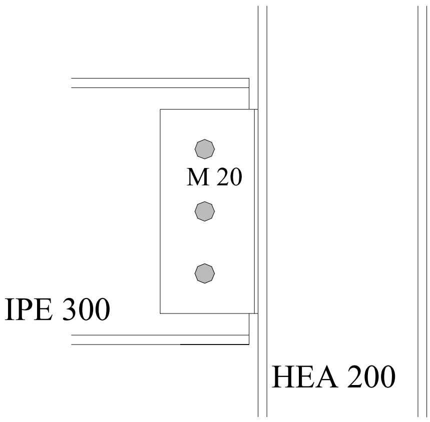
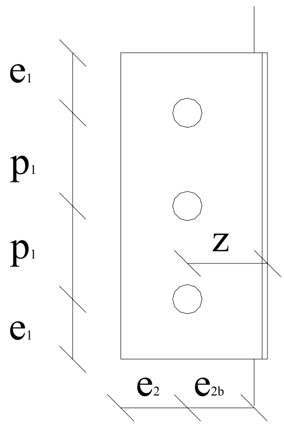
5.2 WORKED EXAMPLE
Fin plate connection

5.2.1 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	Fin plate connection
Fin plate	230 x 110 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_f	=	200,00	mm
Thickness of the flange	t_{cf}	=	10,00	mm
Root radius	r	=	18,00	mm
Area	A	=	53,83	cm^2
Inertia	I	=	3692,16	cm^4
Yield strength	f_{yc}	=	235,00	N/mm^2
Ultimate strength	f_{uc}	=	360,00	N/mm^2

Beam IPE 300, S235

Depth	h	=	300,00	mm
Thickness of the web	t_{bw}	=	7,10	mm
Width	b_f	=	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

Fin plate 230 x 110 x 10, S 235

Vertical gap	g_v	=	35,00	mm
Horizontal gap (end beam to column flange)	g_h	=	10,00	mm
Depth	h_p	=	230,00	mm
Width	b_p	=	110,00	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
Beam edge to first bolt row distance	e_{1b}	=	80,00	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	=	1	
Edge to first bolt row distance	e_{21}	=	50,00	mm
last bolt row to beam edge distance	e_{2b}	=	50,00	mm
Lever arm	z	=	60,00	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	=	5,00	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} = 100 kN

5.2.2 *Requirements to ensure sufficient rotation capacity*

(1) $h_p \leq d_b$

h_p = 230,00 mm
d_b = $h - 2\ t_{bf} - 2\ r$
= 300,00 – 2 10,70 – 2 15,00 = 248,60 mm
→ ok

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

5.2.3 *Requirements to avoid premature weld failure*

$$a > 0{,}4\ t_p\ \beta_w\ \sqrt{3}\ \frac{f_{yp}}{f_{up}}\ \frac{\gamma_{M2}}{\gamma_{M0}} = 4{,}52\ \text{mm}$$

t_p = 10,00 mm
f_{yp} = 235,00 N/mm²
f_{up} = 360,00 N/mm²
β_w = 0,80

a = 5,00 mm → ok

5.2.4 *Joint shear resistance*

Bolts in shear

$$V_{Rd\ 1} = \frac{n\ \ F_{v,Rd}}{\sqrt{1 + \left(\frac{6\ z}{(n+1)\ p_1}\right)^2}} = 173{,}28\ \text{kN}$$

n = 3

$z \quad = 60{,}00 \text{ mm}$

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

$\alpha_v \quad = 0{,}6$

$A \quad = A_s = 245{,}00 \text{ mm}^2$

$f_{ub} \quad = 800{,}00 \text{ N/mm}^2$

Fin plate in bearing

$$V_{Rd\,2} = \frac{1}{\sqrt{\left(\dfrac{\dfrac{1}{n} + \alpha}{F_{b,ver,Rd}}\right)^2 + \left(\dfrac{\beta}{F_{b,hor,Rd}}\right)^2}} = 192{,}59 \text{ kN}$$

$n \quad = 3$

$\alpha \quad = 0$

$1 / n \quad = 1 / 3$

$$\beta \quad = \frac{6\,z}{p_1 \;\, n\,(n+1)} = 0{,}43$$

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

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

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

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

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

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

$\quad = \min (4{,}66 \; ; \; 2{,}5) = 2{,}5$

$F_{b,Rd,hor} = \; k_1 \, \alpha_b \, d \;\; t_p \;\; f_{up} / \gamma_{M2} = 109{,}09 \text{ kN}$

$\alpha_b \quad = \min (\alpha_1 \, , \, \alpha_2 \; , \, 1) = 0{,}75$

$\alpha_1 \quad = e_2 / 3d_0 = 0{,}75$

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

$k_1 \quad = \min (2{,}8 \; e_1 / d_0 - 1{,}7 \; ; \; 1{,}4 \; p_1 / d_0 - 1{,}7 \; ; \; 2{,}5)$

$\quad = \min (4{,}03 \; ; \; 2{,}75 \; ; \; 2{,}5) = 2{,}5$

$d \quad = 20{,}00 \text{ mm}$

$t_p \quad = 10{,}00 \text{ mm}$

$f_{ub} \quad = 800{,}00 \text{ N/mm}^2$

$f_{up} \quad = 360{,}00 \text{ N/mm}^2$

Gross section of the fin plate in shear

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

$A_v = h_p\, t_p = 23{,}00\ cm^2$
$f_{yp} = 235{,}00\ N/mm^2$

Net section of the fin plate in shear

$V_{Rd\,4} = A_{v,net}\, f_{up} / (\sqrt{3}\, \gamma_{M2}) = 272{,}69\ kN$

$A_{v,net} = (h_p - n_1\, d_0)\, t_p = 16{,}40\ cm^2$
$h_p = 230{,}00\ mm$
$n_1 = 3$
$d_0 = 22{,}00\ mm$
$t_p = 10{,}00\ mm$
$f_{up} = 360{,}00\ N/mm^2$

Shear block of the fin plate

$V_{Rd\,5} = F_{eff,2,Rd} = 232{,}54\ kN$

$F_{eff,2,Rd} = 0{,}5\, f_{up}\, A_{nt} / \gamma_{M2} + f_{yp}\, A_{nv} / (\sqrt{3}\, \gamma_{M0}) = 232{,}54\ kN$

$A_{nt} = t_p\, (e_2 - d_0/2) = 390{,}00\ mm^2$
$t_p = 10{,}00\ mm$
$e_2 = 50{,}00\ mm$
$d_0 = 22{,}00\ mm$
$A_{nv} = t_p\, (h_p - e_1 - (n_1 - 0{,}5)\, d_0) = 1300{,}00\ mm^2$
$n_1 = 3$
$h_p = 230{,}00\ mm$
$e_1 = 45{,}00\ mm$
$f_{yp} = 235{,}00\ N/mm^2$
$f_{up} = 360{,}00\ N/mm^2$

Fin plate in bending

$h_p = 230\ mm \ \geq\ 2{,}73\ z = 163{,}8\ mm$

$V_{Rd\,6} = \infty$

Buckling of the fin plate

$$V_{Rd\,7} = \frac{W_{el}}{z}\ \frac{\sigma}{\gamma_{M0}} = 776{,}97\ kN$$

$$W_{el} = \frac{t_p\, h_p^2}{6} = 88\ 166{,}67\ mm^3$$

$$\sigma = 81 \left(\frac{t_p}{z}\right)^2 235 = 528{,}75 \text{ N/mm}^2$$

Beam web in bearing

$$V_{Rd\,8} = \frac{1}{\sqrt{\left(\frac{\frac{1}{n}+\alpha}{F_{b,ver,Rd}}\right)^2 + \left(\frac{\beta}{F_{b,hor,Rd}}\right)^2}} = 146{,}19 \text{ kN}$$

$n = 3$

$\alpha = 0$

$1 / n = 1 / 3$

$$\beta = \frac{6\,z}{p_1\ n\,(n+1)} = 0{,}43$$

$F_{b,Rd,ver} = k_1\ \alpha_b\ d\ \ t_{bw}\ \ f_{ubw} / \gamma_{M2} = 82{,}88$ kN

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

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

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

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

$= \min(4{,}66 ; 2{,}5) = 2{,}5$

$F_{b,Rd,hor} = k_1\ \alpha_b\ d\ \ t_{bw}\ \ f_{ubw} / \gamma_{M2} = 77{,}45$ kN

$\alpha_b = \min(\alpha_1 , \alpha_2 , 1) = 0{,}75$

$\alpha_1 = e_{2b} / 3d_0 = 0{,}75$

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

$k_1 = \min(1{,}4\ p_1 / d_0 - 1{,}7 ; 2{,}5)$

$= \min(2{,}75 ; 2{,}5) = 2{,}5$

$d = 20{,}00$ mm

$t_{bw} = 7{,}10$ mm

$f_{ub} = 800{,}00$ N/mm²

$f_{ubw} = 360{,}00$ N/mm²

Gross section of the beam web in shear

$V_{Rd\,9} = A_{b,v}\ f_{ybw} / (\sqrt{3}\ \gamma_{M0}) = 348{,}42$ kN

$A_{b,v} = 25{,}68$ cm²

$f_{ybw} = 235{,}00$ N/mm²

Net section of the beam web in shear

$V_{Rd10} = A_{v,net}\ f_{ubw} / (\sqrt{3}\ \gamma_{M2}) = 349{,}11$ kN

$A_{b,v,net} = A_{b,v} - n_1\ d_0\ t_{bw} = 21{,}00$ cm²

$A_{b,v} = 25{,}68$ cm²

$n_1 = 3$

$d_0 = 22{,}00$ mm

$t_{bw} = 7{,}10$ mm

$f_{ubw} = 360{,}00$ N/mm²

Shear block of the beam web

$V_{Rd11} = F_{eff,2,Rd} = 198{,}82$ kN

$F_{eff,2,Rd} = 0{,}5\ f_{ubw}\ A_{nt} / \gamma_{M2} + f_{ybw}\ A_{nv} / (\sqrt{3}\ \gamma_{M0}) = 198{,}82$ kN

$A_{nt} = t_{bw}\ (e_{2b} - d_0/2) = 276{,}9$ mm²

$t_{bw} = 7{,}10$ mm

$e_{2b} = 50{,}00$ mm

$d_0 = 22{,}00$ mm

$A_{nv} = t_{bw}\ (e_{1b} + (n_1 - 1)\ p_1 - (n_1 - 0{,}5)\ d_0) = 1171{,}50$ mm²

$n_1 = 3$

$p_1 = 70{,}00$ mm

$e_{1b} = 45{,}00 + 35{,}00 = 80{,}00$ mm

$f_{ybw} = 235{,}00$ N/mm²

$f_{ubw} = 360{,}00$ N/mm²

Joint shear resistance

Shear resistance of the joint $V_{Rd} = 146{,}18$ kN

Failure Mode: Beam web in bearing

5.2.5 Requirements to ensure the safety of the shear design rules

(1) $V_{Rd} < \min(V_{Rd\,1} ; V_{Rd\,7})$

$V_{Rd} = 146{,}18$ kN

$\min(V_{Rd\,1} ; V_{Rd\,7}) = 178{,}28$ kN

$V_{Rd\,1} = 178{,}28$ kN

$V_{Rd\,7} = 776{,}97$ kN

→ ok,

(2) $\mathbf{n_2 = 1}$:

$F_{b,hor,Rd} \leq \min (F_{v,Rd} ; V_{Rd\,7}\ \beta)$

$V_{Rd\,7} = 776{,}97$ kN
$F_{v,Rd} = 94{,}08$ kN

for the beam web :
$F_{b,hor,Rd} = 77{,}45$ kN
$\beta = 0{,}43$
$\min (F_{v,Rd} ; V_{Rd\,7}\ \beta) = \min (94{,}08 ; 334{,}09) = 94{,}08$ kN
$\rightarrow$ ok,

One of the two inequalities is satisfied, $\rightarrow$ ok,

(3) $V_{Rd} = V_{Rd\,8}$ $\rightarrow$ ok,

5.2.6 Design check

Applied shear force: $V_{Sd} = 100$ kN
Shear resistance: $V_{Rd} = 146{,}18$ kN $\Rightarrow$ Design O,K,

5.2.7 Joint tying resistance

Bolts in shear

$N_{u\,1} = n\, F_{v,u} = 352{,}80$ kN

$n = 3$
$F_{v,u} = \alpha_v\ f_{ub}\ A = 117{,}60$ kN
$A = A_s = 245{,}00$ mm²
$\alpha_v = 0{,}6$

Fin plate in bearing

$N_{u\,2} = n\, F_{b,u,\,hor} = 409{,}09$ kN

$n = 3$
$F_{b,u,hor} = k_1\ \alpha_b\ f_{up}\ d\ t_p = 136{,}36$ kN

$\alpha_b = \min (\alpha_1 , \alpha_2 , 1) = 0{,}75$
$\alpha_1 = e_2 / 3d_0 = 0{,}75$
$\alpha_2 = f_{ub} / f_{up} = 2{,}22$

$k_1 = \min (2{,}8\, e_1 / d_0 - 1{,}7 ; 1{,}4\, p_1 / d_0 - 1{,}7 ; 2{,}5)$
$= \min (4{,}03 ; 2{,}75 ; 2{,}5) = 2{,}5$

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

Fin plate in tension : gross section

$N_{u\,3} = t_p\, h_p\, f_{up} = 828{,}00$ kN

Fin plate in tension : net section

$N_{u\,4} = 0{,}9\, A_{net,p}\, f_{up} = 531{,}36$ kN

$A_{net,p} = t_p\, h_p - d_0\, n_1\, t_p = 1640{,}00$ mm²
$n_1 = 3$
$h_p = 230{,}00$ mm
$t_p = 10{,}00$ mm
$d_0 = 22{,}00$ mm

Beam web in bearing

$N_{u\,5} = n\, F_{b,u,\,hor} = 290{,}45$ kN

$n = 3$
$F_{b,u,hor} = k_1\, \alpha_b\, f_{ubw}\, d\, t_{bw} = 96{,}82$ kN
$\alpha_b = \min(\alpha_1 , \alpha_2 , 1) = 0{,}75$
$\alpha_1 = e_{2b} / 3d_0 = 0{,}75$
$\alpha_2 = f_{ub} / f_{ubw} = 2{,}22$

$k_1 = \min(1{,}4\, p_1 / d_0 - 1{,}7 ; 2{,}5)$
$= \min(2{,}75 ; 2{,}5) = 2{,}5$

$d = 20{,}00$ mm
$t_{bw} = 7{,}10$ mm
$f_{ub} = 800{,}00$ N/mm²
$f_{ubw} = 360{,}00$ N/mm²

Beam web in tension : gross section

$N_{u\,6} = t_{bw}\, h_{bw}\, f_{ubw} = 587{,}88$ kN

Beam web in tension : net section

$N_{u\,7} = 0{,}9\, A_{net,bw}\, f_{ubw} = 377{,}27$ kN

$A_{net,bw} = t_{bw}\, h_{bw} - d_0\, n_1\, t_{bw} = 1164{,}40\ mm^2$

$t_{bw} = 7{,}10\ mm$

$h_{bw} = 230{,}00\ mm$

$n_1 = 3$

$d_0 = 22{,}00\ mm$

Supporting member in bending

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Welds

Conditions for full-strength behaviour of the welds are fulfilled

Joint tying resistance

Tying resistance of the joint $N_u = 290{,}45\ kN$

Failure mode : Beam web in bearing

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.