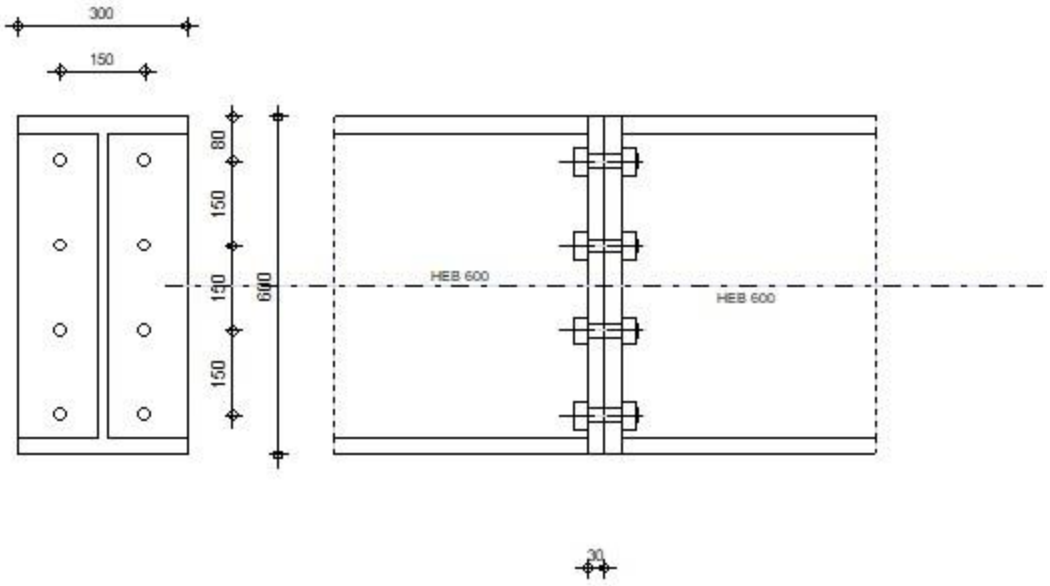
Robot Structural Analysis Professional 2024

Design of fixed beam-to-beam connection

EN 1993-1-8:2005/AC:2009

OK

Ratio
0,88



GENERAL

Connection no.: 7
Connection name: Beam-Beam

GEOMETRY

LEFT SIDE

BEAM

Section: HEB 600

α =	-180,00	[Deg]	Inclination angle
h_{bl} =	600	[mm]	Height of beam section
b_{fbl} =	300	[mm]	Width of beam section
t_{wbl} =	16	[mm]	Thickness of the web of beam section
t_{fbl} =	30	[mm]	Thickness of the flange of beam section
r_{bl} =	27	[mm]	Radius of beam section fillet
A_{bl} =	269,96	[cm^2]	Cross-sectional area of a beam
I_{xbl} =	171041,00	[cm^4]	Moment of inertia of the beam section

Material: S355

f_{yb} =	355,00	[MPa]	Resistance

RIGHT SIDE

BEAM

Section: HEB 600

α =	0,00	[Deg]	Inclination angle
h_{br} =	600	[mm]	Height of beam section
b_{fbr} =	300	[mm]	Width of beam section
t_{wbr} =	16	[mm]	Thickness of the web of beam section
t_{fbr} =	30	[mm]	Thickness of the flange of beam section
r_{br} =	27	[mm]	Radius of beam section fillet
A_{br} =	269,96	[cm^2]	Cross-sectional area of a beam
I_{xbr} =	171041,00	[cm^4]	Moment of inertia of the beam section

Material: S355

f_{yb} =	355,00	[MPa]	Resistance

BOLTS

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

d =	24	[mm]	Bolt diameter
Class =	8.8		Bolt class
F_{tRd} =	203,33	[kN]	Tensile resistance of a bolt
n_h =	2		Number of bolt columns
n_v =	4		Number of bolt rows
h_1 =	80	[mm]	Distance between first bolt and upper edge of front plate

Horizontal spacing e_i = 150 [mm]

Vertical spacing p_i = 150;150;150 [mm]

PLATE

h_{pr} =	600	[mm]	Plate height
b_{pr} =	300	[mm]	Plate width
t_{pr} =	30	[mm]	Plate thickness

Material: S235

f_{ypr} =	235,00	[MPa]	Resistance

FILLET WELDS

a_w =	5	[mm]	Web weld
a_f =	8	[mm]	Flange weld

MATERIAL FACTORS

γ_{M0} =	1,00	Partial safety factor	[2.2]
γ_{M1} =	1,00	Partial safety factor	[2.2]
γ_{M2} =	1,25	Partial safety factor	[2.2]
γ_{M3} =	1,25	Partial safety factor	[2.2]

LOADS

Ultimate limit state

Case: Manual calculations.

$M_{b1,Ed}$ =	300,00	[kN*m]	Bending moment in the right beam
$V_{b1,Ed}$ =	300,00	[kN]	Shear force in the right beam

RESULTS

BEAM RESISTANCES

SHEAR

A_{vb} = 110,81 [cm^2] Shear area EN1993-1-1:[6.2.6.(3)]

$V_{cb,Rd} = A_{vb} (f_{yb} / \sqrt{3}) / \gamma_{M0}$

$V_{cb,Rd}$ = 2271,11 [kN] Design sectional resistance for shear EN1993-1-1:[6.2.6.(2)]

$V_{b1,Ed} / V_{cb,Rd} \leq 1,0$ 0,13 < 1,00 verified (0,13)

BENDING - PLASTIC MOMENT (WITHOUT BRACKETS)

W_{plb} = 6425,41 [cm^3] Plastic section modulus EN1993-1-1:[6.2.5.(2)]

$M_{b,pl,Rd} = W_{plb} f_{yb} / \gamma_{M0}$

$M_{b,pl,Rd}$ = 2281,02 [kN*m] Plastic resistance of the section for bending (without stiffeners) EN1993-1-1:[6.2.5.(2)]

BENDING ON THE CONTACT SURFACE WITH PLATE OR CONNECTED ELEMENT

W_{pl} = 6425,41 [cm^3] Plastic section modulus EN1993-1-1:[6.2.5]

$M_{cb,Rd} = W_{pl} f_{yb} / \gamma_{M0}$

$M_{cb,Rd}$ = 2281,02 [kN*m] Design resistance of the section for bending EN1993-1-1:[6.2.5]

FLANGE AND WEB - COMPRESSION

$M_{cb,Rd}$ = 2281,02 [kN*m] Design resistance of the section for bending EN1993-1-1:[6.2.5]

h_f = 570 [mm] Distance between the centroids of flanges [6.2.6.7.(1)]

$F_{c,fb,Rd} = M_{cb,Rd} / h_f$

$F_{c,fb,Rd}$ = 4001,79 [kN] Resistance of the compressed flange and web [6.2.6.7.(1)]

GEOMETRICAL PARAMETERS OF A CONNECTION

EFFECTIVE LENGTHS AND PARAMETERS - FRONT PLATE

Nr	m	m_x	e	e_x	p	$l_{eff,cp}$	$l_{eff,nc}$	$l_{eff,1}$	$l_{eff,2}$	$l_{eff,cp,g}$	$l_{eff,nc,g}$	$l_{eff,1,g}$	$l_{eff,2,g}$
1	62	-	75	-	150	387	413	387	413	344	318	318	318
2	62	-	75	-	150	387	340	340	340	300	150	150	150
3	62	-	75	-	150	387	340	340	340	300	150	150	150
4	62	-	75	-	150	387	340	340	340	344	245	245	245

m – Bolt distance from the web

m_x – Bolt distance from the beam flange

e – Bolt distance from the outer edge

e_x – Bolt distance from the horizontal outer edge

p – Distance between bolts

$l_{eff,cp}$ – Effective length for a single bolt row in the circular failure mode

$l_{eff,nc}$ – Effective length for a single bolt row in the non-circular failure mode

$l_{eff,1}$ – Effective length for a single bolt row for mode 1

$l_{eff,2}$ – Effective length for a single bolt row for mode 2

$l_{eff,cp,g}$ – Effective length for a group of bolts in the circular failure mode

$l_{eff,nc,g}$ – Effective length for a group of bolts in the non-circular failure mode

$l_{eff,1,g}$ – Effective length for a group of bolts for mode 1

$l_{eff,2,g}$ – Effective length for a group of bolts for mode 2

CONNECTION RESISTANCE FOR BENDING

$F_{t,Rd}$ = 203,33 [kN] Bolt resistance for tension [Table 3.4]

$B_{p,Rd}$ = 586,30 [kN] Punching shear resistance of a bolt [Table 3.4]

$F_{t,fc,Rd}$ – column flange resistance due to bending

$F_{t,wc,Rd}$ – column web resistance due to tension

$F_{t,ep,Rd}$ – resistance of the front plate due to bending

$F_{t,fc,Rd}$ – column flange resistance due to bending

$F_{t,wb,Rd}$ – resistance of the web in tension

$F_{t,fc,Rd} = Min (F_{T,1,fc,Rd} , F_{T,2,fc,Rd} , F_{T,3,fc,Rd})$ [6.2.6.4] , [Tab.6.2]

$F_{t,wc,Rd} = \omega\ b_{eff,t,wc}\ t_{wc}\ f_{yc} / \gamma_{M0}$ [6.2.6.3.(1)]

$F_{t,ep,Rd} = Min (F_{T,1,ep,Rd} , F_{T,2,ep,Rd} , F_{T,3,ep,Rd})$ [6.2.6.5] , [Tab.6.2]

$F_{t,wb,Rd} = b_{eff,t,wb}\ t_{wb}\ f_{yb} / \gamma_{M0}$ [6.2.6.8.(1)]

RESISTANCE OF THE BOLT ROW NO. 1

$F_{t1,Rd,comp}$ - Formula	**$F_{t1,Rd,comp}$**	**Component**
$F_{t1,Rd} = Min (F_{t1,Rd,comp})$	406,66	Bolt row resistance
$F_{t,ep,Rd(1)} = 406,66$	406,66	Front plate - tension
$F_{t,wb,Rd(1)} = 2129,47$	2129,47	Beam web - tension
$B_{p,Rd} = 1172,59$	1172,59	Bolts due to shear punching
$F_{c,fb,Rd} = 4001,79$	4001,79	Beam flange - compression

RESISTANCE OF THE BOLT ROW NO. 2

$F_{t2,Rd,comp}$ - Formula	**$F_{t2,Rd,comp}$**	**Component**
$F_{t2,Rd} = Min (F_{t2,Rd,comp})$	402,27	Bolt row resistance
$F_{t,ep,Rd(2)} = 406,66$	406,66	Front plate - tension
$F_{t,wb,Rd(2)} = 1871,52$	1871,52	Beam web - tension
$B_{p,Rd} = 1172,59$	1172,59	Bolts due to shear punching
$F_{c,fb,Rd} - \sum_1^1 F_{tj,Rd} = 4001,79 - 406,66$	3595,13	Beam flange - compression
$F_{t,ep,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 808,92 - 406,66$	402,27	Front plate - tension - group
$F_{t,wb,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 2575,37 - 406,66$	2168,71	Beam web - tension - group

Additional reduction of the bolt row resistance

$F_{t2,Rd} = F_{t1,Rd}\ h_2/h_1$

$F_{t2,Rd} =$ 285,87 [kN] Reduced bolt row resistance [6.2.7.2.(9)]

RESISTANCE OF THE BOLT ROW NO. 3

$F_{t3,Rd,comp}$ - Formula	**$F_{t3,Rd,comp}$**	**Component**
$F_{t3,Rd} = Min (F_{t3,Rd,comp})$	392,96	Bolt row resistance
$F_{t,ep,Rd(3)} = 406,66$	406,66	Front plate - tension
$F_{t,wb,Rd(3)} = 1871,52$	1871,52	Beam web - tension
$B_{p,Rd} = 1172,59$	1172,59	Bolts due to shear punching
$F_{c,fb,Rd} - \sum_1^2 F_{tj,Rd} = 4001,79 - 692,52$	3309,27	Beam flange - compression
$F_{t,ep,Rd(3+2)} - \sum_2^2 F_{tj,Rd} = 678,83 - 285,87$	392,96	Front plate - tension - group
$F_{t,wb,Rd(3+2)} - \sum_2^2 F_{tj,Rd} = 1650,75 - 285,87$	1364,88	Beam web - tension - group
$F_{t,ep,Rd(3+2+1)} - \sum_2^1 F_{tj,Rd} = 1148,34 - 692,52$	455,81	Front plate - tension - group
$F_{t,wb,Rd(3+2+1)} - \sum_2^1 F_{tj,Rd} = 3400,74 - 692,52$	2708,22	Beam web - tension - group

Additional reduction of the bolt row resistance

$F_{t3,Rd} = F_{t1,Rd}\ h_3/h_1$

$F_{t3,Rd} =$ 165,08 [kN] Reduced bolt row resistance [6.2.7.2.(9)]

RESISTANCE OF THE BOLT ROW NO. 4

$F_{t4,Rd,comp}$ - Formula	**$F_{t4,Rd,comp}$**	**Component**
$F_{t4,Rd} = Min (F_{t4,Rd,comp})$	406,66	Bolt row resistance
$F_{t,ep,Rd(4)} = 406,66$	406,66	Front plate - tension
$F_{t,wb,Rd(4)} = 1871,52$	1871,52	Beam web - tension
$B_{p,Rd} = 1172,59$	1172,59	Bolts due to shear punching
$F_{c,fb,Rd} - \sum_1^3 F_{tj,Rd} = 4001,79 - 857,60$	3144,19	Beam flange - compression
$F_{t,ep,Rd(4+3)} - \sum_3^3 F_{tj,Rd} = 752,43 - 165,08$	587,35	Front plate - tension - group
$F_{t,wb,Rd(4+3)} - \sum_3^3 F_{tj,Rd} = 2173,82 - 165,08$	2008,75	Beam web - tension - group
$F_{t,ep,Rd(4+3+2)} - \sum_3^2 F_{tj,Rd} = 1091,84 - 450,95$	640,89	Front plate - tension - group
$F_{t,wb,Rd(4+3+2)} - \sum_3^2 F_{tj,Rd} = 2999,20 - 450,95$	2548,25	Beam web - tension - group

$F_{t4,Rd,comp}$ - Formula	$F_{t4,Rd,comp}$	Component
$F_{t,ep,Rd(4+3+2+1)} - \sum_3^1 F_{tj,Rd}$ = 1561,35 - 857,60	703,75	Front plate - tension - group
$F_{t,wb,Rd(4+3+2+1)} - \sum_3^1 F_{tj,Rd}$ = 4749,19 - 857,60	3891,59	Beam web - tension - group

Additional reduction of the bolt row resistance

$F_{t4,Rd} = F_{t1,Rd}\ h_4/h_1$

$F_{t4,Rd}$ = 44,29 [kN] Reduced bolt row resistance [6.2.7.2.(9)]

SUMMARY TABLE OF FORCES

Nr	h_j	$F_{tj,Rd}$	$F_{t,fc,Rd}$	$F_{t,wc,Rd}$	$F_{t,ep,Rd}$	$F_{t,wb,Rd}$	$F_{t,Rd}$	$B_{p,Rd}$
1	505	406,66	-	-	406,66	2129,47	406,66	1172,59
2	355	285,87	-	-	406,66	1871,52	406,66	1172,59
3	205	165,08	-	-	406,66	1871,52	406,66	1172,59
4	55	44,29	-	-	406,66	1871,52	406,66	1172,59

CONNECTION RESISTANCE FOR BENDING $M_{j,Rd}$

$M_{j,Rd} = \sum h_j\ F_{tj,Rd}$

$M_{j,Rd}$ = 343,12 [kN*m] Connection resistance for bending [6.2]

$M_{b1,Ed} / M_{j,Rd} \le 1,0$ 0,87 < 1,00 verified (0,87)

CONNECTION RESISTANCE FOR SHEAR

α_v = 0,60 Coefficient for calculation of $F_{v,Rd}$ [Table 3.4]

β_{Lf} = 0,98 Reduction factor for long connections [3.8]

$F_{v,Rd}$ = 170,46 [kN] Shear resistance of a single bolt [Table 3.4]

$F_{t,Rd,max}$ = 203,33 [kN] Tensile resistance of a single bolt [Table 3.4]

$F_{b,Rd,int}$ = 518,40 [kN] Bearing resistance of an intermediate bolt [Table 3.4]

$F_{b,Rd,ext}$ = 465,23 [kN] Bearing resistance of an outermost bolt [Table 3.4]

Nr	$F_{tj,Rd,N}$	$F_{tj,Ed,N}$	$F_{tj,Rd,M}$	$F_{tj,Ed,M}$	$F_{tj,Ed}$	$F_{vj,Rd}$
1	406,66	0,00	406,66	355,55	355,55	128,01
2	406,66	0,00	285,87	249,94	249,94	191,25
3	406,66	0,00	165,08	144,33	144,33	254,49
4	406,66	0,00	44,29	38,72	38,72	317,73

$F_{tj,Rd,N}$ – Bolt row resistance for simple tension

$F_{tj,Ed,N}$ – Force due to axial force in a bolt row

$F_{tj,Rd,M}$ – Bolt row resistance for simple bending

$F_{tj,Ed,M}$ – Force due to moment in a bolt row

$F_{tj,Ed}$ – Maximum tensile force in a bolt row

$F_{vj,Rd}$ – Reduced bolt row resistance

$F_{tj,Ed,N} = N_{j,Ed}\ F_{tj,Rd,N} / N_{j,Rd}$

$F_{tj,Ed,M} = M_{j,Ed}\ F_{tj,Rd,M} / M_{j,Rd}$

$F_{tj,Ed} = F_{tj,Ed,N} + F_{tj,Ed,M}$

$F_{vj,Rd} = \text{Min}\ (n_h\ F_{v,Ed} / (1 - F_{tj,Ed} / (1.4\ n_h\ F_{t,Rd,max})),\ n_h\ F_{v,Rd}\ ,\ n_h\ F_{b,Rd})$

$V_{j,Rd} = n_h \sum_1^n F_{vj,Rd}$ [Table 3.4]

$V_{j,Rd}$ = 891,48 [kN] Connection resistance for shear [Table 3.4]

$V_{b1,Ed} / V_{j,Rd} \le 1,0$ 0,34 < 1,00 verified (0,34)

WELD RESISTANCE

A_w = 85,48 [cm^2] Area of all welds [4.5.3.2(2)]

A_{wy} = 36,88 [cm^2] Area of horizontal welds [4.5.3.2(2)]

A_{wz} = 48,60 [cm^2] Area of vertical welds [4.5.3.2(2)]

I_{wy} = 35662,72 [cm^4] Moment of inertia of the weld arrangement with respect to the hor. axis [4.5.3.2(5)]

$\sigma_{\perp max} = \tau_{\perp max}$ = 158,22 [MPa] Normal stress in a weld [4.5.3.2(6)]

$\sigma_{\perp} = \tau_{\perp}$ = 144,54 [MPa] Stress in a vertical weld [4.5.3.2(5)]

A_w =	85,48	[cm^2]	Area of all welds	[4.5.3.2(2)]
τ_{II} =	61,73	[MPa]	Tangent stress	[4.5.3.2(5)]
β_w =	0,80		Correlation coefficient	[4.5.3.2(7)]

$\sqrt{[\sigma_{\perp max}^2 + 3*(\tau_{\perp max}^2)]} \le f_u/(\beta_w*\gamma_{M2})$	316,45 < 360,00	verified	(0,88)
$\sqrt{[\sigma_{\perp}^2 + 3*(\tau_{\perp}^2+\tau_{II}^2)]} \le f_u/(\beta_w*\gamma_{M2})$	308,22 < 360,00	verified	(0,86)
$\sigma_{\perp} \le 0.9*f_u/\gamma_{M2}$	158,22 < 259,20	verified	(0,61)

CONNECTION STIFFNESS

t_{wash} =	5	[mm]	Washer thickness	[6.2.6.3.(2)]
h_{head} =	17	[mm]	Bolt head height	[6.2.6.3.(2)]
h_{nut} =	24	[mm]	Bolt nut height	[6.2.6.3.(2)]
L_b =	90	[mm]	Bolt length	[6.2.6.3.(2)]
k_{10} =	6	[mm]	Stiffness coefficient of bolts	[6.3.2.(1)]

STIFFNESSES OF BOLT ROWS

Nr	hj	k_3	k_4	k_5	$k_{eff,j}$	$k_{eff,j}$ h_j	$k_{eff,j}$ h_j^2
					Sum	44,60	1750,78
1	505	∞	∞	33	5	22,88	1155,51
2	355	∞	∞	16	3	12,31	436,91
3	205	∞	∞	16	3	7,11	145,69
4	55	∞	∞	25	4	2,30	12,67

$k_{eff,j} = 1 / (\sum_3^5 (1 / k_{i,j}))$ [6.3.3.1.(2)]

$z_{eq} = \sum_j k_{eff,j} h_j^2 / \sum_j k_{eff,j} h_j$

z_{eq} = 393 [mm] Equivalent force arm [6.3.3.1.(3)]

$k_{eq} = \sum_j k_{eff,j} h_j / z_{eq}$

k_{eq} = 11 [mm] Equivalent stiffness coefficient of a bolt arrangement [6.3.3.1.(1)]

$S_{j,ini} = E z_{eq}^2 k_{eq}$ [6.3.1.(4)]

$S_{j,ini}$ = 367664,21 [kN*m] Initial rotational stiffness [6.3.1.(4)]

μ = 2,08 Stiffness coefficient of a connection [6.3.1.(6)]

$S_j = S_{j,ini} / \mu$ [6.3.1.(4)]

S_j = 176801,27 [kN*m] Final rotational stiffness [6.3.1.(4)]

Connection classification due to stiffness.

$S_{j,rig}$ = 574697,76 [kN*m] Stiffness of a rigid connection [5.2.2.5]

$S_{j,pin}$ = 35918,61 [kN*m] Stiffness of a pinned connection [5.2.2.5]

$S_{j,pin} \le S_{j,ini} < S_{j,rig}$ SEMI-RIGID

WEAKEST COMPONENT:

WELDS

Connection conforms to the code Ratio 0,88