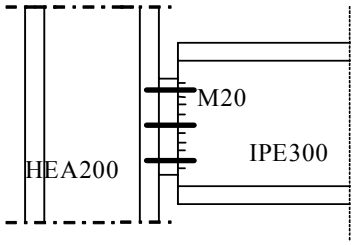
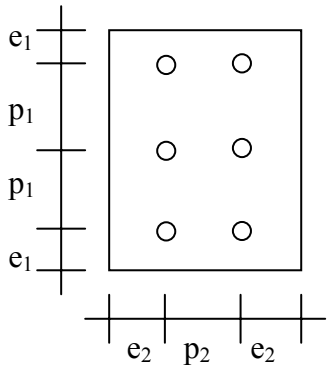
5.1 WORKED EXAMPLE
Header plate connection

5.1.1 Geometrical and mechanical data





Main joint data

Configuration	Beam to column flange
Column	HEA 200 S 235
Beam	IPE 300 S 235
Type of connection	Header plate connection
Header plate	230 x 200 x 10, S 235

Detailed characteristics

Column HEA 200, S235

Depth	h	=	190,00	mm
Thickness of the web	t_{cw}	=	6,50	mm
Width	b_c	=	200,00	mm
Thickness of the flange	t_{cf}	=	10,00	mm
Root radius	r	=	18,00	mm
Area	A	=	53,83	cm²
Inertia	I	=	3692,16	cm^4
Yield strength	f_{yc}	=	235,00	N/mm²
Ultimate strength	f_{uc}	=	360,00	N/mm²

Beam IPE 300, S235

Depth	h	=	300,00	mm
Thickness of the web	t_{bw}	=	7,10	mm
Width	b_b	=	150,00	mm
Thickness of the flange	t_{bf}	=	10,70	mm
Root radius	r	=	15,00	mm
Area	A	=	53,81	cm²
Inertia	I	=	8356,11	cm^4

Yield strength	f_{yb}	=	235,00	N/mm²
Ultimate strength	f_{ub}	=	360,00	N/mm²

Header plate 230 x 200 x 10, S 235

Vertical gap	g_v	=	35,00	mm
Depth	h_p	=	230,00	mm
Width	b_p	=	200,00	mm
Thickness	t_p	=	10,00	mm

Direction of load transfer (1)

Number of bolts rows	n_1	=	3	
Edge to first bolt row distance	e_{11}	=	45,00	mm
Pitch between bolt row 1 and 2	$p_{1[1]}$	=	70,00	mm
Pitch between bolt row 2 and 3	$p_{1[2]}$	=	70,00	mm
last bolt row to edge distance	e_{1n}	=	45,00	mm

Direction perpendicular to Load transfer (2)

Number of bolts rows	n_2	=	2	
Edge to first bolt row distance	e_{21}	=	50,00	mm
Pitch between bolt row 1 and 2	p_2'	=	100,00	mm
last bolt row to edge distance	e_{2n}	=	50,00	mm
last bolt row to edge distance (column flange)	e_{2s}	=	50,00	mm

Yield strength	f_{yp}	=	235,00	N/mm²
Ultimate strength	f_{up}	=	360,00	N/mm²

Bolts M20, 8.8

Resistant area	A_s	=	245,00	mm²
Diameter of the shank	d	=	20,00	mm
Diameter of the holes	d_0	=	22,00	mm
Yield strength	f_{yb}	=	640,00	N/mm²
Ultimate strength	f_{ub}	=	800,00	N/mm²

Welds

Throat thickness of the weld	a_w	=	4,00	mm
Length of the weld	l_w	=	230,00	mm

Safety factors

γ_{M0}	=	1,00
γ_{M2}	=	1,25

Applied shear force

$V_{Sd} = 200$ kN

5.1.2 Ductility and rotation requirements

Rotation requirements

(1) $h_p \leq d_b$

$h_p = 230{,}00$ mm

$d_b = h - 2\,t_{bf} - 2\,r$

$= 300{,}00 - 2 \cdot 10{,}70 - 2 \cdot 15{,}00 = 248{,}60$ mm

$\rightarrow$ ok

(2) $\phi_{available} > \phi_{required}$ we suppose that this requirement is fulfilled,

Ductility requirements

(1) $\frac{d}{t_p} \geq 2{,}8 \sqrt{\frac{f_{yp}}{f_{ub}}}$

$d / t_p = 2{,}00$

$f_{yp} / f_{ub} = 0{,}29$

$\rightarrow \quad 2{,}00 \geq 1{,}52$ ok

(2) $a \geq 0{,}4\, t_{bw}\, \beta_w \sqrt{3}\, \frac{f_{ybw}}{f_{ubw}} \frac{\gamma_{M2}}{\gamma_{M0}} = 3{,}21$ mm

$t_{bw} = 7{,}1$ mm

$f_{ybw} = 235{,}00$ N/mm²

$f_{ubw} = 360{,}00$ N/mm²

$\beta_w = 0{,}80$

$a = 4{,}00$ mm $\rightarrow$ ok

5.1.3 Joint shear resistance

Bolts in shear

$V_{Rd\,1} = 0{,}8\, n\, F_{v,Rd} = 451{,}58$ kN

$n = 6$

$F_{v,Rd} = \alpha_v\, A\, f_{ub} / \gamma_{M2} = 94{,}08$ kN

$\alpha_v = 0{,}6$

$A = A_S = 245{,}00$ mm²

f_{ub} = 800,00 N/mm²

Header plate in bearing

$V_{Rd\,2} = n\,F_{b,Rd} = 589{,}09$ kN

$n = 6$

$F_{b,Rd} = k_1\,\alpha_b\,d\,t_p\,f_{up} / \gamma_{M2} = 98{,}18$ kN

$\alpha_b = \min(\alpha_1 , \alpha_2 , \alpha_3 , 1) = 0{,}68$

$\alpha_1 = e_1 / 3d_0 = 0{,}68$

$\alpha_2 = p_1 / 3d_0 - 1/4 = 0{,}81$

$\alpha_3 = f_{ub} / f_{up} = 2{,}22$

$k_1 = \min(2{,}8\,e_2 / d_0 - 1{,}7 ; 2{,}5)$
$= \min(4{,}66 ; 2{,}5) = 2{,}5$

d = 20,00 mm
t_p = 10,00 mm
f_{ub} = 800,00 N/mm²
f_{up} = 360,00 N/mm²

Column flange in bearing

$V_{Rd\,3} = n\,F_{b,Rd} = 700{,}36$ kN

$n = 6$

$F_{b,Rd} = k_1\,\alpha_b\,d\,t_{cf}\,f_{ucf} / \gamma_{M2} = 116{,}73$ kN

$\alpha = \min(\alpha_1 , \alpha_2 , 1) = 0{,}81$

$\alpha_1 = p_1 / 3d_0 - 1/4 = 0{,}81$

$\alpha_2 = f_{ub} / f_{ucf} = 2{,}22$

$k_1 = \min(2{,}8\,e_{2s} / d_0 - 1{,}7 ; 2{,}5)$
$= \min(4{,}66 ; 2{,}5) = 2{,}5$

d = 20,00 mm
t_{cf} = 10,00 mm
f_{ub} = 800,00 N/mm²
f_{ucf} = 360,00 N/mm²

Gross section of the header plate in shear

$V_{Rd\,4} = 2\,F_{v,Rd} = 491{,}44$ kN

$F_{v,Rd} = A_v\,f_{yp} / (1{,}27\,\sqrt{3}\,\gamma_{M0}) = 245{,}72$ kN

$A_v = h_p\,t_p = 23{,}00$ cm²

$f_{yp} = 235{,}00$ N/mm²

Net section of the header plate in shear

$V_{Rd\,5} = 2\,F_{v,Rd} = 545{,}39$ kN

$F_{v,Rd} = A_{v,net}\,f_{up} / (\sqrt{3}\,\gamma_{M2}) = 272{,}69$ kN

$A_{v,net} = (h_p - n_1\,d_0)\,t_p = 16{,}40$ cm²

$h_p = 230{,}00$ mm

$n_1 = 6$

$d_0 = 22{,}00$ mm

$t_p = 10{,}00$ mm

$f_{up} = 360{,}00$ N/mm²

Shear block of the header plate

$V_{Rd\,6} = 2\,F_{eff,Rd} = 577{,}40$ kN

$1{,}36\,p_2' = 136{,}00$ mm $\rightarrow$ $h_p > 1{,}36\,p_2'$

$n_1 = 3$ $\rightarrow$ $n_1 > 1$

$F_{eff,Rd} = F_{eff,1,Rd} = f_{up}\,A_{nt} / \gamma_{M2} + f_{yp}\,A_{nv} / (\sqrt{3}\,\gamma_{M0}) = 288{,}70$ kN

$A_{nt} = t_p\,(e_2 - d_0/2) = 390{,}00$ mm²

$t_p = 10{,}00$ mm

$e_2 = 50{,}00$ mm

$d_0 = 22{,}00$ mm

$A_{nv} = t_p\,(h_p - e_1 - (n_1 - 0{,}5)\,d_0) = 1300{,}00$ mm²

$n_1 = 3$

$h_p = 230{,}00$ mm

$e_1 = 45{,}00$ mm

$f_{yp} = 235{,}00$ N/mm²

$f_{up} = 360{,}00$ N/mm²

Header plate in bending

$V_{Rd\,7} = \infty$

$h_p = 230{,}00$ mm

$1{,}36\,p_2' = 136{,}4$ mm $\rightarrow$ $h_p > 1{,}36\,p_2'$

Beam web in shear

$V_{Rd\,8} = F_{v,Rd} = 221{,}56$ kN

$F_{v,Rd} = A_v\,f_{ybw} / (\sqrt{3}\,\gamma_{M0}) = 221{,}56$ kN

$A_v = h_p\,t_{bw} = 16{,}33$ cm²

$f_{ybw} = 235{,}00$ N/mm²

Joint shear resistance

Shear resistance of the joint V_{Rd} = 221,56 kN
Failure Mode: Beam web in shear

5.1.4 Design check

Applied shear force: V_{Sd} = 200 kN
Shear resistance: V_{Rd} = 221,56 kN ⇒ Design ok

5.1.5 Joint tying resistance

Bolts in tension

$N_{u\,1} = n\,B_{t,u} = 1176{,}00$ kN

n = 6
$B_{t,u} = f_{ub}\,A_s = 196{,}00$ kN
$A_s = 245{,}00$ mm²
$F_{ub} = 800{,}00$ N/mm²

Header plate in bending

$N_{u\,2} = \min(F_{hp,u,1}\,;\,F_{hp,u,2}) = 684{,}69$ kN

$$F_{hp,u,1} = \frac{(8\,n_p - 2\,e_w)\,l_{eff.p.t,1}\,m_{u.p}}{2\,m_p\,n_p - e_w\,(m_p + n_p)} = 852{,}83 \text{ kN}$$

$$F_{hp,u,2} = \frac{2\,l_{eff.p.t,2}\,m_{u.p} + n\,B_{t.u}\,n_p}{m_p + n_p} = 684{,}69 \text{ kN}$$

n = 6
$m_p = (p_2' - t_w - 2 \text{ x } 0{,}8\,a\,2^{-0{,}5}) / 2 = 41{,}925$ mm
$n_p = \min(e_2\,;\,1{,}25\,m_p) = \min(50\,;\,52{,}4) = 50{,}00$ mm
$$m_{u,p} = \frac{t_p^2\,f_{up}}{4} = 9000{,}00 \text{ N mm/mm}$$
$l_{eff,p1} = l_{eff,p2} = h_p = 230{,}00$ mm
$e_w = 37{,}00$ mm

Supporting member in bending (column flange)

$N_{u\,2} = \min (F_{cf,u,1} ; F_{cf,u,2}) = \ldots$

$$F_{cf,u,1} = \frac{(8\, n_{cf} - 2\, e_w)\, l_{eff.cf.t,1}\, m_{u.cf}}{2\, m_{cf}\, n_{cf} - e_w\, (m_{cf} + n_{cf})} = \ldots$$

$$F_{cf,u,2} = \frac{2\, l_{eff.cf.t,2}\, m_{u.cf} + n\, B_{t.u}\, n_{cf}}{m_{cf} + n_{cf}} = \ldots$$

$n = 6$
$m_{cf} = (p_2' - t_{cw} - 2 \times 0{,}8\, r_c) / 2 = 32{,}35$ mm
$n_{cf} = \min (e_{2s} ; 1{,}25\, m_p) = \min (50 ; 40{,}438) = 40{,}438$ mm
$m_{u,cf} = \frac{t_{cf}^2\, f_{ucf}}{4} = 9000{,}00$ N mm/mm
$l_{eff,cf1} = \ldots$
$l_{eff,cf2} = \ldots$
$e_w = 37{,}00$ mm

Comment : More resistance than for the header plate (higher l_{eff} values and smaller values of m and n).

Beam web in tension

$N_{u\,4} = t_w\, h_p\, f_{ubw} = 587{,}88$ kN

$t_w = 7{,}10$ mm
$h_p = 230{,}00$ mm
$f_{ubw} = 360{,}00$ N/mm²

Welds

Conditions for full-strength behaviour of the welds are fulfilled

Joint tying resistance

Tying resistance of the joint $N_u = 587{,}88$ kN
Failure mode : Beam web in tension

Based on paper Jaspart J.P., Renkin S., Guillaume M.L.: European Recommendations for the Design of Simple Joints in Steel Structures, 1st draft of a forthcoming publication of the Technical Committee 10 “Joints and Connections” of the European Convention of Constructional Steelwork (ECCS TC10) prepared at the University of Liège, September 2003.