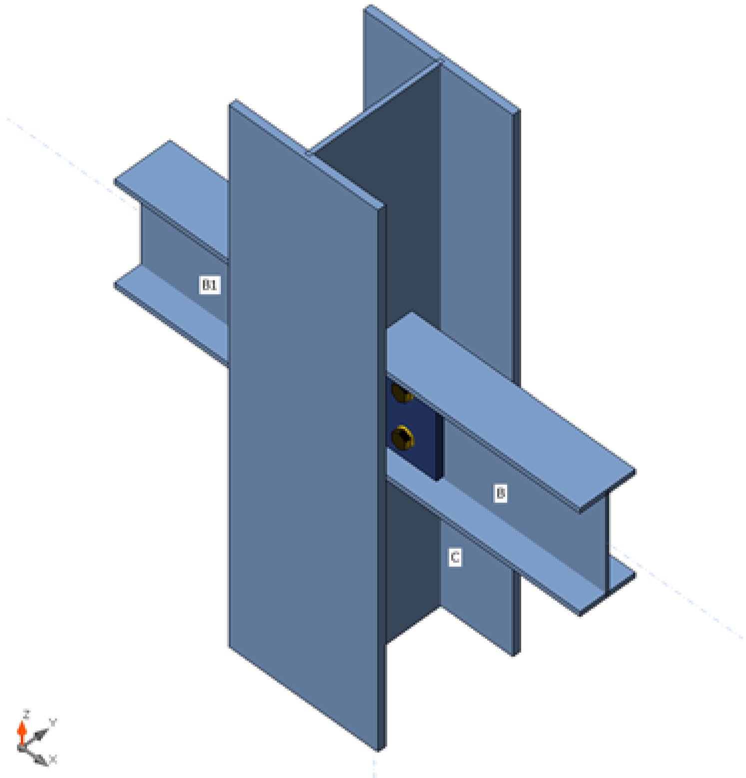
Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
C	4 - HEA220	0.0	-90.0	90.0	0	0	0	Node	0
B	5 - IPE160	0.0	0.0	0.0	0	0	0	Bolts	59
B1	5 - IPE160	180.0	0.0	0.0	0	0	0	Bolts	58



Cross-sections

Name	Material
4 - HEA220	S 235
5 - IPE160	S 235

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 10.9	M12 10.9	12	1000.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	-1.3	0.1	-0.3	0.0	0.1	0.0
	B1	-6.4	0.1	-0.3	0.0	0.1	0.0
LE2	B	1.3	-0.1	0.3	0.0	-0.1	0.0
	B1	6.4	-0.1	0.3	0.0	-0.1	0.0
LE3	B	-1.3	0.1	0.3	0.0	0.1	0.0
	B1	6.4	-0.1	-0.3	0.0	-0.1	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	15.3 < 100%	OK
Welds	13.8 < 100%	OK
Buckling	Not calculated	

Plates

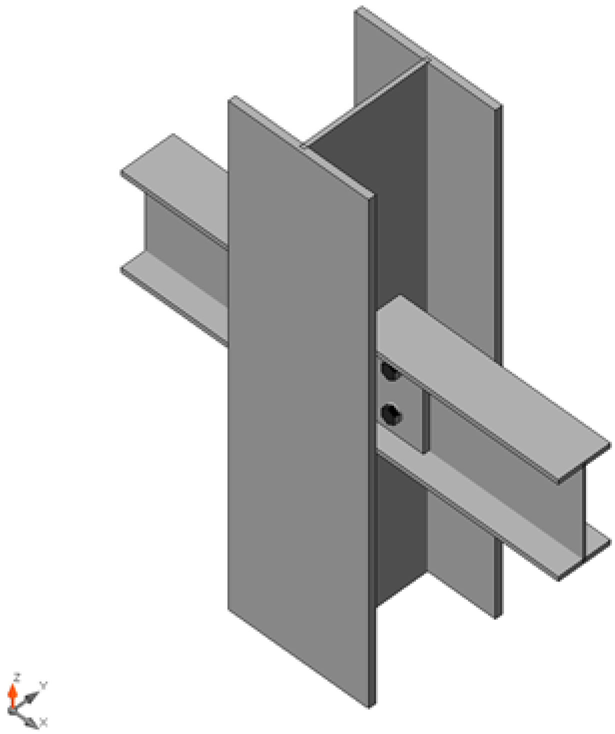
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	11.0	LE3	16.8	0.0	0.0	OK
C-tfl 1	11.0	LE3	17.0	0.0	0.0	OK
C-w 1	7.0	LE3	105.1	0.0	0.0	OK
B-bfl 1	7.4	LE3	4.1	0.0	0.0	OK
B-tfl 1	7.4	LE3	2.4	0.0	0.0	OK
B-w 1	5.0	LE1	30.8	0.0	1.3	OK
B1-bfl 1	7.4	LE3	6.5	0.0	0.0	OK
B1-tfl 1	7.4	LE2	5.0	0.0	0.0	OK
B1-w 1	5.0	LE1	65.6	0.0	2.5	OK
FP1	10.0	LE3	26.1	0.0	1.3	OK
FP2	10.0	LE2	39.7	0.0	2.9	OK

Design data

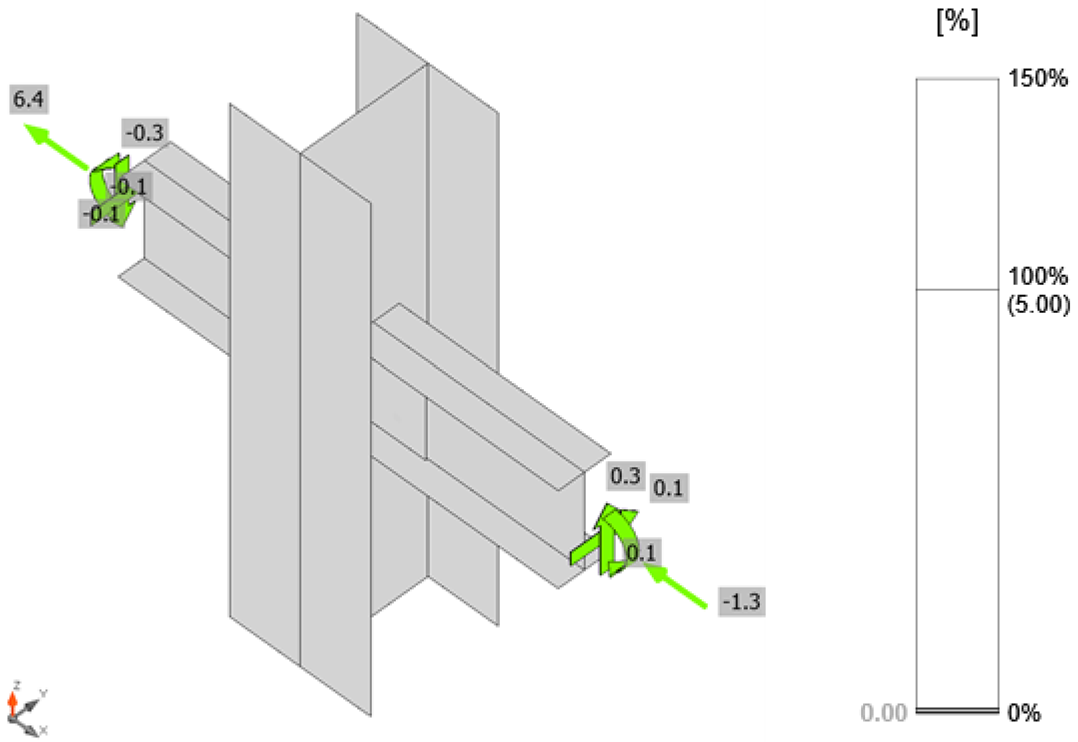
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

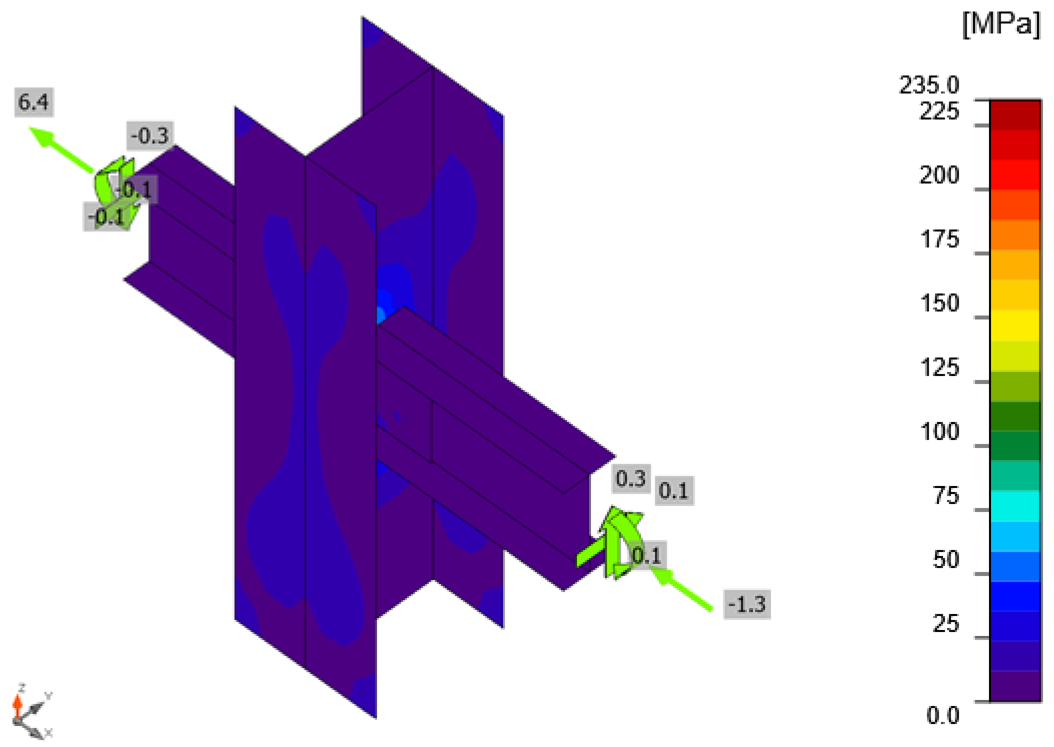
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE3

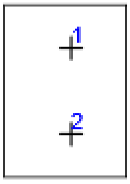
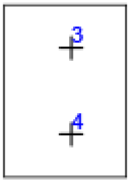


Strain check, LE3



Equivalent stress, LE3

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	0.2	0.8	0.4	43.2	2.4	2.6	OK
	B2	LE2	0.4	2.1	0.7	43.2	6.2	6.7	OK
	B3	LE3	0.8	1.8	1.4	43.2	5.3	6.3	OK
	B4	LE2	1.3	4.6	2.1	43.2	13.8	15.3	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 10.9 - 1	60.5	62.4	33.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
C-w 1	FP1	◢4.0◣	140	LE3	27.4	0.0	-10.5	5.4	-13.6	7.6	2.8	OK
		◢4.0◣	140	LE3	39.2	0.0	-20.2	-9.0	17.1	10.9	3.5	OK
C-w 1	FP2	◢4.0◣	140	LE3	28.4	0.0	12.2	-5.2	-13.9	7.9	2.7	OK
		◢4.0◣	140	LE3	49.7	0.0	24.3	10.6	22.7	13.8	5.7	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2

Item	Value	Unit	Reference
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/14/2022
Design code	EN

Material

Steel	S 235

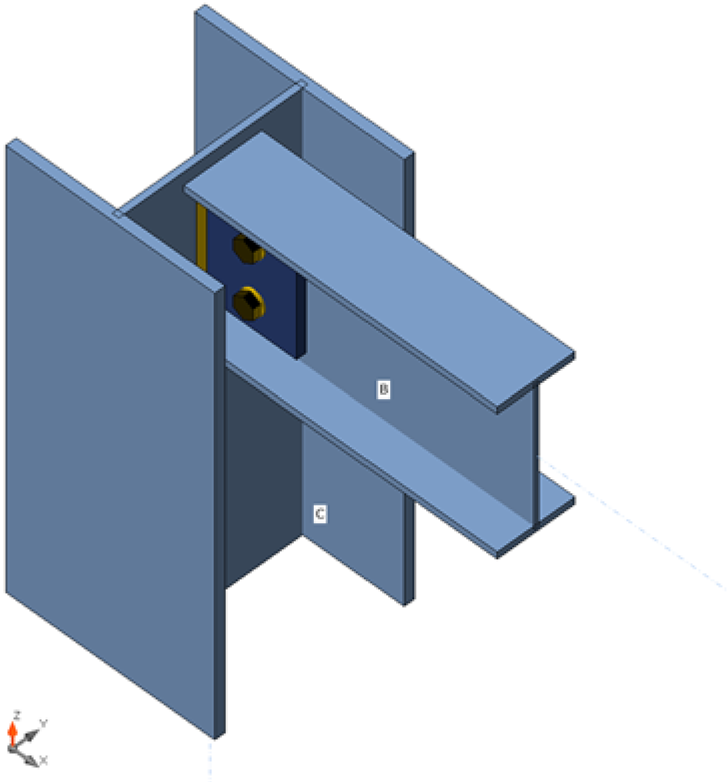
Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
C	4 - HEA220	0.0	90.0	90.0	0	0	0	Node	0
B	3 - IPE160	0.0	0.0	0.0	0	0	0	Bolts	58



Cross-sections

Name	Material
4 - HEA220	S 235
3 - IPE160	S 235

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 10.9	M12 10.9	12	1000.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	-6.4	0.1	-0.3	0.0	0.1	0.0
LE2	B	6.4	-0.1	0.3	0.0	-0.1	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	16.0 < 100%	OK
Welds	17.5 < 100%	OK
Buckling	Not calculated	

Plates

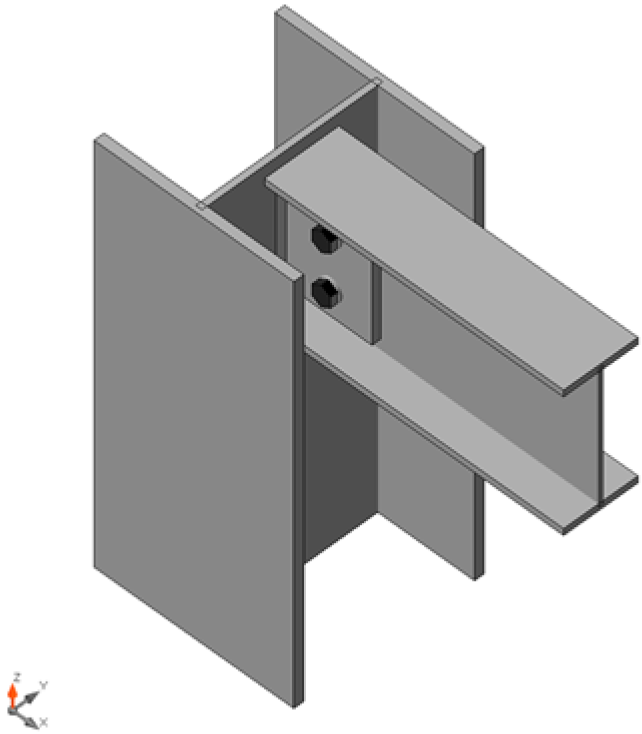
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	11.0	LE2	29.4	0.0	0.0	OK
C-tfl 1	11.0	LE1	29.0	0.0	0.0	OK
C-w 1	7.0	LE1	103.7	0.0	0.0	OK
B-bfl 1	7.4	LE1	4.9	0.0	0.0	OK
B-tfl 1	7.4	LE1	4.7	0.0	0.0	OK
B-w 1	5.0	LE1	68.7	0.0	2.7	OK
FP1	10.0	LE2	51.9	0.0	2.7	OK

Design data

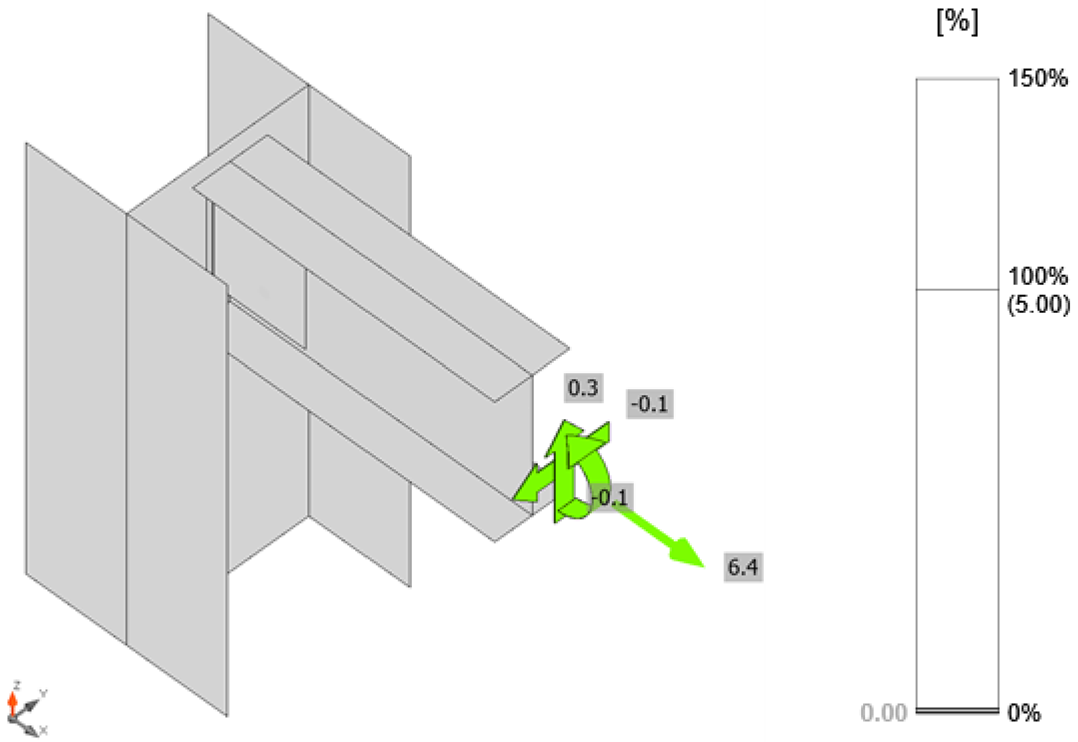
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

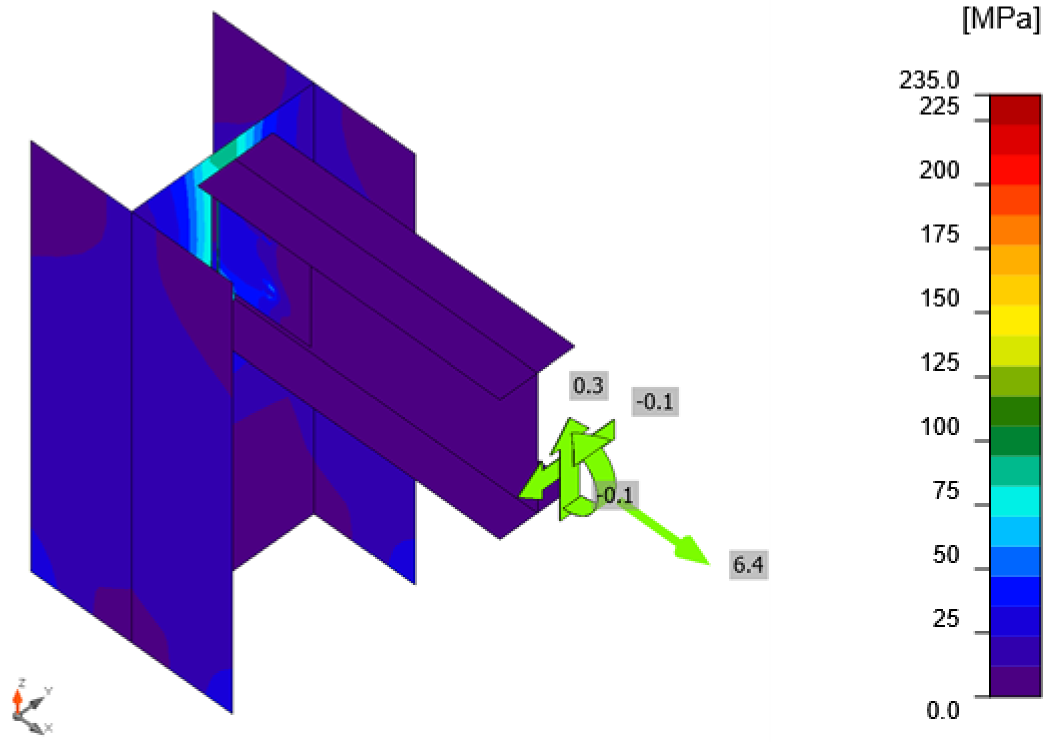
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE2

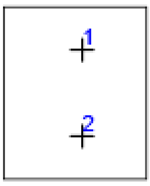


Strain check, LE2



Equivalent stress, LE2

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE2	0.7	1.5	1.2	43.2	4.6	5.4	OK
	B2	LE2	1.3	4.9	2.1	43.2	14.5	16.0	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 10.9 - 1	60.5	62.4	33.6

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Welds (Plastic redistribution)

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
C-w 1	FP1	◢4.0◣	120	LE2	31.8	0.0	13.4	-1.3	16.6	8.8	4.0	OK
		◢4.0◣	120	LE1	62.9	0.0	-32.4	-10.8	29.2	17.5	7.1	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 235	0.80	360.0	259.2

Symbol explanation

ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_C	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5

Item	Value	Unit	Reference
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	7/12/2022
Design code	EN

Material

Steel	S 235

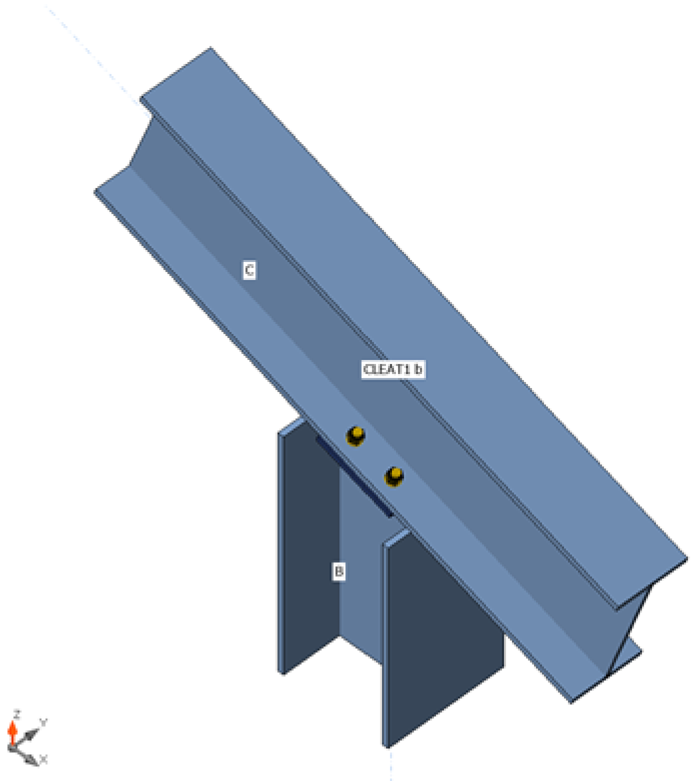
Project item CON1

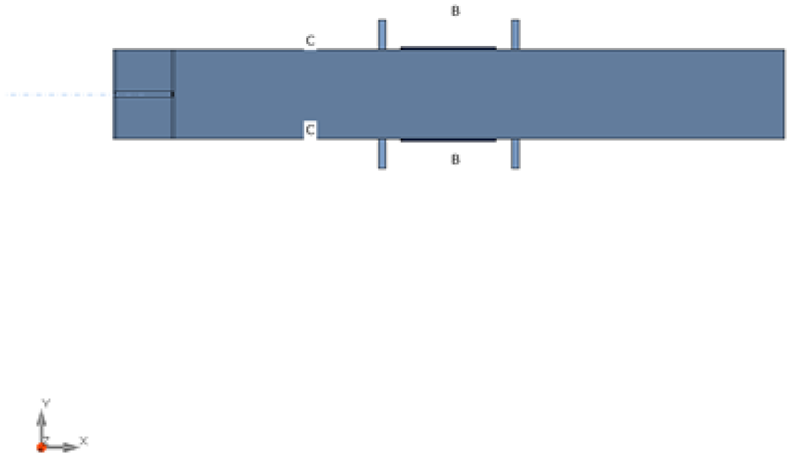
Design

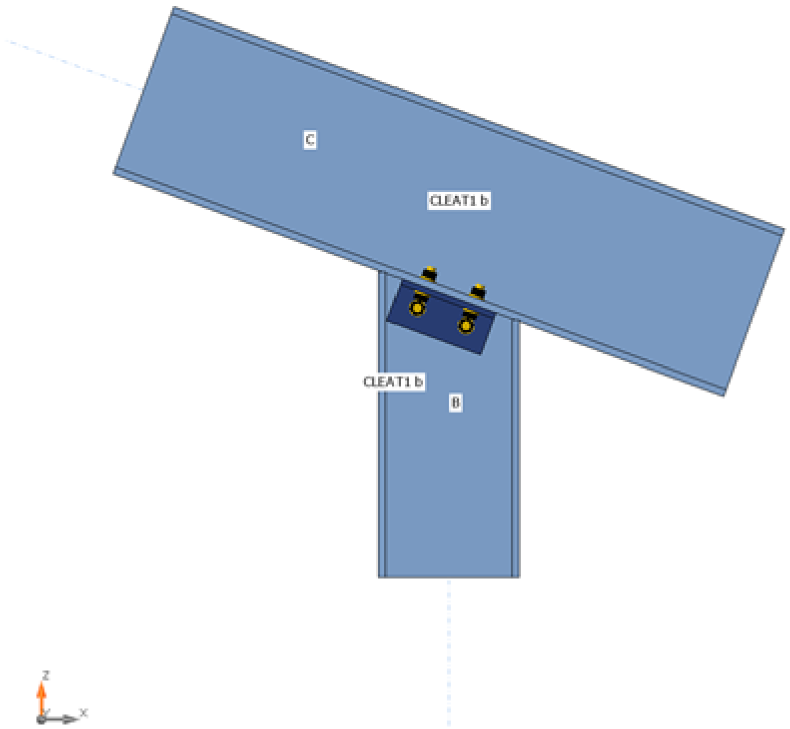
Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

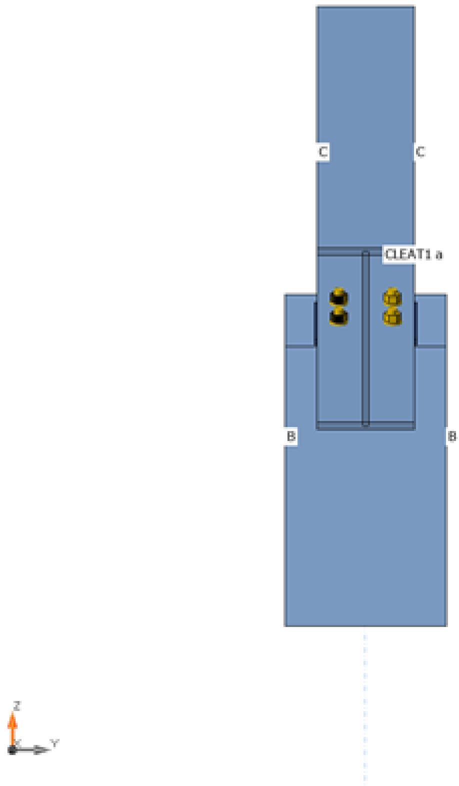
Beams and columns

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
C	3 - IPE240	0.0	20.0	0.0	0	0	0	Node
B	1 - CON1(HEA200)	0.0	90.0	0.0	0	0	0	Node




B
C
C
B
Y
X

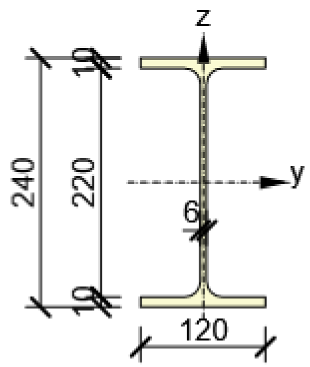
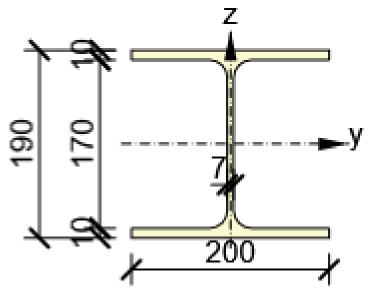
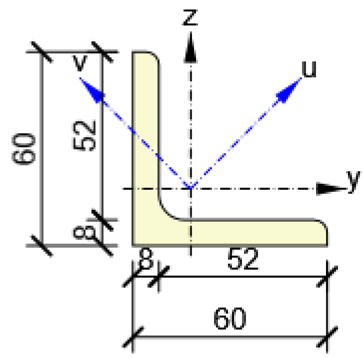

C
CLEAT1 b
CLEAT1 b
B
Z
X



Cross-sections

Name	Material
3 - IPE240	S 235
1 - CON1(HEA200)	S 235
4 - L60X8	S 235

Cross-sections

Name	Material	Drawing
3 - IPE240	S 235	
1 - CON1(HEA200)	S 235	
4 - L60X8	S 235	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M12 8.8	M12 8.8	12	800.0	113

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	C	4.3	0.0	-3.6	0.0	-1.4	0.0
	C	-6.6	0.0	-4.2	0.0	1.4	0.0
LE2	C	-4.3	0.0	3.6	0.0	1.4	0.0
	C	6.6	0.0	4.2	0.0	-1.4	0.0
LE3	C	14.0	0.0	-9.3	0.0	-3.7	0.0
	C	-18.3	0.0	-11.3	0.0	3.7	0.0
LE4	C	-14.0	0.0	9.3	0.0	3.7	0.0
	C	18.3	0.0	11.3	0.0	-3.7	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.6 < 5.0%	OK
Bolts	75.1 < 100%	OK
Buckling	Not calculated	

Plates

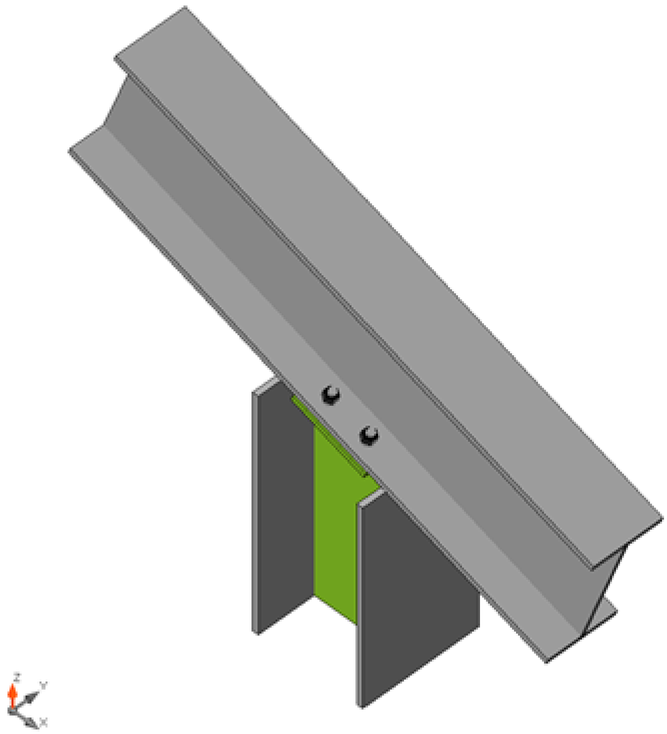
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Status
C-bfl 1	9.8	LE4	210.1	0.0	61.7	OK
C-tfl 1	9.8	LE4	12.2	0.0	0.0	OK
C-w 1	6.2	LE4	52.6	0.0	0.0	OK
B-bfl 1	10.0	LE4	23.5	0.0	0.0	OK
B-tfl 1	10.0	LE3	16.9	0.0	0.0	OK
B-w 1	6.5	LE3	236.3	0.6	5.9	OK
CLEAT1 a-bfl 1	8.0	LE4	223.5	0.0	61.7	OK
CLEAT1 a-w 1	8.0	LE4	235.1	0.0	61.7	OK
CLEAT1 b-bfl 1	8.0	LE4	223.5	0.0	61.7	OK
CLEAT1 b-w 1	8.0	LE4	235.1	0.0	61.7	OK

Design data

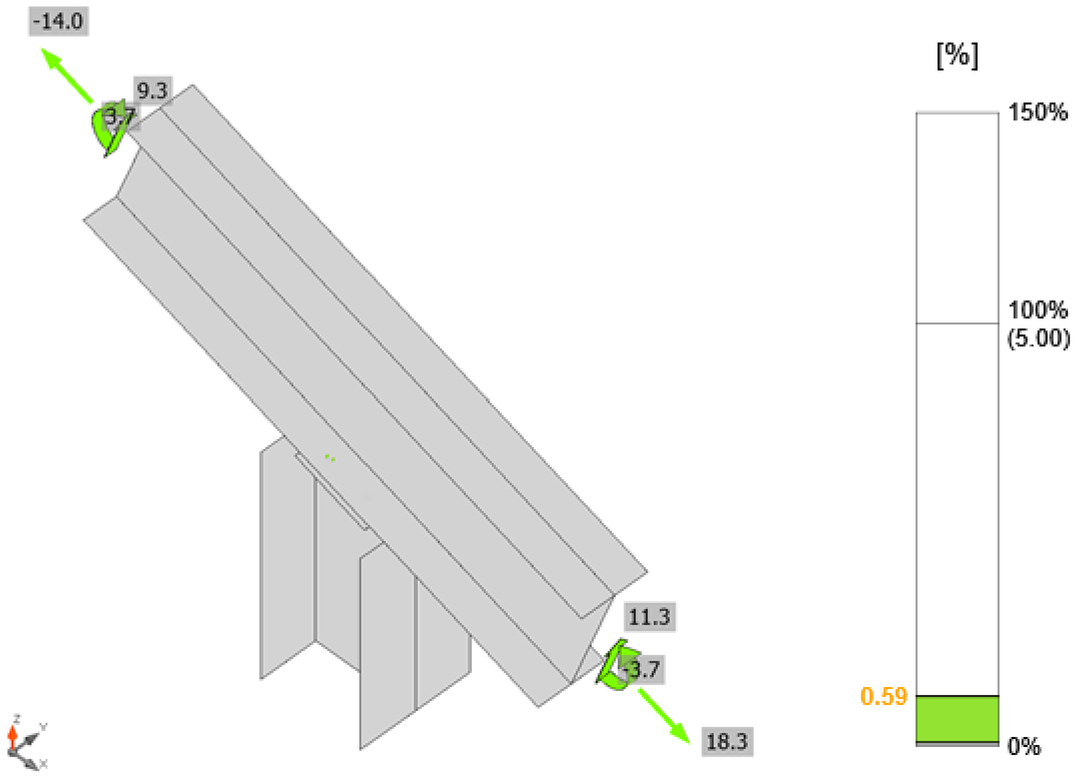
Material	f_y [MPa]	ε_{lim} [%]
S 235	235.0	5.0

Symbol explanation

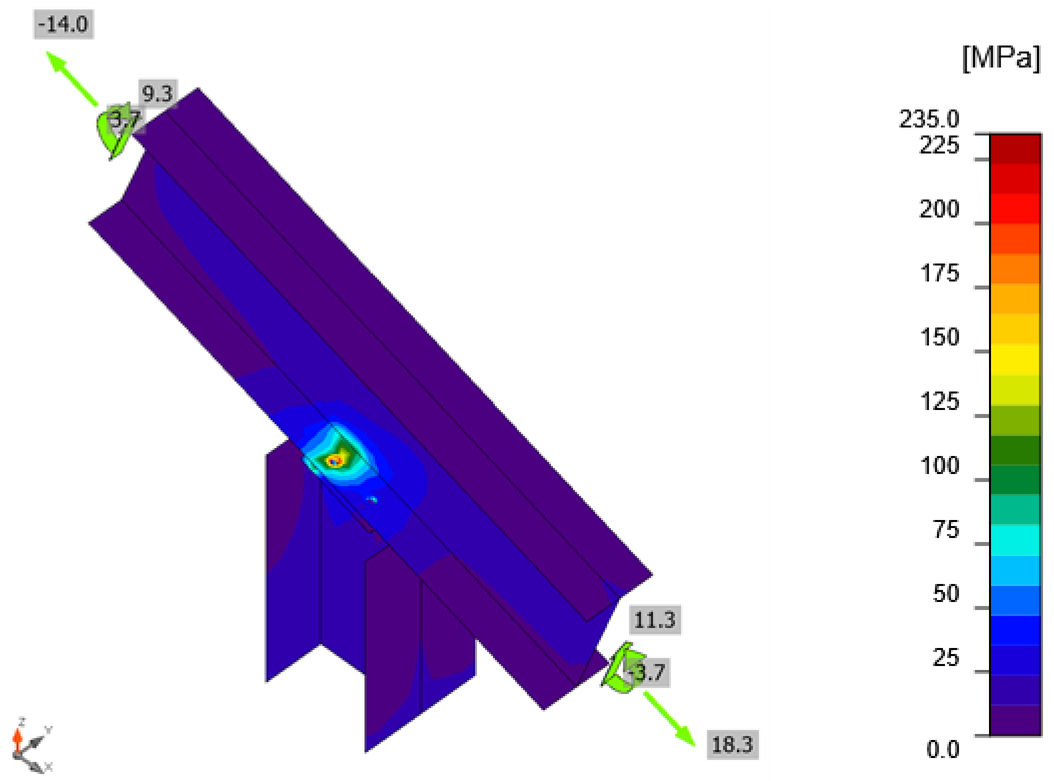
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
σc_{Ed}	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE4

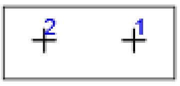
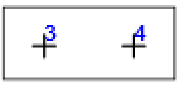
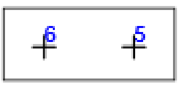


Strain check, LE4



Equivalent stress, LE4

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE4	8.4	16.2	17.5	43.2	75.1	62.7	OK
	B2	LE3	1.9	6.0	3.9	43.2	27.7	21.4	OK
	B3	LE4	20.7	1.1	42.7	69.1	3.4	33.9	OK
	B4	LE4	4.4	1.2	9.0	69.1	3.6	10.1	OK
	B5	LE4	20.7	1.1	42.7	69.1	3.4	33.9	OK
	B6	LE4	4.4	1.2	9.0	69.1	3.6	10.1	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M12 8.8 - 1	48.4	86.9	32.3

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of shear forces Vy, Vz in bolt
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Buckling

Buckling analysis was not calculated.

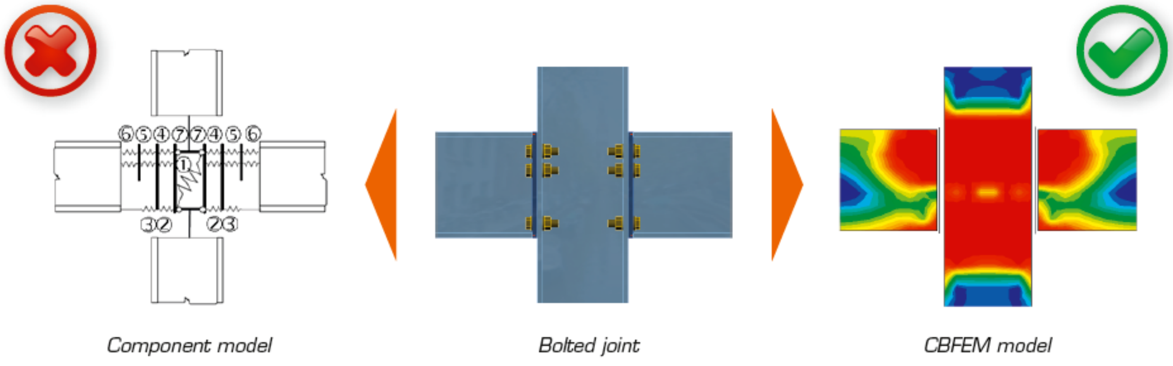
Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	Both		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

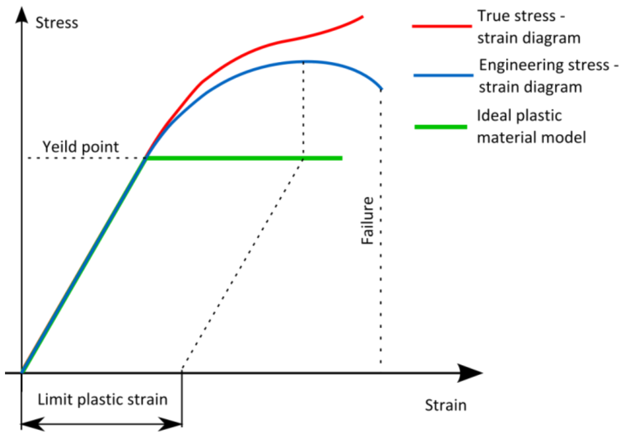
Theoretical Background

CBFEM versus Component method

The weak point of standard Component method is in analyzing of internal forces and stress in a joint. CBFEM replaces specific analysis of internal forces in joint with general FEA.

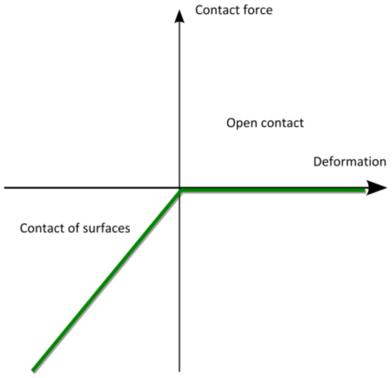


Check methods of specific components like bolts or welds are done according to standard Component method (Eurocode).
For the fasteners – bolts and welds – special FEM components had to be developed to model the welds and bolts behaviour in joint. All parts of 1D members and all additional plates are modelled as plate/walls. These elements are made of steel (metal in general) and the behaviour of this material is significantly nonlinear.
The real stress-strain diagram of steel is replaced by the ideal plastic material for design purposes in building practice. The advantage of ideal plastic material is, that only yield strength and modulus of elasticity must be known to describe the material curve. The granted ductility of construction steel is 15 %. The real usable value of limit plastic strain is 5% for ordinary design (1993-1-5 appendix C paragraph C.8 note 1).
The stress in steel cannot exceed the yield strength when using the ideal elastic-plastic stress-strain diagram.



Real tension curve and the ideal elastic-plastic diagram of material

CBFEM method aims to model the real state precisely. Meshes of plates / walls are not merged, no intersections are generated between them, unlike it is used to when modelling structures and buildings. Mesh of finite elements is generated on each individual plate independently on mesh of other plates.
Between the meshes, special massless force interpolation constraints are added. They ensure the connection between the edge of one plate and the surface or edge of the other plate.
This unique calculation model provides very good results – both for the point of view of precision and of the analysis speed. The method is protected by patent.
The steel base plate is placed loosely on the concrete foundation. It is a contact element in the analysis model – the connection resists compression fully, but does not resist tension.

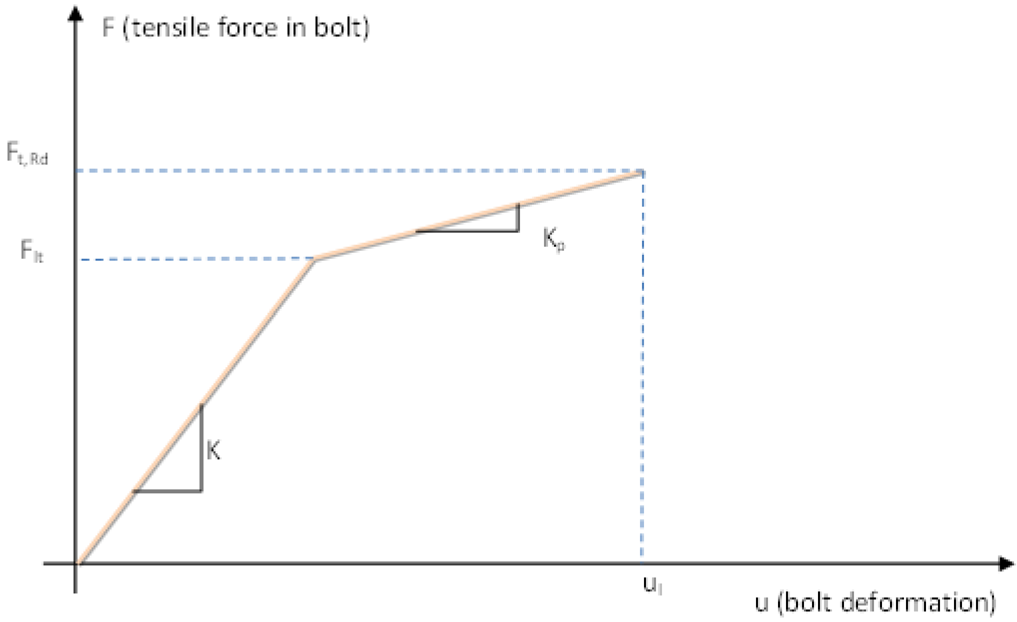


Stress-strain diagram of contact between the concrete block and the base plate

Welds are modelled using a special elastoplastic element, which is added to the interpolation links between the plates. The element respects the weld throat thickness, position and orientation. The plasticity state is controlled by stresses in the weld throat section. The plastic redistribution of stress in welds allows for stress peaks to be redistributed along the longer part of the weld.

Bolted connection consists of two or more clasped plates and one or more bolts. Plates are placed loosely on each other.
A contact element is inserted between plates in the analysis model, which acts only in compression. No forces are carried in tension.

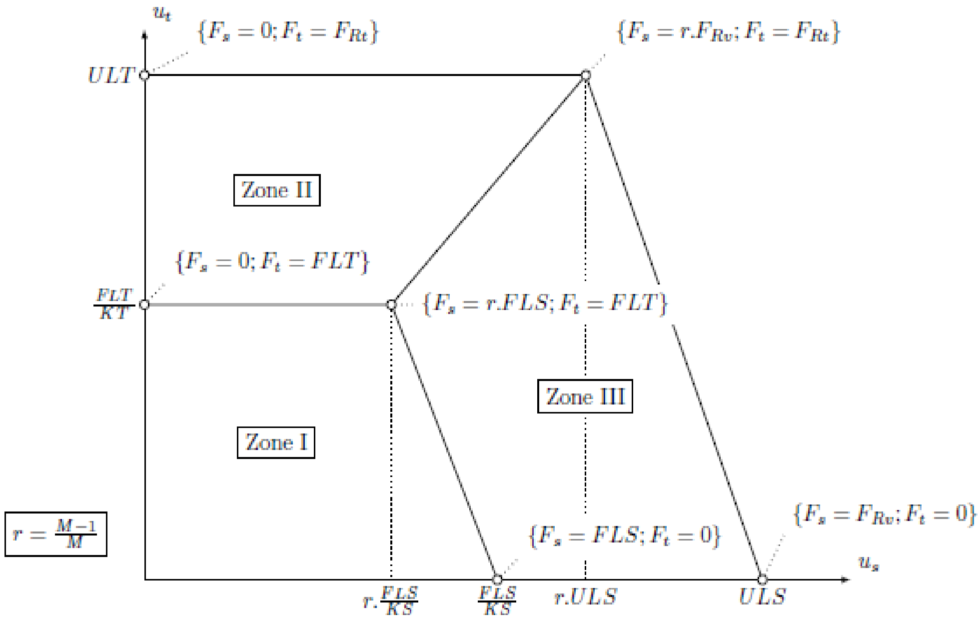
Shear force is taken by bearing. Special model for its transferring in the force direction only is implemented. IDEA StatiCa Connection can check bolts for interaction of shear and tension. The bolt behavior is implemented according to the following picture.



Bolt – tension

Symbols explanation:

- K – linear stiffness of bolt,
- K_p – stiffness of bolt at plastic branch,
- F_{lt} – limit force for linear behaviour of bolt,
- $F_{t,Rd}$ – limit bolt resistance,
- u_l – limit deformation of bolt.

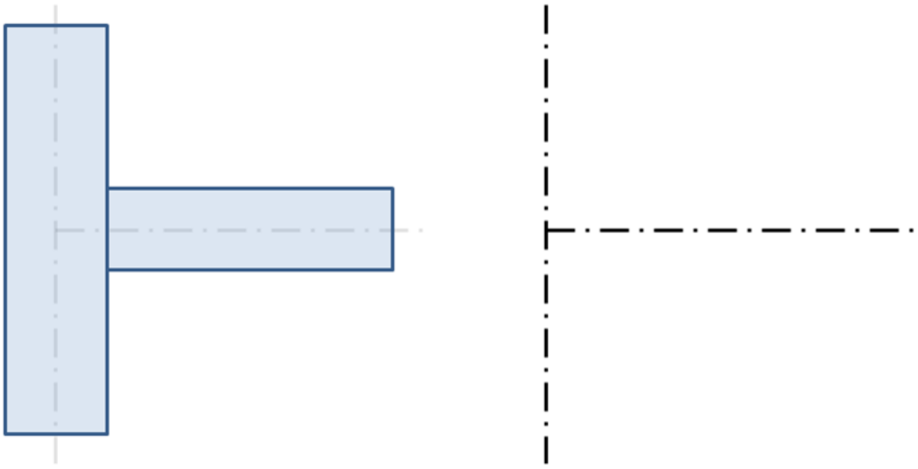


Bolt – interaction of shear and tension

The concrete block in CBFEM is modelled using Winkler-Pasternak subsoil model. The stiffness of subsoil is determined using modulus of elasticity of concrete and effective height of subsoil. The concrete block is not designed by CBFEM method.

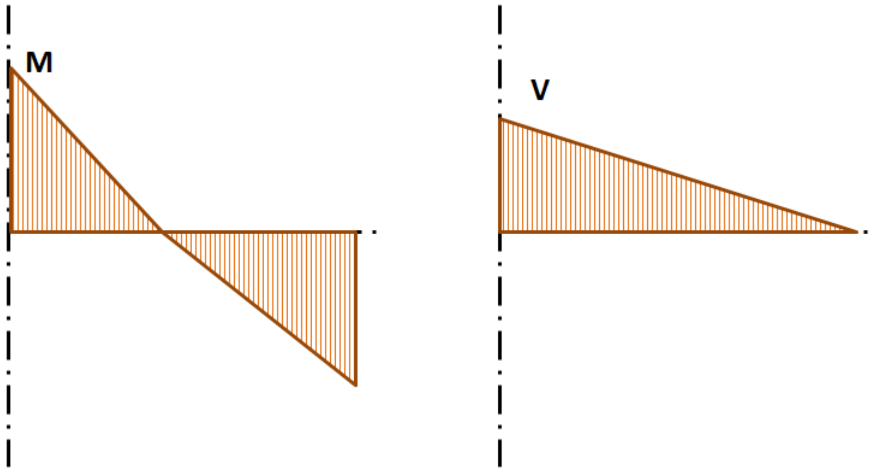
Loads

End forces of member of the frame analysis model are transferred to the ends of member segments. Eccentricities of members caused by the joint design are respected during load transfer.
The analysis model created by CBFEM method corresponds to the real joint very precisely, whereas the analysis of internal forces is performed on very idealised 3D FEM 1D model, where individual beams are modelled using centrelines and the joints are modelled using immaterial nodes.



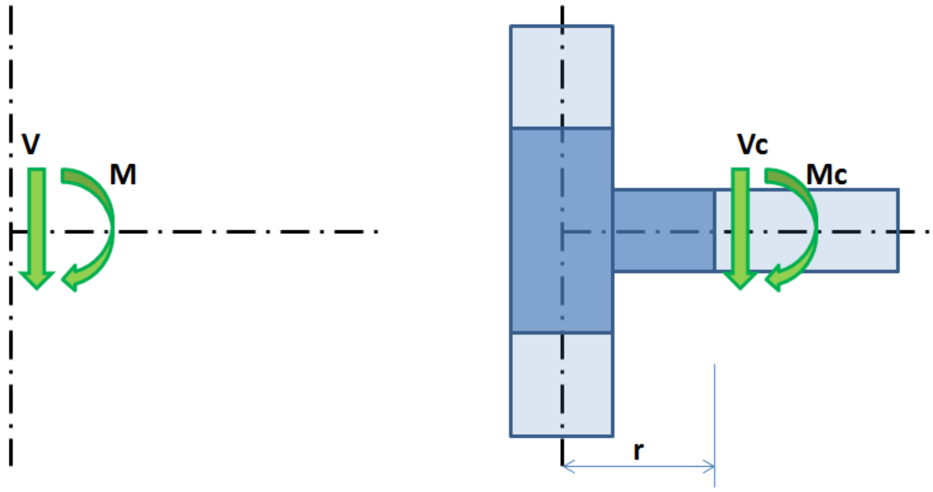
Joint of a vertical column and a horizontal beam

Internal forces are analysed using 1D members in 3D model. There is an example of courses of internal forces in the following picture.



Internal forces in horizontal beam. M and V are the end forces at joint.

The effects caused by member on the joint are important to design the joint (connection). The effects are illustrated in the following picture.



Effects of the member on the joint. CBFEM model is drawn in dark blue color.

Moment *M* and shear force *V* act in a theoretical joint. The point of theoretical joint does not exist in CBFEM model, thus the load cannot be applied here. The model must be loaded by actions *M* and *V*, which have to be transferred to the end of segment in the distance *r*.
$M_c = M - V \cdot r$
$V_c = V$
In CBFEM model, the end section of segment is loaded by moment M_c and force V_c.

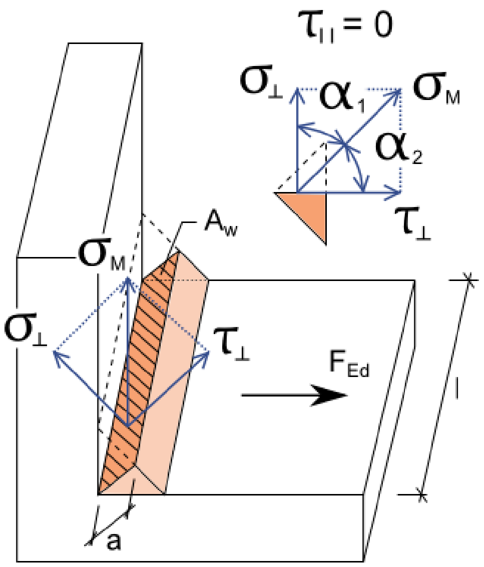
Welds

Design resistance

The stress in the throat section of fillet weld is determined according to EN 1993-1-8 – Cl. 4.5.3:
$\sigma_{w,Ed} = [\sigma_{\perp}^2 + 3 (\tau_{\perp}^2 + \tau_{||}^2)]^{0.5}$
$\sigma_{w,Rd} = f_u / (\beta_w \gamma_{M2})$
$0.9 \cdot \sigma_{w,Rd} = f_u / \gamma_{M2}$

Weld utilisation

$U_t = \min (\sigma_{w,Ed}/\sigma_{w,Rd}; \sigma_{\perp}/0.9 \cdot \sigma_{w,Rd})$
β_w – correlation factor – Tab. 4.1



Bolts

Design tension resistance of bolt: $F_{t,Rd} = 0.9\ f_{ub}\ A_s / \gamma_{M2}$.
Design shear resistance at punching of bolt head or nut EN 1993-1-8: $B_{p,Rd} = 0.6\ \pi\ d_m\ t_p\ f_u / \gamma_{M2}$.
Design shear resistance per one shear plane: $F_{v,Rd} = \alpha_v\ f_{ub}\ A / \gamma_{M2}$.
Design bearing resistance of plate EN 1993-1-8: $F_{b,Rd} = k_1\ a_b\ f_u\ d\ t / \gamma_{M2}$.
Utilisation in tension [%]: $Utt = F_{t,Ed} / \min(F_{t,Rd}, B_{p,Rd})$.
Utilisation in shear [%]: $Uts = V / \min(F_{v,Rd}, F_{b,Rd})$.
Interaction of shear and tension [%]: $Utts = (V / F_{v,Rd}) + (F_{t,Ed} / 1.4\ F_{t,Rd})$.
where

- A – gross cross-section of the bolt or tensile stress area of the bolt if threads are intercepted by shear area,
- A_s – tensile stress area of the bolt,
- f_{ub} – ultimate tensile strength,
- d_m – bolt head diameter,
- d – bolt diameter,
- t_p – plate thickness under the bolt head/nut,
- f_u – ultimate steel strength,
- $\alpha_v = 0.6$ for classes (4.6, 5.6, 8.8)
  $\alpha_v = 0.5$ for classes (4.8, 5.8, 6.8, 10.9),
- $k_1 \le 2.5$ – factor from Table 3.4,
- $a_b \le 1.0$ – factor from Table 3.4,
- $F_{t,Ed}$ – design tensile force in bolt,
- V – resultant of shear forces in bolt.

Preloaded bolts

The design slip resistance of a preloaded class 8.8 or 10.9 bolt is subjected to an applied tensile force, $F_{t,Ed}$.
Preloading force to be used EN 1993-1-8 – 3.9 (3.7)
$F_{p,C} = 0.7\ f_{ub}\ As$
Design slip resistance per bolt EN 1993-1-8 3.9 – (3.8)
$F_{s,Rd} = k_s\ n\ \mu\ (F_{p,C} - 0.8\ F_{t,Ed}) / \gamma_{M3}$
Utilisation in shear [%]:
$U_{ts} = V / F_{s,Rd}$ where

- A_s – tensile stress area of the bolt,
- f_{ub} – ultimate tensile strength,
- k_s – coefficient given in Table 3.6; $k_s = 1$,
- μ – slip factor obtained,
- n – number of the friction surfaces. Check is calculated for each friction surface separately,
- γ_{M3} – safety factor,

- V – shear force,
- $F_{t,Ed}$ – design tensile force in bolt.

Anchors

Anchors are checked according to EN 1992-4. The following checks are performed:

- Tensile steel resistance (Cl. 7.2.1.3) is checked for each individual anchor.
- Concrete cone failure resistance (Cl. 7.2.1.4) is checked for an anchor or a group of anchors loaded in tension with a common concrete cone.
- Pull-out resistance (Cl. 7.2.1.5) is checked for each individual anchor with washer plate.
- Concrete blowout resistance (Cl. 7.2.1.8) is checked for a group of anchors with washer plates near a concrete edge.
- Anchor shear steel resistance (Cl. 7.2.2.3) is checked for each individual anchor. Anchoring with stand-off: direct is considered as shear without lever arm (Cl. 7.2.2.3.1), and anchoring with stand-off: mortar joint is considered as shear with lever arm (Cl. 7.2.2.3.2).
- Concrete pryout failure (Cl. 7.2.2.4) is checked for a group of anchors.
- Concrete edge failure (Cl. 7.2.2.5) is checked for a group of anchors near a concrete edge. It is assumed that the full shear load acting on a base plate is transferred via this group of anchors.

Note that pull-out and combined pull-out and concrete failures of bonded anchors are not checked due to missing values of shear strength of glue. Concrete splitting failure is not checked due to missing splitting forces of post-installed anchor. These checks, if relevant, must be verified by anchor manufacturer.

Anchors with stand-off

Anchor with stand-off is designed as a bar element loaded by shear force, bending moment, and compressive or tensile force. The bar element is designed according to EN 1993-1-1. The linear interaction of tension (compression) and bending moment is assumed.

Concrete block

Concrete resistance at concentrated compression:
$F_{jd} = \beta_j \, k_j \, f_{ck} / \gamma_C$.
Average stress under the base plate:
$\sigma = N / A_{eff}$.

Utilisation in compression [%]:
$U_t = \sigma / F_{jd}$,
where

- f_{ck} – characteristic compressive concrete strength,
- $\beta_j = 0.67$ – foundation joint material coefficient,
- k_j – concentration factor,
- γ_c – safety factor,
- A_{eff} – effective area, on which the column force N is distributed.

Shear in concrete block

1. Shear is transferred only by friction:
   $V_{Rd,y} = N \cdot C_f$,
   $V_{Rd,z} = N \cdot C_f$.
2. Shear is transferred by shear iron:
   $V_{Rd,y} = A_{vy} \cdot f_y / (\sqrt{3} \, \gamma_{M0})$,
   $V_{Rd,z} = A_{vz} \cdot f_y / (\sqrt{3} \, \gamma_{M0})$.
   Plates of shear lug, welds to the base plate and concrete in bearing are checked.
3. Shear is transferred by anchors:
   Anchors loaded in shear are checked according to EN 1992-4.

Utilisation in shear [%]:
$U_t = \min (V_y/V_{Rd,y}, V_z/V_{Rd,z})$,
where

- A_{vy} – shear area of shear iron cross-section,
- A_{vz} – shear area of shear iron cross-section,

- f_y – yield strength,
- γ_{M0} – safety factor,
- V_y – shear force component in the base plate plane in y-direction,
- V_z – shear force component in the base plate plane in z-direction,
- N – compressive force perpendicular to the base plate,
- C_f – coefficient of friction between steel and concrete.

Software info

Application	IDEA StatiCa Connection
Version	20.1.5115.1
Developed by	Idea StatiCa