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: $A = 53.83$ cm²
Inertia: $I = 3692.16$ cm⁴

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: $b_f = 150.00$ mm
Thickness of the flange: $t_{bf} = 10.70$ mm
Root radius: $r = 15.00$ mm
Area $A = 53,81 \, \text{cm}^2$
Inertia $I = 8356,11 \, \text{cm}^4$

Yield strength $f_{yb} = 235,00 \, \text{N/mm}^2$
Ultimate strength $f_{ub} = 360,00 \, \text{N/mm}^2$

**Fin plate 230 x 110 x 10, S 235**

Vertical gap $g_v = 35,00 \, \text{mm}$
Horizontal gap (end beam to column flange) $g_{h} = 10,00 \, \text{mm}$
Depth $h_p = 230,00 \, \text{mm}$
Width $b_p = 110,00 \, \text{mm}$
Thickness $t_p = 10,00 \, \text{mm}$

*Direction of load transfer (1)*

Number of bolts rows $n_1 = 3$
Edge to first bolt row distance $e_{11} = 45,00 \, \text{mm}$
Beam edge to first bolt row distance $e_{1b} = 80,00 \, \text{mm}$
Pitch between bolt row 1 and 2 $p_{1[1]} = 70,00 \, \text{mm}$
Pitch between bolt row 2 and 3 $p_{1[2]} = 70,00 \, \text{mm}$
Last bolt row to edge distance $e_{1n} = 45,00 \, \text{mm}$

*Direction perpendicular to Load transfer (2)*

Number of bolts rows $n_2 = 1$
Edge to first bolt row distance $e_{21} = 50,00 \, \text{mm}$
Last bolt row to beam edge distance $e_{2b} = 50,00 \, \text{mm}$
Lever arm $z = 60,00 \, \text{mm}$

Yield strength $f_{yp} = 235,00 \, \text{N/mm}^2$
Ultimate strength $f_{up} = 360,00 \, \text{N/mm}^2$

**Bolts M20, 8,8**

Resistant area $A_s = 245,00 \, \text{mm}^2$
Diameter of the shank $d = 20,00 \, \text{mm}$
Diameter of the holes $d_0 = 22,00 \, \text{mm}$
Yield strength $f_{yb} = 640,00 \, \text{N/mm}^2$
Ultimate strength $f_{ub} = 800,00 \, \text{N/mm}^2$

**Welds**

Throat thickness of the weld $a_w = 5,00 \, \text{mm}$
Length of the weld $l_w = 230,00 \, \text{mm}$

*Safety factors*
\[ \gamma_{M0} = 1,00 \]
\[ \gamma_{M2} = 1,25 \]

**Applied shear force**

\[ V_{sd} = 100 \text{ kN} \]

5.2.2 **Requirements to ensure sufficient rotation capacity**

1. \( h_p \leq d_b \)
   \[ h_p = 230,00 \text{ mm} \]
   \[ d_b = h - 2 \ t_{bf} - 2 \ r \]
   \[ = 300,00 - 2 \times 10,70 - 2 \times 15,00 = 248,60 \text{ mm} \]
   \[ \rightarrow \text{ok} \]

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

5.2.3 **Requirements to avoid premature weld failure**

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

\[ t_p = 10,00 \text{ mm} \]
\[ f_{\text{yp}} = 235,00 \text{ N/mm}^2 \]
\[ f_{\text{up}} = 360,00 \text{ N/mm}^2 \]
\[ \beta_w = 0,80 \]

\[ a = 5,00 \text{ mm} \quad \rightarrow \text{ok} \]

5.2.4 **Joint shear resistance**

**Bolts in shear**

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

\[ n = 3 \]
\( z = 60.00 \text{ mm} \)

\[
F_{v,Rd} = \alpha_v A \frac{f_{ub}}{\gamma_{M2}} = 94.08 \text{ kN}
\]

\( \alpha_v = 0.6 \)

\( A = A_s = 245.00 \text{ mm}^2 \)

\( f_{ub} = 800.00 \text{ N/mm}^2 \)

**Fin plate in bearing**

\[
V_{Rd,2} = \frac{1}{\left( \frac{1 + \alpha}{n} \frac{F_{b,ver,Rd}}{F_{b,Rd,2}} + \beta \frac{F_{b,hor,Rd}}{F_{b,Rd,2}} \right)^2} = 192.59 \text{ kN}
\]

\( n = 3 \)

\( \alpha = 0 \)

\( 1 / n = 1 / 3 \)

\( \beta = \frac{6 z}{p_1 n (n + 1)} = 0.43 \)

\[
F_{b,Rd,ver} = k_1 \alpha_b d t_p \frac{f_{up}}{\gamma_{M2}} = 98.18 \text{ kN}
\]

\( \alpha_b = \min (\alpha_1, \alpha_2, \alpha_3, 1) = 0.68 \)

\( \alpha_1 = e_1 / 3d_0 = 0.68 \)

\( \alpha_2 = p_1 / 3d_0 - 1/4 = 0.81 \)

\( \alpha_3 = \frac{f_{ub}}{f_{up}} = 2.22 \)

\( k_1 = \min (2.8 e_2 / d_0 - 1.7 ; 2.5) \)

\( = \min (4.66 ; 2.5) = 2.5 \)

\[
F_{b,Rd,hor} = k_1 \alpha_b d t_p \frac{f_{up}}{\gamma_{M2}} = 109.09 \text{ kN}
\]

\( \alpha_b = \min (\alpha_1, \alpha_2, 1) = 0.75 \)

\( \alpha_1 = e_2 / 3d_0 = 0.75 \)

\( \alpha_2 = \frac{f_{ub}}{f_{up}} = 2.22 \)

\( k_1 = \min (2.8 e_1 / d_0 - 1.7 ; 1.4 p_1 / d_0 - 1.7 ; 2.5) \)

\( = \min (4.03 ; 2.75 ; 2.5) = 2.5 \)

\( d = 20.00 \text{ mm} \)

\( t_p = 10.00 \text{ mm} \)

\( f_{ub} = 800.00 \text{ N/mm}^2 \)

\( f_{up} = 360.00 \text{ N/mm}^2 \)

**Gross section of the fin plate in shear**

\[
V_{Rd,3} = A_\alpha f_{yp} / (1.27 \sqrt{3} \gamma_{M0}) = 245.72 \text{ kN}
\]
\[ A_v = h_p \, t_p = 23,00 \text{ cm}^2 \]
\[ f_{yp} = 235,00 \text{ N/mm}^2 \]

**Net section of the fin plate in shear**

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

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

**Shear block of the fin plate**

\[ V_{Rd\,5} = F_{\text{eff,2,Rd}} = 232,54 \text{ kN} \]

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

\[ A_{nt} = t_p \, (e_2 - d_0/2) = 390,00 \text{ mm}^2 \]
\[ t_p = 10,00 \text{ mm} \]
\[ e_2 = 50,00 \text{ mm} \]
\[ d_0 = 22,00 \text{ mm} \]

\[ A_{nv} = t_p \, (h_p - e_1 - (n_1 - 0,5) \, d_0) = 1300,00 \text{ mm}^2 \]
\[ n_1 = 3 \]
\[ h_p = 230,00 \text{ mm} \]
\[ e_1 = 45,00 \text{ mm} \]
\[ f_{yp} = 235,00 \text{ N/mm}^2 \]
\[ f_{up} = 360,00 \text{ N/mm}^2 \]

**Fin plate in bending**

\[ h_p = 230 \text{ mm} \quad \geq 2,73 \, z = 163,8 \text{ mm} \]

\[ V_{Rd\,6} = \infty \]

**Buckling of the fin plate**

\[ V_{Rd\,\gamma} = \frac{W_{el}}{\gamma_{M0}} \quad \frac{\sigma}{\gamma_{M0}} = 776,97 \text{ kN} \]

\[ W_{el} = \frac{t_p \, h_p^2}{6} = 88 \, 166,67 \text{ mm}^3 \]
\[ \sigma = 81 \left( \frac{t_p}{z} \right)^2 = 235 \text{ N/mm}^2 \]

**Beam web in bearing**

\[
V_{Rd,8} = \frac{1}{\sqrt{\left( \frac{1}{n} + \alpha \right)^2 + \left( \frac{\beta}{F_{b,ver,Rd}} \right)^2}} = 146.19 \text{ kN}
\]

\[ n = 3 \]
\[ \alpha = 0 \]
\[ 1/n = 1/3 \]
\[ \beta = \frac{6z}{p_1 n (n+1)} = 0.43 \]

\[
F_{b,Rd,ver} = k_1 \alpha_b d \ t_{bw} \ f_{ubw} / \gamma_{M2} = 82.88 \text{ kN}
\]
\[ \alpha_b = \min (\alpha_1, \alpha_2, 1) = 0.81 \]
\[ \alpha_1 = \frac{p_1}{3d_0 - 1/4} = 0.81 \]
\[ \alpha_3 = f_{ub} / f_{ubw} = 2.22 \]

\[ k_1 = \min (2.8 e_{2b} / d_0 - 1.7 ; 2.5) = \min (4.66 ; 2.5) = 2.5 \]

\[
F_{b,Rd,hor} = k_1 \alpha_b d \ t_{bw} \ f_{ubw} / \gamma_{M2} = 77.45 \text{ kN}
\]
\[ \alpha_b = \min (\alpha_1, \alpha_2, 1) = 0.75 \]
\[ \alpha_1 = e_{2b} / 3d_0 = 0.75 \]
\[ \alpha_2 = f_{ub} / f_{ubw} = 2.22 \]

\[ k_1 = \min (1.4 p_1 / d_0 - 1.7 ; 2.5) = \min (2.75 ; 2.5) = 2.5 \]

\[ d = 20.00 \text{ mm} \]
\[ t_{bw} = 7.10 \text{ mm} \]
\[ f_{ub} = 800.00 \text{ N/mm}^2 \]
\[ f_{ubw} = 360.00 \text{ N/mm}^2 \]

**Gross section of the beam web in shear**

\[
V_{Rd,9} = A_{b,v} f_{ybw} / (\sqrt{3} \gamma_{M0}) = 348.42 \text{ kN}
\]

\[ A_{b,v} = 25.68 \text{ cm}^2 \]
\[ f_{ybw} = 235.00 \text{ N/mm}^2 \]

**Net section of the beam web in shear**
\[ V_{Rd10} = A_{b,v,net} f_{ubw} / (\sqrt[3]{\gamma M2}) = 349.11 \text{ kN} \]

\[ A_{b,v,net} = A_{b,v} - n_1 d_0 t_{bw} = 21,00 \text{ cm}^2 \]
\[ A_{b,v} = 25,68 \text{ cm}^2 \]
\[ n_1 = 3 \]
\[ d_0 = 22,00 \text{ mm} \]
\[ t_{bw} = 7,10 \text{ mm} \]
\[ f_{ubw} = 360,00 \text{ N/mm}^2 \]

Shear block of the beam web

\[ V_{Rd11} = F_{eff,2,Rd} = 198,82 \text{ kN} \]

\[ F_{eff,2,Rd} = 0.5 f_{ubw} A_{nt} / \gamma M2 + f_{ybw} A_{nv} / (\sqrt[3]{\gamma M0}) = 198,82 \text{ kN} \]
\[ A_{nt} = t_{bw} (e_{2b} - d_0/2) = 276,9 \text{ mm}^2 \]
\[ t_{bw} = 7,10 \text{ mm} \]
\[ e_{2b} = 50,00 \text{ mm} \]
\[ d_0 = 22,00 \text{ mm} \]
\[ A_{nv} = t_{bw} (e_{1b} + (n_1 - 1) p_1 - (n_1 - 0.5) d_0) = 1171,50 \text{ mm}^2 \]
\[ n_1 = 3 \]
\[ p_1 = 70,00 \text{ mm} \]
\[ e_{1b} = 45,00 + 35,00 = 80,00 \text{ mm} \]
\[ f_{ybw} = 235,00 \text{ N/mm}^2 \]
\[ f_{ubw} = 360,00 \text{ N/mm}^2 \]

Joint shear resistance

Shear resistance of the joint \( V_{Rd} = 146,18 \text{ kN} \)
Failure Mode: Beam web in bearing

5.2.5 **Requirements to ensure the safety of the shear design rules**

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

\[ V_{Rd} = 146,18 \text{ kN} \]
\[ \min( V_{Rd 1} ; V_{Rd 7} ) = 178,28 \text{ kN} \]
\[ V_{Rd 1} = 178,28 \text{ kN} \]
\[ V_{Rd 7} = 776,97 \text{ kN} \]
\[ \rightarrow \text{ok,} \]

(2) \( n_2 = 1 : \)

\[ F_{b,hor,Rd} \leq \min( F_{v,Rd} ; V_{Rd 7} \beta) \]
\[ V_{Rd,7} = 776,97 \text{ kN} \]
\[ F_{v,Rd} = 94,08 \text{ kN} \]

_for the beam web:

\[ F_{b,\text{hor},Rd} = 77,45 \text{ kN} \]
\[ \beta = 0,43 \]
\[ \min ( F_{v,Rd} ; V_{Rd,7} \beta) = \min (94,08 ; 334,09) = 94,08 \text{ kN} \]
\[ \rightarrow \text{ok}, \]

One of the two inequalities is satisfied, \( \rightarrow \text{ok}, \)

(3) \[ V_{Rd} = V_{Rd,8} \rightarrow \text{ok}, \]

5.2.6 Design check

Applied shear force: \[ V_{Sd} = 100 \text{ kN} \]
Shear resistance: \[ V_{Rd} = 146,18 \text{ kN} \] \( \Rightarrow \) Design O,K

5.2.7 Joint tying resistance

Bolts in shear

\[ N_{u,1} = n F_{v,u} = 352,80 \text{ kN} \]
\[ n = 3 \]
\[ F_{v,u} = \alpha_v f_{ub} A = 117,60 \text{ kN} \]
\[ A = A_s = 245,00 \text{ mm}^2 \]
\[ \alpha_v = 0,6 \]

Fin plate in bearing

\[ N_{u,2} = n F_{b,u,\text{hor}} = 409,09 \text{ kN} \]
\[ n = 3 \]
\[ F_{b,u,\text{hor}} = k_1 \alpha_b f_{up} d_t = 136,36 \text{ kN} \]
\[ \alpha_b = \min (\alpha_1 , \alpha_2 , 1) = 0,75 \]
\[ \alpha_1 = e_2 / 3d_0 = 0,75 \]
\[ \alpha_2 = f_{ub} / f_{up} = 2,22 \]
\[ k_1 = \min (2,8 e_1 / d_0 - 1,7 ; 1,4 p_1 / d_0 - 1,7 ; 2,5) \]
\[ = \min (4,03 ; 2,75 ; 2,5) = 2,5 \]
\[
\begin{align*}
\text{d} & = 20,00 \text{ mm} \\
\text{tp} & = 10,00 \text{ mm} \\
\text{f}_{ub} & = 800,00 \text{ N/mm}^2 \\
\text{f}_{up} & = 360,00 \text{ N/mm}^2 \\
\end{align*}
\]

**Fin plate in tension : gross section**

\[
\begin{align*}
\text{Nu}_3 = \text{tp} \cdot \text{hp} \cdot \text{f}_{up} & = 828,00 \text{ kN} \\
\end{align*}
\]

**Fin plate in tension : net section**

\[
\begin{align*}
\text{Nu}_4 = 0,9 \cdot \text{Anet,p} \cdot \text{f}_{up} & = 531,36 \text{ kN} \\
\text{Anet,p} & = \text{tp} \cdot \text{hp} - \text{d}_0 \cdot \text{n}_1 \cdot \text{tp} = 1640,00 \text{ mm}^2 \\
\text{n}_1 & = 3 \\
\text{hp} & = 230,00 \text{ mm} \\
\text{tp} & = 10,00 \text{ mm} \\
\text{d}_0 & = 22,00 \text{ mm} \\
\end{align*}
\]

**Beam web in bearing**

\[
\begin{align*}
\text{Nu}_5 = n \cdot \text{F}_{b,u,hor} & = 290,45 \text{ kN} \\
\text{n} & = 3 \\
\text{F}_{b,u,hor} & = \text{k}_1 \cdot \alpha_b \cdot \text{f}_{ubw} \cdot \text{d} \cdot \text{tbw} = 96,82 \text{ kN} \\
\alpha_b & = \min (\alpha_1, \alpha_2, 1) = 0,75 \\
\alpha_1 & = \frac{\text{e}_{2b}}{3\text{d}_0} = 0,75 \\
\alpha_2 & = \frac{\text{f}_{ub}}{\text{f}_{ubw}} = 2,22 \\
\text{k}_1 & = \min (1,4 \cdot \text{p}_1 / \text{d}_0 - 1,7 ; 2,5) \\
& = \min (2,75 ; 2,5) = 2,5 \\
\text{d} & = 20,00 \text{ mm} \\
\text{tbw} & = 7,10 \text{ mm} \\
\text{f}_{ub} & = 800,00 \text{ N/mm}^2 \\
\text{f}_{ubw} & = 360,00 \text{ N/mm}^2 \\
\end{align*}
\]

**Beam web in tension : gross section**

\[
\begin{align*}
\text{Nu}_6 = \text{tbw} \cdot \text{hbw} \cdot \text{f}_{ubw} & = 587,88 \text{ kN} \\
\end{align*}
\]

**Beam web in tension : net section**

\[
\begin{align*}
\text{Nu}_7 = 0,9 \cdot \text{A}_{\text{net,bw}} \cdot \text{f}_{ubw} & = 377,27 \text{ kN} \\
\end{align*}
\]
Supporting member in bending

..., 

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